



Abdelhamid Ibn Badis University - Mostaganem

Faculty of Economics, Business and Management Sciences



Department of Economics

Dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Doctorate in
Economic Sciences, Option: Quantitative Economics

**The Impact of Economic Conditions and Policy Decisions on Renewable Energy Deployment
in Algeria (1980-2021)**

Presented by the Candidate: **CHERIFI Asmaa**

Board of Examiners:

ZEROUAT Fatima Zohra	Professor	University of Mostaganem	President
BOUGUEROUA Mariem	MCA	University of Mostaganem	Supervisor
DEKKICHE Mokhtar	MCA	University of Mostaganem	Co-Supervisor
BRAHAMI Mohammed Amine	Professor	Higher School of Economics Oran	Examiner
TAYEB Saida	MCA	University of Relizane	Examiner
BENZIDANE Hadj	Professor	University of Mostaganem	Examiner

Academic Year 2024/2025

DEDICATION

I would like to dedicate this work to

My parents

Meziane and Hayet

My siblings

Hacene, Manel and Amine

My Husband

Ahmed

And all my Family and Friends

CHERIFI Asmaa

ACKNOWLEDGMENT

I am deeply grateful to Allah for granting me the willpower and strength to complete this work (Alhamdulillah).

*I wish to first extend my sincere appreciation to my supervisor, **Dr. BOUGHEROUA Mariem**, for her ongoing support of my Ph.D. studies and associated research. Her patience, encouragement, and profound expertise have greatly contributed to my development.*

*In addition to my advisor, I would like to thank my Co-Supervisor **Dr. DEKKICHE Mokhtar** for helping me with his valuable and critical remarks, which have greatly improved the quality of my thesis.*

I must express profound thankfulness to my family, and a special feeling of gratitude to my loving parents and husband for their constant moral support during the writing of this thesis and throughout my life's journey. Their unwavering presence has been my guiding light, illuminating every step of this challenging path.

Finally, I express profound gratitude to everyone who generously supported and motivated me.

CHERIFI Asmaa

ABSTRACT

To promote environmental sustainability, many countries are setting ambitious renewable energy targets and enacting supportive policies. This study employs the Auto-Regressive Distributed Lag (ARDL) model to examine how economic factors, specifically oil prices (OILP) and economic growth (GDPc), and policy measures, including Algeria's National Renewable Energy and Energy Efficiency Program (NREP), and Governance Indicators influence Renewable Energy Generation (REG) within Algeria's electric power sector from 1980 to 2021.

The long-term model estimates indicate that Oil Price (OILP) negatively impacts renewable electricity generation (REG), whereas the Gross Domestic Product per capita (GDPc) has a positive effect on REG. In both the short and long term, there exists a positive correlation between policy tools and the REG. This relationship underscores the critical role of a stable political climate, effective governance, and well-structured economic policies in advancing renewable energy promotion.

Keywords: Oil price ; Economic growth ; Policy Measures ; Electricity.

المخلص

لتحقيق الاستدامة البيئية، تسعى العديد من الدول إلى تحديد أهداف طموحة في مجال الطاقة المتجددة وسنّ سياسات داعمة. تستخدم هذه الدراسة نموذج الانحدار الذاتي للفجوات الموزعة (ARDL) لتحليل تأثير العوامل الاقتصادية، وخاصة أسعار النفط (OILP) والنمو الاقتصادي (GDPc)، بالإضافة إلى التدابير السياسية، بما في ذلك البرنامج الوطني للطاقات المتجددة والفعالية الطاقوية (NREP) في الجزائر، ومؤشرات الحوكمة على إنتاج الطاقة المتجددة (REG) في قطاع الكهرباء الجزائري خلال الفترة من 1980 إلى 2021.

تشير تقديرات النموذج طويلة الأجل إلى أن أسعار النفط (OILP) تؤثر سلبيًا على إنتاج الكهرباء المتجددة (REG)، بينما يؤثر الناتج المحلي الإجمالي للفرد (GDPc) إيجابيًا على REG. على المدى القصير والطويل، توجد علاقة إيجابية بين الأدوات السياسية وإنتاج الطاقة المتجددة. يبرز هذا الارتباط الدور الحاسم لمناخ سياسي مستقر، وحوكمة فعالة، وسياسات اقتصادية مُحكمة في تعزيز تطوير الطاقة المتجددة.

الكلمات المفتاحية: سعر النفط، النمو الاقتصادي، أدوات السياسة، الكهرباء.

RÉSUMÉ

Pour promouvoir la durabilité environnementale, de nombreux pays fixent des objectifs ambitieux en matière d'énergie renouvelable et adoptent des politiques de soutien. Cette étude utilise Le modèle Auto-régressif à Retards Distribués (ARDL) pour analyser l'impact des facteurs économiques, en particulier les Prix du Pétrole (OILP) et la croissance économique (GDPc), ainsi que des mesures politiques, y compris le Programme National des Énergies Renouvelables et de l'Efficacité Énergétique (NREP) de l'Algérie et les indicateurs de gouvernance sur la Production d'Énergie Renouvelable (REG) dans le secteur électrique algérien entre 1980 et 2021.

Les estimations du modèle à long terme révèlent que le prix du pétrole (OILP) a un impact négatif sur la production d'électricité renouvelable (REG), tandis que le Produit Intérieur Brut par habitant (GDPc) exerce un effet positif. À court et à long terme, il existe une corrélation positive entre les instruments politiques et REG. Cette relation met en évidence le rôle essentiel d'un climat politique stable, d'une gouvernance efficace et de politiques économiques bien structurées dans la promotion des énergies renouvelables.

Mots-clés : Prix du pétrole ; Croissance économique ; Mesures politiques ; Électricité.

Table of Contents	
Subjects	Page
Dedication	I
Acknowledgment	II
English Abstract	III
Arabic Abstract	IV
French Abstract	V
Table of contents	VI
List of tables	IX
List of Figures	X
List of Appendices	XI
List of Abbreviations	XIV
Chapter One	
Introduction	
1.1 Preface	2
1.2 Hypothesis of the Study	7
1.3 Objectives of the Study	8
1.4 Importance of the study	8
1.5 Structure of the study	9
Chapter Two	
Theoretical Framework	
2.1 Introduction	11
2.2 Global Energy: State of the Art	11
2.2.1 Exploring Energy: Concepts and Definitions	11
2.2.2 Understanding Diverse Energy Sources Worldwide	12
2.2.2.1 Non-Renewable Energy	13
2.2.2.2 Renewable Energy	16
2.2.3 Energy Use: An Economic, Social, and Environmental Challenge	20
2.2.3.1 Domestic use	21
2.2.3.2 Industrial Sector Use	22
2.2.3.3 Agricultural Use	23
2.2.3.4 Transport Sector	24
2.2.4 Development of Energy: Global Production and Consumption	26
2.2.4.1 Energy Generation Worldwide	26
2.2.4.2 World Energy Consumption	35
2.2.5 Facing the Global Energy Crisis: Impacts and Consequences	43

2.2.5.1 The Wood Crisis in England Drives the First Industrial Revolution	43
2.2.5.2 Global Oil Crisis And its Repercussions	44
2.2.5.3 Fukushima Nuclear Crisis	46
2.2.5.4 The Global Energy Crisis Caused by The Covid-19 Pandemic	47
2.2.6 Comparative Analysis of Renewable Energy Policies: EU, China, USA	48
2.2.6.1 European Union's Policy on Renewable Energy	48
2.2.6.2 United States Policy on Renewable Energy	50
2.2.6.3 China's Policy on Renewable Energy	51
2.3 Economic and Political Challenges of Renewable Energy in Algeria	54
2.3.1 Algeria's Energy Sector: A Current Overview	54
2.3.1.1 Assessing current Energy Dynamics: Production and Consumption analysis	55
2.3.1.2 Electric Power Generation and Consumption Patterns in Algeria	59
2.3.1.3 Algeria's CO2 Emissions: Trends and Implications for Climate Policy	65
2.3.2 Assessing the Impact of Policy Decisions on Renewable Energy Integration	68
2.3.2.1 Governance's Framework: Policy and Regulation Perspectives	68
2.3.2.2 Key Contributors to Algeria's Renewable Energy Sector	81
2.3.2.3 Empowering Sustainability: Renewable Energy and Energy Efficiency Program	83
2.3.3 Exploring Algeria's Renewable Energy Potential	93
2.3.3.1 Solar Energy	93
2.3.3.2 Wind Energy	95
2.3.3.3 Geothermal Energy	99
2.3.3.4 Hydropower	100
2.3.3.5 Biomass Fuel	101
2.3.4 Challenges Hindering Renewable Energy Adoption in Algeria	102
2.3.5 Crucial Elements to Guarantee the Sustainable Growth of RES in Algeria	104
2.4 Conclusion	107
Chapter three	
Empirical Literature	
3.1 Introduction	109
3.2 Research Method	109
3.3 Data Origins	109
3.4 Systematic Search and Study Selection	109
3.5 Quality Assessment and Data Extraction	110
3.6 Review and Survey Selected Studies	110
3.7 Study Impact	135
3.8 Conclusion	136

Chapter Four	
Data and Methodology	
4.1 Introduction	138
4.2 Research Approach	138
4.3 Study's Data	139
4.3.1 Source of Data	139
4.3.2 Variables of the Study	139
4.3.2.1 The Dependent Variable	140
4.3.2.2 The Independent Variable	140
4.4 Principal Component Analysis (PCA)	142
4.4.1 Performing Sphericity Tests for PCA	143
4.4.2 Studying the Correlation between the Study Variables	144
4.4.3 Graphical Representation of the Study Variables	145
4.5 Methodology of the Study	148
4.5.1 Econometric Model of the Study	149
4.6 Conclusion	150
Chapter Five	
Results and Discussion	
5.1 Introduction	152
5.2 Statistical Analysis	152
5.2.1 Descriptive statistics	152
5.2.2 The Optimal Lag	153
5.2.3 Stationary Tests	154
5.2.4 Cointegration Examination Using ARDL Bounds Test	157
5.3 Diagnostics tests	163
5.3.1 Parameter Stability	163
5.3.2 Diagnostic tests for the model's validity	164
5.4 Conclusion	166
Chapter Six	
Conclusion	
6.1 Introduction	168
6.2 Key Findings of the Study	168
6.3 Testing Hypothesis	169
6.4 Implications and Recommendations	171
6.5 Limits and Perspectives	173
References	174-188
Appendices	190-227

List of tables

Table N°	Title	Page
Table 1.1.	Levelized Cost of Electricity Trends by Energy Source	2
Table 2.1	Renewable Energy Sources and their Use	25
Table 2.2	Oil Generation (Mb/d) by Country 2022	27
Table 2.3	Top 10 Nations Producing Natural Gas by Generating Share	29
Table 2.4	Renewable Energy Capacities in 2023	32
Table 2.5	Top 10 Consumers of Coal 2024	38
Table 2.6	Comparative Analysis of Renewable Energy Policies: EU, China, USA	51
Table 2.7	Primary Energy Production in Algeria	55
Table 2.8	Final Energy Consumption by Product	57
Table 2.9	Final Consumption by Sector (K Tep)	59
Table 2.10	Renewable And Conventional Generated Power (1980-2022)	60
Table 2.11	Algeria's CO2 Emissions from 1980 To 2022	67
Table 2.12	Developments of Main Legislation on Renewable Energies	74
Table 2.13	Share of Selected Renewable Resources	84
Table 2.14	Program Schedule (2011 Version)	84
Table 2.15	Renewable Energy Goals for Electricity Generation in Algeria's (2015–30)	88
Table 2.16	The Installed Capacity and Produced Energy from The Launch Date to June 2017	89
Table 2.17	Award Data for SKTM's 50 MWp Market in 2019	91
Table 2.18	Solar Potential in Algeria	94
Table 2.19	The Annual Average Wind Velocities in The Six Designated Locations	97
Table 2.20	Distribution per Province of The Photovoltaic/Wind Installations	98
Table 2.21	Distribution of Installed Power per Application and per Resource	98
Table 2.22	Location and Temperature of Some Algerian Thermal Springs	99
Table 2.23	Hydropower Plant Installed in Algeria	101
Table 3.1	Previous Studies	119
Table 4.1	The Definitions and Sources of Variables	140
Table 5.1	Summary Statistics	152
Table 5.2	Augmented Dickey-Fuller Test	155
Table 5.3	Dickey-Fuller GLS Test	156
Table 5.4	Phillips-Perron Test	156
Table 5.5	Nonlinear Unit Root Test (Zivot-Andrews)	157
Table 5.6	Bound Test Cointegration Results	158
Table 5.7	Long and Short-Run ARDL Estimations	159
Table 5.8	Diagnostic Tests Outcomes	165

List of Figures

Figure N°	Title	Page
Figure 1.1.	Renewable Power Capacity Growth (2018-2023)	3
Figure 1.2	Renewable Power Generation Capacity by Source	4
Figure 1.3	Renewables Share of Power Generation in The Net Zero Scenario (2010-2030)	4
Figure 1.4	Renewable Energy Goals for Electricity Generation in Algeria	7
Figure 2.1	Global Oil Production from 2000 To 2023	27
Figure 2.2	Coal Production Worldwide from 2000 To 2023 (in Terawatt-Hours)	30
Figure 2.3	Nuclear Power Generation Worldwide (TWh)	31
Figure 2.4	Renewable Share of Annual Energy Capacity Growth	33
Figure 2.5	World Electricity Generation by Source 2022 (GW)	34
Figure 2.6	Global Electricity Generation 1990-2023 (TWh)	35
Figure 2.7	Global Oil Consumption 1970 - 2022 (in Million Metric Tons)	36
Figure 2.8	Global Natural Gas Consumption 1998-2023 (in Billion Cubic Meters)	37
Figure 2.9	Coal Global Consumption 1965-2022 (Exajoules/ Years)	37
Figure 2.10	Globally Distributed Nuclear Energy Consumption In 2022, by Nation	39
Figure 2.11	Renewable Energy Consumption 2000-2022	39
Figure 2.12	Global Final Electricity Consumption by Sector	42
Figure 2.13	Summary of Energy Flows (M Toe) in 2022	54
Figure 2.14	Structure of Primary Energy Production	56
Figure 2.15	Structure of Final Energy Consumption by Product	58
Figure 2.16	Structure of Final Energy Consumption by Sector	59
Figure 2.17	Evolution of Electricity Generation Sources in Algeria	61
Figure 2.18	Total Electricity Production in Algeria (GWh)	62
Figure 2.19	Imports and Exports of Electricity in Algeria	63
Figure 2.20	Electricity Consumption in Algeria (GWh)	64
Figure 2.21	The Evolution of Electricity Consumption (TJ) In Algeria by Sector	65
Figure 2.22	CO2 Emissions by Sector in Algeria	67
Figure 2.23	CO2 Emissions by Source in Algeria	67
Figure 2.24	Estimated Development of The National Power Generation Fleet	84
Figure 2.25	Solar Potential Distribution in Algeria	94
Figure 2.26	(Grand Vent) 100 kW Wind Turbine	96
Figure 2.27	Wind Power Potential in Algeria	97
Figure 2.28	Process of Producing Geothermal Energy	100
Figure 4.1	Graphical Representation of Study Variables	146
Figure 5.1	The Optimal Lag for The Model	154
Figure 5.2	Forecast Performance Test	163
Figure 5.3	CUSUM and CUSUM of Squares Plot of Recursive Residual	164

List of Appendices

Appendix N°	Title	Page
Appendix 4.1	KMO and Bartlett Test for Sphericity	189
Appendix 4.2	Matrix of Correlation of the Study	189
Appendix 4.3	Total Explained Variance of the Model	189
Appendix 4.4	Matrix of Components Regarding all Independent Variables and REG	190
Appendix 4.5	Graphical Representation of Political Variables	190
Appendix 4.6	Matrix of Components regarding Political variables and REG	191
Appendix 4.7	Output Without PCA Method	191
Appendix 5.1	Descriptive Statistics of the Variables	192
Appendix 5.2	ADF Stationarity Test (REG at Level Only Cons)	192
Appendix 5.3	ADF Stationarity Test (REG at Level Cons and Trend)	193
Appendix 5.4	ADF Stationarity Test (REG at 1 st Difference Only Cons)	193
Appendix 5.5	ADF Stationarity Test (REG at 1 st Difference Cons and Trend)	193
Appendix 5.6	DF Stationarity Test (REG at Level Only Cons)	194
Appendix 5.7	DF Stationarity Test (REG at Level Cons and Trend)	194
Appendix 5.8	DF Stationarity Test (REG at 1 st Difference Only Cons)	195
Appendix 5.9	DF Stationarity Test (REG at 1 st Difference Cons and Trend)	195
Appendix 5.10	Phillips-Perron Stationarity Test (REG at Level Only Cons)	195
Appendix 5.11	Phillips-Perron Stationarity Test (REG at Level Cons and Trend)	196
Appendix 5.12	Phillips-Perron Stationarity Test (REG at 1 st Difference Only Cons)	196
Appendix 5.13	Phillips-Perron Stationarity Test (REG at 1 st Difference Cons and Trend)	197
Appendix 5.14	Zivot-Andrew Stationarity Test (REG at Level Only Cons)	197
Appendix 5.15	Zivot-Andrew Stationarity Test (REG at Level Cons and Trend)	197
Appendix 5.16	Zivot-Andrew Stationarity Test (REG at 1 st Difference Only Cons)	198
Appendix 5.17	Zivot-Andrew Stationarity Test (REG at 1 st Difference Cons and Trend)	199
Appendix 5.18	ADF for Stationarity (OILP at Level Only Cons)	199
Appendix 5.19	ADF for Stationarity (OILP at Level Cons and Trend)	200
Appendix 5.20	ADF for Stationarity (OILP at 1 st Difference Only Cons)	200
Appendix 5.21	ADF for Stationarity (OILP at 1 st Difference Cons and Trend)	200
Appendix 5.22	DF Stationarity Test (OILP at Level Only Cons)	201
Appendix 5.23	DF Stationarity Test (OILP at Level Cons and Trend)	201
Appendix 5.24	DF Stationarity Test (OILP at 1 st Difference Only Cons)	202
Appendix 5.25	DF Stationarity Test (OILP at 1 st Difference Cons and Trend)	202
Appendix 5.26	Zivot-Andrew Stationarity Test (OILP at Level Only Cons)	202
Appendix 5.27	Zivot-Andrew Stationarity Test (OILP at Level Cons and Trend)	203
Appendix 5.28	Zivot-Andrew Stationarity Test (OILP at 1 st Difference Only Cons)	203
Appendix 5.29	Zivot-Andrew Stationarity Test (OILP at 1 st Difference Cons and Trend)	204
Appendix 5.30	Phillips-Perron Stationarity Test (OILP at Level Only Cons)	204
Appendix 5.31	Phillips-Perron Stationarity Test (OILP at Level Cons and Trend)	205
Appendix 5.32	Phillips-Perron Stationarity Test (OILP at 1 st Difference Only Cons)	205
Appendix 5.33	Phillips-Perron Stationarity Test (OILP at 1 st Difference Cons and Trend)	206
Appendix 5.34	ADF for Stationarity (GDPc at Level Only Cons)	206

Appendix 5.35	ADF for Stationarity (GDPc at Level Cons and Trend)	206
Appendix 5.36	ADF for Stationarity (GDPc at 1 st Difference Only Cons)	207
Appendix 5.37	ADF for Stationarity (GDPc at 1 st Difference Cons and Trend)	207
Appendix 5.38	DF Stationarity Test (GDPc at Level Only Cons)	208
Appendix 5.39	DF Stationarity Test (GDPc at Level Cons and Trend)	208
Appendix 5.40	DF Stationarity Test (GDPc at 1 st Difference Only Cons)	208
Appendix 5.41	DF Stationarity Test (GDPc at 1 st Difference Cons and Trend)	209
Appendix 5.42	Phillips-Perron Stationarity Test (GDPc at Level Only Cons)	209
Appendix 5.43	Phillips-Perron Stationarity Test (GDPc at Level Cons and Trend)	210
Appendix 5.44	Phillips-Perron Stationarity Test (GDPc at 1 st Difference Only Cons)	210
Appendix 5.45	Phillips-Perron Stationarity Test (GDPc at 1 st Difference Cons and Trend)	210
Appendix 5.46	Zivot-Andrew Stationarity Test (GDPc at Level Only Cons)	211
Appendix 5.47	Zivot-Andrew Stationarity Test (GDPc at Level Cons and Trend)	211
Appendix 5.48	Zivot-Andrew Stationarity Test (GDPc at 1 st Difference Only Cons)	212
Appendix 5.49	Zivot-Andrew Stationarity Test (GDPc at 1 st Difference Cons and Trend)	212
Appendix 5.50	ADF for Stationarity (PF at Level Only Cons)	213
Appendix 5.51	ADF for Stationarity (PF at Level Cons and Trend)	213
Appendix 5.52	ADF for Stationarity (PF at 1st Difference Only Cons)	214
Appendix 5.53	ADF for Stationarity (PF at 1st Difference Cons and Trend)	214
Appendix 5.54	DF Stationarity Test (PF at Level Only Cons)	214
Appendix 5.55	DF Stationarity Test (PF at Level Cons and Trend)	215
Appendix 5.56	DF Stationarity Test (PF at 1st Difference Only Cons)	215
Appendix 5.57	DF Stationarity Test (PF at 1st Difference Cons and Trend)	215
Appendix 5.58	Phillips-Perron Stationarity Test (PF at Level Only Cons)	216
Appendix 5.59	Phillips-Perron Stationarity Test (PF at Level Cons and Trend)	216
Appendix 5.60	Phillips-Perron Stationarity Test (PF at 1st Difference Only Cons)	216
Appendix 5.61	Phillips-Perron Stationarity Test (PF at Level Cons and Trend)	217
Appendix 5.62	ADF for Stationarity (RQF at Level Only Cons)	217
Appendix 5.63	ADF for Stationarity (RQF at Level Cons and Trend)	217
Appendix 5.64	ADF for Stationarity (RQF at 1st Difference Only Cons)	218
Appendix 5.65	ADF for Stationarity (RQF at 1st Difference Cons and Trend)	218
Appendix 5.66	DF Stationarity Test (RQF at Level Only Cons)	218
Appendix 5.67	DF Stationarity Test (RQF at Level Cons and Trend)	219
Appendix 5.68	DF Stationarity Test (RQF at 1st Difference Only Cons)	219
Appendix 5.69	DF Stationarity Test (RQF at 1st Difference Cons and Trend)	219
Appendix 5.70	Phillips-Perron Stationarity Test (RQF at Level Only Cons)	220
Appendix 5.71	Phillips-Perron Stationarity Test (RQF at Level Cons and Trend)	220
Appendix 5.72	Phillips-Perron Stationarity Test (RQF at 1st Difference Only Cons)	220
Appendix 5.73	Phillips-Perron Stationarity Test (RQF at Level Cons and Trend)	221
Appendix 5.74	Akaike Information Criteria	221
Appendix 5.75	The results of the ARDL estimation	221
Appendix 5.76	The results of the ARDL Long Run Form and Bounds Test	223
Appendix 5.77	The Findings of the ARDL Error Correction Regression	223
Appendix 5.78	The Findings of the Jaque Bera Normality Test	225

Appendix 5.79	The Findings of the Breusch-Godfrey Serial Correlation LM Test	225
Appendix 5.80	The Findings of the Heteroskedasticity Test: Breusch-Pagan-Godfrey	225
Appendix 5.81	The Findings of the Ramsey RESET Test	226

List of Abbreviations	
APRUE	National Agency for the Promotion and Rationalization of Energy Use
ARDL	Auto-Regressive Distributed Lag
CEREFE	Commissioner for Renewable Energies and Energy Efficiency
CREG	Electricity and Gas Regulatory Commission
CSP	Concentrated Solar Power
DOLS	Dynamic Ordinary Least Squares
EU	European Union
FAO	Food and Agriculture Organization
FMOLS	Fully Modified Ordinary Least Squares
GDPc	Gross Domestic Product per Capita
GECF	Gas Exporting Countries Forum
GMM	Generalized Method of Moments
IEA	International Energy Agency
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
MEM	Ministry of Energy and Mines
MTEER	Ministry of Energy Transition and Renewable Energy
NREP	National Renewable Energy and Energy Efficiency Program
OECD	Economic Co-operation and Development countries
OILP	Oil Price
OLS	Ordinary Least Squares
PV	Photovoltaic
RE	Renewable Energy
REC	Renewable Energy Consumption
REG	Renewable Electricity Generation
RES	Renewable Energy Sources
SDG	Sustainable Development Goal
U.S	United States Dollars
VECM	Vector Error Correction Model
WHO	World Health Organization

Chapter One

Introduction

1.1 Preface

1.2 Problem Statement and Hypothesis

1.3 Objectives of the study

1.4 Importance of the study

1.5 Structure of the study

1.1 Preface

In light of the ever-growing energy demand and the urgent need to meet sustainable development goals, several countries have embraced renewable energy by setting deployment targets and implementing various policy measures to support their expansion (SDG7, 2022). According to the International Renewable Energy Agency (IRENA, 2022), by mid-2022, at least 176 countries had integrated at least one type of renewable energy. This global shift toward renewable energy is driven by environmental concerns and economic and geopolitical factors. As countries adopt renewable energy sources to preserve natural resources, they also seek to reduce their reliance on fossil fuels, subject to price volatility and supply constraints. In addition to enhancing energy security, renewable energy fosters sustainable economic growth, job creation, and poverty reduction, making it a key driver of long-term development (Zhao et al., 2022).

In addition, IRENA, (2019) projects that by 2050, renewable energy could and should account for 90% of global electricity generation. This transition is increasingly feasible, as renewable energy has become the most cost-effective power source in many regions worldwide. For instance, the cost of solar PV electricity dropped by 89% between 2010 and 2020, while the costs of onshore and offshore wind power declined by 69% and 59%, respectively (IRENA, 2023). (Table. 1.1) presents the levelized cost of electricity (LCOE)¹ for various renewable energy sources.

Table 1.1. Levelized Cost of Electricity Trends by Energy Source

Renewable Energy Sources	2010	2022	Change (%)
Bioenergy	0.082	0.061	-25%
Geothermal	0.053	0.056	6%
Hydropower	0.042	0.061	47%
Solar Photovoltaic (PV)	0.445	0.049	-89%
Concentrating Solar Power (CSP)	0.380	0.118	-69%
Onshore wind	0.107	0.033	-69%
Offshore wind	0.197	0.081	-59%

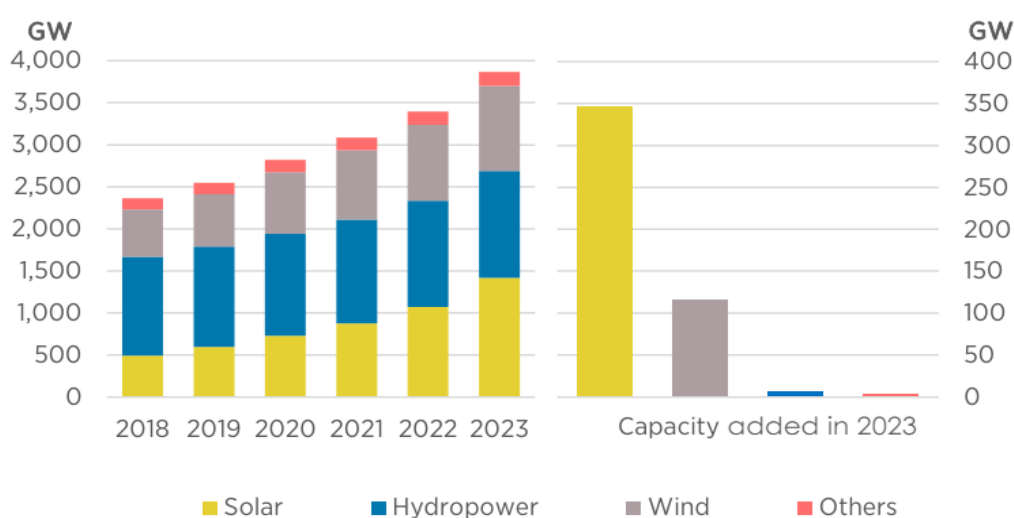
Source: (IRENA, 2023)

¹ The levelized cost of electricity (LCOE) represents the average net present value of the total cost of generating electricity for a particular generator over its entire operational life.

According to (IRENA, 2024), the capacity of renewable energy rose by 473 GW (+13.9%) in 2023. With a significant growth of 346 GW (+32.2%), solar energy continues to lead capacity expansion. Wind energy came in second with 116 GW (+12.9%). Bioenergy output rose by 4.4 GW (+3.0%) and renewable hydropower capacity by 7.0 GW (+0.6%). The extremely slight increase in geothermal energy was 0.2 GW.

Together, solar and wind energy accounted for 97.6% of all net renewable additions in 2023, continuing to lead the way in the increase of renewable capacity. The capacity of renewable energy sources increased at the fastest rate ever recorded in both annual growth and percentage terms, thanks to the expansion of wind and solar power.

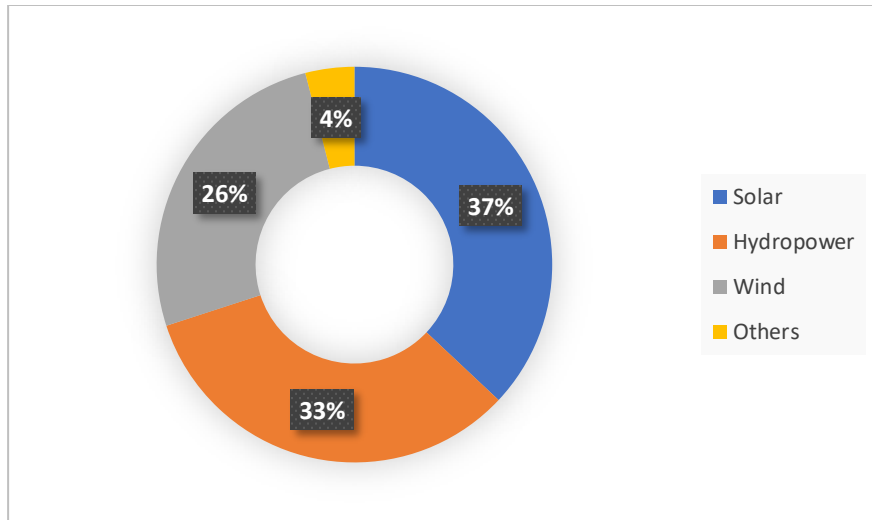
Figure 1.1. Renewable Power Capacity Growth (2018-2023)



Source: (IRENA, 2024)

Global renewable power capacity reached 3870 GW by the end of 2023. With a capacity of 1419 GW (37%), solar accounted for the greatest portion of the global total. The majority of the remaining energy was provided by wind and hydropower, with respective capacities of 1268 GW (33%) and 1017 GW (26%). Other renewable capacities comprised 150 GW of bioenergy, 15 GW of geothermal, and 0.5 GW of marine energy. (Figure. 1.1).

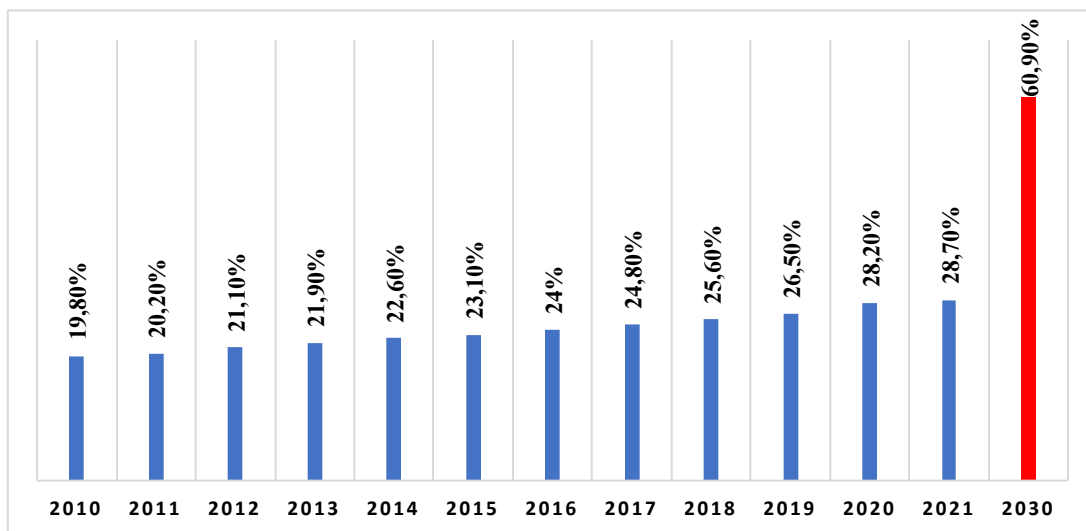
Figure 1.2. Renewable Power Generation Capacity by Source



Source: (IRENA, 2024)

The International Energy Agency (IEA, 2022), emphasizes that achieving net-zero targets between 2022 and 2030 requires renewable energy generation to grow by more than 12% annually. Although renewable energy capacity has reached record levels, the growth in generation during 2021 remained significantly below the pace needed to meet net-zero goals. To bridge this gap, the global deployment of all renewable technologies must accelerate substantially (Figure. 1.3).

Figure 1.3. Renewables Share of Power Generation in the Net Zero Scenario (2010-2030)



Source: Realized by the researcher using data from the IEA

Based on the findings of the (World Bank, 2024), Algeria's economy continues to be strongly reliant on the fossil fuel sector, with oil and gas playing a dominant role. Between 2019 and 2023, hydrocarbons contributed around 14% of the national GDP, made up 86% of total exports, and generated 47% of government revenue. In the third quarter of 2022, Algeria's hydrocarbon sector

contributed approximately 2.5 trillion Algerian dinars (around 18 billion U.S. dollars) to the GDP, marking its highest level. Since 2019, the sector's value-added has fluctuated, experiencing a significant decline during the COVID-19 outbreak in the second quarter of 2020 (**Statista, 2024**).

The price of Algeria's Sahara Blend crude oil has fluctuated significantly over time. In 2002, it was approximately \$25 per barrel, rising to around \$110 per barrel by 2012. By 2023, it had settled at \$83.64 per barrel. In 2024, prices varied between a peak of \$90.79 per barrel in April and a low of \$76.21 per barrel in September (**Statista, 2024**).

Prior to the Ukraine crisis, Algeria was ranked as the third-largest provider of natural gas in Europe, behind Russia and Norway. It is a prominent producer and exporter of fossil fuels, occupying second place in the region after Nigeria in terms of crude oil output and ranked 17th worldwide (**EIA, 2023**). Algeria ranked tenth in the world among producers of natural gas, accounting for 2.4% of worldwide production in 2022 (**BP Statistical Review, 2023**). The nation had 4.5 billion cubic meters of natural gas reserves, or 2.4% of the world's total reserves, before the revisions made by BP in 2021 (**Abada et Bouharkat, 2018**). Algeria now ranks second in terms of gas supply to Europe, behind Norway, according to the Gas Exporting Countries Forum report (**GECF, 2023**).

As stated by the International Energy Agency (**IEA, 2022**), the primary origin of Algeria's electricity power generation in 2022 was natural gas with 99% of total generation, in 2000 the Algerian electricity production from natural gas was 24.585 GWh, which increased to 90.220 GWh in 2022, marking a rise of 267%. Meanwhile, electricity production from oil has consistently declined, dropping from 775 GWh in 2000 to 311 GWh in 2021, representing a decrease of 59.87%. There is a complete lack of diversification, with virtually no contribution from renewable energy sources such as hydro, solar, or wind power.

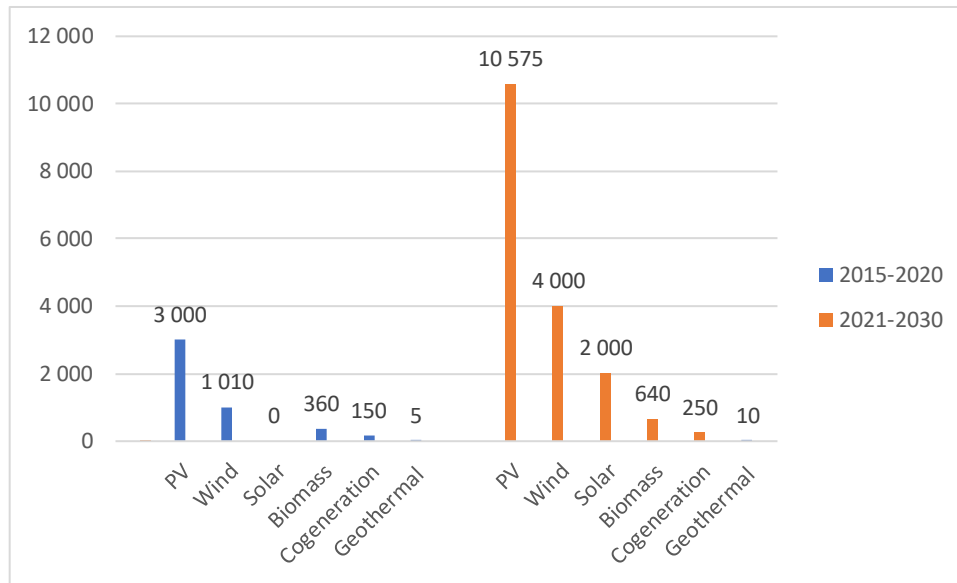
Moreover, Algeria's carbon dioxide (CO₂) emissions in 2022 amounted to 177.079 megatons, signaling a decline of 1.717 megatons, placing Algeria 153rd in the 184 country CO₂ emissions ranking. Consequently, Algeria has pledged to cut its emissions of greenhouse gases (GHGs) by 2020–2030 (**Ritchie, Roser et Rosado, 2020**). Additionally, Algeria has reaffirmed its commitment to decrease its GHG emissions by 7% by 2030, as outlined in the Paris Climate Agreement of 2015 (**IEA, 2024**).

In order to reduce dependence on oil and gas for fossil fuels and to reduce CO₂ emissions, Algeria is currently focusing more and more on developing the renewable energy sector. In terms of renewable energy potential, Algeria has great potential in solar energy. With an average annual sunshine of 3000 hours, reaching 3500 hours in the highlands and Sahara desert which composes 86%

of the territory, its solar power is estimated at 1700 KWh/m²/year in the north and 2650 KWh/m²/year in the south (**Bouraiou et al., 2020**), which corresponds to a capacity 8 times greater than the country's natural gas reserves, and the largest solar fields in the world (**Tagrerout et Atmania, 2021**). It is estimated that only one-twentieth of the surface of the Sahara covered with solar panels could supply the entire planet in electricity (**Bélaïd et Youssef, 2017**). Wind energy potential is relatively moderate, with speeds varying between 2 and 6 m/s (**Stambouli et al., 2012**). This energy potential is ideal for pumping water in the highlands but is marginal for large commercial projects (**Boukli Hacène et al., 2016**). It is estimated that biomass has a potential of 1.33 Mtoe/year, including waste recycling from human activities, urban trash, and agricultural waste. As explained by geothermal has a better outlook with 200 hot springs listed (**Abada et Bouharkat, 2018**). The hydraulic sector includes 103 identified dam sites, with more than 50 dams currently operational. Despite a large total volume of water estimated at 65 billion m³ on Algerian territory, the country derives only minimal benefit from it due to factors such as concentrated distribution in specific areas, high evaporation rates, and rapid run-off into the sea (**Tagrerout et Atmania, 2021**).

To harness this vast RE potential and support its energy transition objectives, Algeria has progressively implemented a legislative and institutional framework to promote renewable energy development. The early steps were marked by the creation of APRUE (1985) and the first general energy laws (1999, 2002). A major turning point occurred in 2004 with Law 04-09, which integrated renewable energy into a sustainable development approach, and Law 04-92, which introduced economic incentives such as feed-in tariffs. According to the Ministry of Energy and Mines (**MEM, n. d.**), Algeria adopted a national program for 2011–2030, setting out a clear roadmap from a pilot phase (2011–2013) to large-scale deployment by 2030. However, the reality fell far short of expectations. By 2020, only three pilot projects had been completed, with a total capacity of 36.3 MW, well below the 110 MW initially planned for the experimental phase. In light of the limited progress under the 2011 framework, Algeria revised its strategy in 2015 by launching an updated and more structured program (NREP), focusing mainly on photovoltaic solar energy at the expense of concentrated solar power (CSP), with a target of 22,000 MW by 2030 (Figure. 1.4). Nevertheless, implementation remained weak, with only 343 MW installed by 2017 out of the 4,525 MW planned for 2020. The 2020 revision of the NREP lowered the ambition to 16,000 MW to be installed by 2035, exclusively in photovoltaic solar energy. Yet, by the end of 2020, only 836 MW had been deployed, representing a shortfall of 81 percent compared to the original target. The period from 2019 to 2022 marked an institutional acceleration with the creation of CEREFÉ (2019), MTEER (2020), SHAEMS (2021), and the High Council for Energy (2022). This sequence reflects a clear intent to better structure energy governance and ensure improved coordination of renewable energy projects.

Figure 1.4. Renewable Energy Goals for Electricity Generation in Algeria



Source: Realized by the researcher using data from the MEM

1.2 Problem Statement and Hypothesis

As a result, the research question is articulated around the following main question: **“How do economic conditions and policy tools affect the development of renewable electricity in Algeria?”**. This leads us to question the following:

- ✚ What are the key drivers behind Algeria's investment in renewable energy?
- ✚ What economic factors influence the implementation of renewable energy in Algeria?
- ✚ What policies are adopted by the Algerian government for promoting renewable energy?

To answer these questions, the study builds on the following hypotheses:

Hypothesis 1: The primary driver for Algeria's investment in renewable energy is the need to diversify its energy mix and economy to reduce dependence on fossil fuels.

Hypothesis 2: Oil prices and Gross Domestic Product significantly influence renewable electricity generation in Algeria.

Hypothesis 3: The National Renewable Energy and Energy Efficiency Program, along with governance indicators, plays a significant and positive role in advancing renewable electricity in Algeria.

1.3 Objectives of the study

The main objective of this research is to evaluate the impact of economic conditions (including economic growth (GDPc) and oil prices (OILP)) and policy decisions (such as governance indicators, which are categorized into [Political Factors (PF) and Regulatory Quality (RQ)], and the national renewable energy program (NREP)) on the growth of renewable electricity (REG) in Algeria from 1980 to 2021. The study analyzes annual data for these variables, employing the ARDL model to achieve this goal. The specific objectives of the study are:

- ✚ Identifying the main factors driving Algeria's investment in renewable energy.
- ✚ Emphasizing and evaluating the potential of various renewable energy sources in Algeria, including solar, wind, hydropower, geothermal, and biomass.
- ✚ Outlining the challenges facing renewable energy adoption in Algeria
- ✚ Highlighting the measures taken to boost the growth of renewable energy in Algeria.
- ✚ Assessing the overall progress and challenges faced in the renewable energy sector in Algeria from 1980 to 2021.

1.4 Importance of the study

To our knowledge, there exist previous studies that have separately investigated the correlation between the adoption of renewable energy in Algeria and the nation's economic conditions, as well as other studies exploring the implementation of renewable energy alongside the country's political decisions. However, **no study has integrated these two aspects**. Consequently, **there are no previous studies exploring the link between renewable energy production and both economic conditions and policy instruments in Algeria**, therefore, our research holds significant importance. As a matter of fact, understanding these dynamics provides valuable insights into how economic, political, and environmental elements interact, assisting policymakers and stakeholders in devising strategies to improve renewable energy growth and sustainability within the country.

1.5 Structure of the study

Besides the current chapter, this study encompasses five additional chapters, following the IMRAD² structure. Chapter two covers the theoretical framework of the research, while chapter three reviews relevant literature and presents related studies. Chapter four explains the adopted methodology, detailing the data and empirical test procedures utilized to achieve the study's objectives. Chapter five analyzes and evaluates the results obtained. Finally, chapter six provides a summary of the topic discussed, along with conclusions and recommendations for future research.

² IMRAD: (Introduction, Methods, Results, and Discussion) is a standard structure commonly used in scientific journals.

Chapter Two

Theoretical Framework

2.1 Introduction

2.2 Global Energy: State of the Art

2.2.1 Exploring Energy: Concepts and Definitions

2.2.2 Understanding Diverse Energy Sources Worldwide

2.2.3 Energy Use: Economic, Social, and Environmental Challenges

2.2.4 Development of Energy: Global Production and Consumption

2.2.5 Facing the Global Energy Crisis: Impacts and Consequences

2.2.6 Comparative Analysis of Renewable Energy Policies: EU, China, USA

2.3 Economic and Political Challenges of Renewable Energy in Algeria

2.3.1 Algeria's Energy Sector: A Current Overview

2.3.2 Assessing the Impact of Policy Decisions on Renewable Energy Integration

2.3.3 Exploring Algeria's Renewable Energy Potential

2.3.4 Challenges Hindering Renewable Energy Adoption in Algeria

2.3.5 Crucial Elements to Guarantee the Sustainable Growth of Renewable Energy

Sources in Algeria

2.4 Conclusion

2.1 Introduction

This chapter refers to the current situation and trends in the energy sector at the global level, as well as at the level of Algeria. It delivers a comprehensive assessment of energy generation, utilization, allocation, and governmental policies.

Understanding the state of the world's energy is essential to meeting challenges such as climate change, energy security, and sustainable development. This overview provides valuable information on the various energy sources, emerging technologies, and environmental impacts that are shaping the global energy landscape.

2.2 Global Energy: State of the Art

Energy is a fundamental concept that plays a crucial role in various aspects of our lives, from powering homes and industries to driving economic growth and transportation. Understanding energy in its diverse forms from fossil fuels to renewable sources, is essential for comprehending global challenges for instance: climate change, resource depletion, and geopolitical tensions. By exploring the basic principles of energy production, consumption, and distribution, we gain valuable insights that inform decision-making processes and shape our collective future, making energy a cornerstone concept indispensable for navigating the complexities of our interconnected world.

2.2.1 Exploring Energy: Concepts and Definitions

"In a general sense, energy is the input required to cause a material system to transform (displacement, modification of form or change of structure)" (**Mérenne-Schoumaker, 2007**). This term refers to the capacity of a body or system to produce work that can lead to movement, heat generation, or electromagnetic waves (**Hermans, 2014**).

Energy powers the tools we use in daily life, working hard to provide us with the comfort we require (heating, lighting, cooling, etc.) (**Chitour, 1996**). It is also known as: "Energy is a scientific term that means the rationalization and regulation of fundamental processes on nature, and we can't observe or measure them directly, but instead study their impact on materials". The definition of energy given in dictionaries and encyclopedias is inadequate. For instance, Le Robert provides: "What a system possesses if it is able to produce work."

Energy is a scientific term meaning the rationalization and regulation of basic processes in nature, and we can't observe or measure it directly, but we do study their effect on materials (**Harribey, 1998**).

In the economic sense: "the ability of certain materials to provide mechanical work, possibly through the intermediary of heat. Energy is the dominant factor in the material civilization of our time (**Baudhuin, 1968**).

However, according to (**Balian, 2013**) the best way to define energy is based on a historical approach. For it turns out that, historically, the development of this concept was born with the search for constancy in movement, since studying a problem on its unchanged aspects of a problem, we can better understand its nature.

We are aware that the idea of energy has changed over time, beginning with a physical foundation. Energy is a property of a system that quantifies its ability to change the state of other systems with which it interacts by generating mechanical work, which causes motion, heat, or electromagnetic radiation.

Energy underpins many human activities, and socio-economic progress is hardly conceivable without it. Indeed, "the production and use of energy are one of the fundamental technical conditions for production in general and for the progress of human societies. On their importance depends the ability of various human groups to produce what they need to live and to ensure their economic and political independence". (**George, 1950**).

We can summarize these definitions as follows: "Energy is the main tool on which humans rely to achieve a better world, greater comfort, satisfaction, and optimum well-being. It is also considered as the main factor in human development and civilization around the world. historical periods of human life on earth. Humans can control energy and utilize its resources in ways that lead to the best outcomes".

2.2.2 Understanding Diverse Energy Sources Worldwide

In terms of sustainability and resource depletion, there are two categories of energy sources: renewable sources and non-renewable sources.

2.2.2.1 Non-Renewable Energy

Non-renewable energy sources include fossil fuels (coal, natural gas, oil), and nuclear energy. Their finite nature poses a significant challenge for humanity, given our heavy reliance on them to fulfill the majority of our energy requirements. Once depleted, these resources cannot be replenished, highlighting the urgent need for diversifying our energy sources to ensure long-term sustainability.

A. **Fossil Fuel**: This is represented in hydrocarbon energy sources and is made up of the following elements.

- Coal

For millions of years, certain plant and animal organisms were buried beneath the earth's surface. It was covered by sedimentary layers of sand and mud and completely isolated from oxygen. These organisms began to decompose in isolation from oxygen, and this decomposition resulted in many types of carbon discharge. As a result of significant changes in pressure, temperature, and other factors, many different types of coal were formed, which can be divided into in terms of use, it is divided into four types (Al-Zawka, 2001):

- *Coking coal* used in coke production
- *Gas coal* used in the production of industrial gases
- *Locomotive coal* used in machinery management
- *Domestic coal* for domestic use

It can be divided in terms of structural characteristics into anthracite, bitumen, and lignite coal, each with its own characteristics in terms of carbon content, specific gravity, and calorific value. According to United Nations statistics, the average calorific value of bituminous coal is 7,000 kcal per kilogram. Mainly used to calculate tons of coal equivalent (Bornan, 2007).

Coal is found at varying depths, from 400 to 4,000 meters. Almost everywhere in the world, and perhaps in the form of an enormous mass stretching for five thousand kilometers. This invites us to reflect on the size and enormity of buried plant masses. The coal mines are located in the temperate zone, which includes the former Soviet Union, the United States, Germany and northern France, China and, if we look at the world map, we can see that the sum of these mines forms a long strip that surrounds the entire Earth.

60% of the world's coal reserves are in the former Soviet Union and 20% in the United States. Coal is used as fuel in the 19th century, the Industrial Revolution began in the Western world, and coal was used as the sole source of energy needed to run factories, heat, and transport. Mainly based

on steam trains and steamships, after the outbreak of the First World War cars, trucks, and airplanes spread to reduce coal use in favor of oil, and coal still retains its place in power stations outside densely populated cities to reduce air pollution (Ammar, 1989).

- Oil

The general term for shale oil is generally used to designate crude oil. It is a fossil condensate composed of a mixture of hydrocarbons. Scientists believe that oil may have formed billions of years ago from the accumulation of very thick or huge sediments on the ocean floor. Micro-organisms that used to live in the sea then died there, and a complete transformation of the organic matter took place it mixed with clay and sand over several thousand years, and the accumulated masses decomposed by the action of bacteria, which continued their work for millions of years, protected from oxygen, and transformed into a thick black oily liquid, such as petroleum.

50% of the oil extracted is used in the operation of various means of transport such as cars, trucks, planes, boats, trains, etc. This is due to the efficiency of gasoline engines compared with coal-fired ones which are only 20% efficient. The other half of the oil produced is used to run machinery in factories, to heat furnaces and to heat our homes, and to generate electricity from thermal power stations.

In addition to using oil as an energy source, around 10% of it is used in the production of petrochemicals, which are the raw materials needed to manufacture plastics and nitrogen fertilizers.

Petrochemicals are the raw materials needed to manufacture plastics and nitrogen fertilizers. Petroleum is also classified according to its specific density, according to a scale developed by the American Petroleum Institute. This classification is specific as follows (Bornan, 2007):

- Light oil: less than 870 kg/m³
- Medium oil: less than 920 kg/m³
- Heavy fuel oil: from 920 to 1000 kg/m³
- Extra-heavy fuel oil: over 1000 kg/m³

Oil can also be classified using the API unit (crude oil specific gravity) as follows:

- Light oil has a very low density (API 20-44) and is fairly easy to extract.
- Heavy oil has a high density (API 10-20) and is difficult to extract.
- Super-heavy oil (below API 10), which is very expensive to extract.

- Natural Gas

Natural gas can be found in the environment in both oilfields and its own reservoirs. Historically, burning any natural gas that came out of the reservoir with the oil or had melted inside it was usual. Due to the lack of pipes to bring it to the cities where it might be utilized, it was then isolated by specialized equipment in the field.

But with the rise in oil prices, large pipelines have been laid over long distances to transport it to cities and industrial areas for use as fuel, which is odorless, burns easily, and is sulfur-free. This makes it non-polluting, and it can be transported after being liquefied at low temperature in special vehicles, in this case, the cost is higher. Natural gas consists mainly of Methane gas with a rate of over 80%, followed by ethane gas, propane gas, then butane gas (**Bornan, 2007**).

Although natural gas is one of today's most important, cleanest, and most efficient energy sources, it suffers from a lack of investment and lags behind oil in technology due to the time lag between their discovery (interest in oil began in 1870), and as for natural gas, the first industrial uses began in the United States of America in 1930 (**Chitour, 1996**).

Three types of natural gas can also be distinguished:

- Dry gas: when a well is drilled, only natural gas is found, a small percentage of oil or water (1% - 2%).
- Associated gas: when natural gas is present with crude oil, whether dissolved or floating on its surface.
- Wet gas: associated with light petroleum gases and LPG in the following proportions: 80% natural gas, 16% light oil, and 04% LPG gas.

B. Nuclear Energy

The first appearance of nuclear energy took place on December 02, 1942, when the first nuclear reactor was operated under the stands of the Chicago stadium (USA), by the greatest physicists: Bohr, Oppenheimer, Fermi, and this reactor looked more like a battery, and that day scientists saw that this battery produced energy from the fission of the uranium atom, so that day was the beginning of the era of fissile nuclear energy and the success of one of the greatest discoveries known to human beings (**Ammar, 1989**).

Physicist Albert Einstein was the first to discover this type of energy. He developed the theory of relativity at the beginning of the 20th century, in which he explains, using a mathematical equation,

that matter can be transformed into energy and, according to the following relationship (**Chitour, 1996**): $E = mc^2$. Where E: energy, m: mass, c: speed of light

This energy has been in use since the construction of the first nuclear reactor in the USA called (1EBR). This reactor operates at a power of 300 kilowatts (**Bornan, 2007**). A group of countries has adopted this approach, led by the former Soviet Union, and is using this energy for two main purposes:

- The first is purely military.
- The second is for peaceful purposes, the most important of which is the production of electrical energy for health and agricultural purposes.

In 2022, the United States was the leading consumer of nuclear energy with a rate of 30% followed by China accounting for 15.6% of global consumption.

2.2.2.2 Renewable Energy

RE can be described as « energy sources that are continually replenished by nature and derived directly from the sun (such as thermal, photo-chemical, and photo-electric), indirectly from the sun (such as wind, hydropower, and photosynthetic energy stored in biomass), or from other natural movements and mechanisms of the environment (such as geothermal and tidal energy) » (**Ellabban et al., 2014**).

An energy source is renewable if consuming it does not limit its future use. This is the case with energy derived from the sun, wind, rivers, earth, and biomass on the scale of the existence of humanity, but not for fossil and nuclear fuels (**Gergaud, 2002**). Renewable energy sources have been exploited by man since the birth of humanity, such as firewood, animal traction, sailboats, and windmills.

Unfortunately, other energy sources that at the time were considered to be interesting were chosen over these energies. It has only recently become clear that environmentally friendly economic development is absolutely essential. essential in light of atmospheric pollution, the greenhouse effect, the risks of nuclear power, and the limits of resources (oil, gas, coal, and uranium).

There are various advantages when choosing clean, renewable energy sources instead of fossil fuels.

- They are environmentally friendly (clean) and do not emit greenhouse gases or toxic waste.
- As their names suggest, they are "inexhaustible".

- They enable decentralized production adapted to local needs.

Renewable energies include solar energy, wind power, hydropower, geothermal energy and biomass.

A. Solar Energy

The sun, a star or shining ball, is located 150 million kilometers from Earth and generates an average thermal current of 4×10^{33} Kilowatt per second, of which only 2.16×10^5 Kilowatt thermal currents reach Earth (Nikolai, 1997).

Solar energy is one of the most abundant renewable resources on earth. The amount of solar energy that the earth receives each year is equivalent to almost 15.000 times what the whole world consumes in energy (Mirecki, 2005).

The sun rises over the Earth daily, providing it with up to 1.73×10^{17} watts of energy. The most widely used source of energy is the radiant energy that the sun sends to the planet. Its significance comes from the fact that it may reach even the most isolated places without restriction or cost. It cannot be accessed by other sources, and it has absolutely no impact on the issues of environmental degradation.

Solar energy provides a variety of benefits over other energy sources, including the fact that it is free and renewable.

- It is not subject to the control of international or local political systems that restrict its use
- It is available in almost any location, so it does not require transportation.
- There is no danger to workers or others, and the conversion and exploitation do not require sophisticated technology.
- The chemical transformation of solar energy takes place in the largest photosynthesis zone of all plants, where it is used to produce energy and electricity.

Additionally, it is possible to transform solar energy into various forms and profit from it. For example (Abdelhamid, 2012):

- Solar thermal energy production reached 523 GWh in 2020, an increase of 9.2% on 2019. This corresponds to a reduction of 151 million tonnes of CO₂ emissions and a saving of 49 million tonnes of oil (IEA, 2021).

- Photovoltaic cells are used to convert solar energy into electrical energy. solar photovoltaic capacity increased from less than 70 gigawatts in 2011 to more than 940 gigawatts in 2021 (Statista, 2023).

B. Hydraulic Energy

Hydropower is a proven RE technology that produces the second-largest share of electricity from renewable sources globally and is commercially viable (Stambouli et al., 2012). In the long term, hydropower can be adjusted to satisfy consumer demand while storing vast amounts of electricity at minimal cost, generating substantial and important economic benefits to human development.

There are two fundamental types of hydroelectric power plants: those with dams and reservoirs and those without. Large reservoir hydroelectric dams have the capacity to temporarily or permanently store water to satisfy peak demand. Additionally, facilities can be separated into smaller dams for various purposes, including seasonal storage, daytime or nighttime use, or reversible pumped-storage plants for both pumping and power generating. Smaller-scale output, typically from a plant built to function in a river without obstructing its flow, is what hydroelectricity without dams or reservoirs refers to. For this reason, a lot of people think that small-scale hydropower is a better choice for the environment.

In 1976, over 23% of the world's electricity was produced by hydropower. 3,200 terawatt-hours, or 18.4% of the world's energy production, were generated in 1985 (Chitour, 1996). Nowadays, hydropower is one of the most economical ways to produce electricity, and, where it is easily available, it is frequently the preferred option. For instance, 99% of the electricity in Norway is generated by hydropower. The Three Gorges Dam in China, which has a 22.5-gigawatt capacity, is the largest hydropower facility in the world. It can power between 70 and 80 million homes with an annual output of 80 to 100 terawatt hours (IRENA, n.d.).

C. Wind Energy

Wind energy is a form of energy that is dependent on the wind. As a result of the sun's uneven heating of the planet, different regions throughout the world experience varying temperatures and atmospheric pressure. These pressure differences give rise to air movements known as wind. By harnessing the power of the wind, this energy is used to power wind turbines, also referred to as wind generators.

The principle of wind power is as old as the windmill itself. Indeed, wheat is ground, and water is pumped using wind energy. This technique has been useful for producing electricity during the past few decades. There are currently millions of wind turbines in operation. In fact, there are two categories of wind turbine installations (**Connaissance des énergies, 2011**): Large-scale wind turbines that are connected to national grids and low-power residential wind turbines that provide electricity for private use. Moreover, it is possible to use wind energy in two different ways: “Onshore” wind turbines are installed on land. “Offshore” wind turbines are installed on the water.

There are a number of reasons why nations all around the world adopt this energy. Since the price per kilowatt-hour (KWh) in areas with good wind is getting closer to that of fossil fuels, it is an economically advantageous kind of energy. energy sources that are fossil. Blade properties, generator efficiency, and, most importantly, average wind speed are the major determinants of a wind turbine's economic feasibility (**Omri, 2016**).

According to the International Renewable Energy Agency (**IRENA, 2021**), wind power is one of the key technologies for achieving the 1.5°C target set by the Paris Climate Agreement. IRENA estimates that global wind power capacity should increase from 650 GW in 2020 to 2,500 GW in 2030 and 7,000 GW in 2050, representing respectively 10%, 20% and 30% of global electricity production.

D. Geothermal Energy

Geothermal energy exploits heat stored in the earth's crust to generate power or heat. Particularly at considerable depths, the subsoil is simply warm. Temperatures in the deepest parts of the earth increase by 3 to 4°C per 100 meters. This hot water is utilized to heat homes and other buildings (**Mirecki, 2005**).

Geothermal energy may emerge as one of the most significant sustainable energies of the future with the development of heat pumps and groundwater exploitation. Here is how a heat pump works: A collector takes heat from the earth outdoors, for instance, under a lawn; the heat comes from the sun's rays. Underfloor heating is used to carry this heat into the house. A heat-transfer fluid is necessary for heat transmission in any circumstance.

Over 350 high- and medium-energy geothermal power plants are now operational globally. Around 8 GW, representing 0.2% of the world's installed electrical capacity is the total capacity of these power plants. Geothermal power, together with biomass (the burning of wood waste and leftovers) and wind power, continue to be one of the world's three primary sources of electricity from

renewable energy sources, far behind hydroelectricity in terms of MWh generated. The way this resource is currently being used is not equitable worldwide. The discrepancy in resources is one cause of the regional disparity in production. The primary generating nations are located around the Pacific coast: six in the Americas, producing 3,390 MW; five in Asia, 3,100 MW; and two in Oceania, 437 MW. There are just two generating nations in Africa, each with 54 MW, compared to six in Europe with a combined capacity of 1,000 MW. Moreover, 0.4 % of the world's electrical demands are met by geothermal energy. Indeed, Global geothermal power generating capacity has grown over the past decade, rising from 10,088 MW in 2011 to over 15,600 MW in 2021 (Statista, 2023).

E. Biomass

The term biomass generally refers to all living matter of plant or animal origin on the earth's surface. This concept has been used to describe organic plant materials utilized for energy since the first oil crisis. Therefore, the term "biomass" applies to any plants that are able to release the solar energy they collected through a variety of transformations. This solar energy is transformed into other types of energy sources, including (Abdelhamid, 2012):

- *Electricity and heat*

This energy is created from wood, domestic garbage, industrial waste from the agri-food sector, and agricultural waste (straw). Combustion, pyrolysis, and gasification are thermochemical processes that are used to convert this waste into heat and power.

- *Biofuel*

Bioethanol fuel: is produced by fermenting starch and glucose, which are taken from cereal crops like corn and wheat, and sugar crops like sugar beets and cane, to generate ethanol.

Bio-diesel fuels: These include oil-rich plants (rapeseed, sunflower, and soya). The oil extracted from their seeds is used to produce bio-diesel, which can replace today's diesel fuel.

2.2.3 Energy Use: an Economic, Social, and Environmental Challenge

Since energy use has become a necessity in all areas and horizons of life, we can divide energy use into four basic uses:

2.2.3.1 Domestic use

Domestic use of energy is the energy used in the home for various purposes, such as cooking, heating, lighting, and powering devices and appliances. Domestic use of energy accounts for almost 43% of total energy use globally in 2021 (**US-IEA, 2023**), and it varies widely depending on the standard of living, the climate, and the age and type of residence. Here are some facts and Figures about domestic use of energy:

- The main sources of energy used in the home are electricity, natural gas, fuel, coal, wood, and batteries. Electricity is the most versatile and convenient source of energy, but it is also the most expensive and carbon-intensive one. Natural gas is cheaper and cleaner than electricity, but it requires a piped network or bottled supply. Fuel, coal, and wood are mainly used for heating and cooking in rural areas or developing countries, but they produce a lot of air pollution and greenhouse gas emissions. Batteries are used for portable devices and appliances, but they have a limited lifespan and need to be recharged or replaced.
- The principal uses of energy in the home are heating, cooling, hot water, lighting, appliances, and cooking. Heating is the most common use in the home, estimated at around 60% of domestic energy consumption. Cooling and refrigeration are also important uses, especially in hot climates or seasons. Hot water is used for bathing, washing, or cleaning, and it accounts for around 10% of domestic energy consumption. Lighting is essential for visibility and comfort, but it can be reduced by using natural light or energy-efficient bulbs. Appliances include various devices and equipment that perform different functions, such as washing machines, dryers, dishwashers, televisions, computers, etc.
- The main challenges of domestic use of energy are the rising cost, the unequal access, and the environmental impact. The rising cost of energy production and consumption affects the affordability and availability of energy for households. The unequal access to reliable and clean sources of energy affects the quality of life and well-being of different groups and regions. The environmental impact of excessive use of fossil fuels and other non-renewable sources of energy contributes to global warming, climate change, and environmental degradation.

According to the International Energy Agency (**IEA, 2023**), the global final energy consumption by households was 44.4 exajoules in 2022, representing 8.9 % of the total final energy consumption. The main sources of energy used by households were electricity (39.5 %), natural gas (25.6 %), biofuels and waste (18.4 %), oil products (11.5 %) and renewable energies (5 %)

To address these challenges, it is necessary to adopt a more sustainable approach to domestic use of energy, based on the following principles:

- Efficiency: improving the performance and productivity of various devices and appliances that use energy, by reducing the amount of energy required per unit of service or output.
- Conservation: reducing the demand for energy by households, by changing the behavior and habits of individuals that consume energy.
- Diversification: increasing the supply of energy from different sources, by developing and deploying renewable and alternative sources of energy that are cleaner and more abundant than fossil fuels.
- Innovation: enhancing the capacity and creativity of households that produce and use energy, by investing in research and development of new technologies and solutions that improve the efficiency, conservation, and diversification of energy.

2.2.3.2 Industrial Sector Use

For the industrial sector, energy is essential for growth and efficiency. Energy is involved at various levels of the industrial value chain, from the manufacture of inputs (seeds, fertilizers, pesticides) through industrial production (irrigation, mechanization, greenhouses), transport, storage, processing, and distribution, to the use of finished products (food, clothing, medicines, etc.) Here are a few examples of energy use in the industrial sector:

- Cogeneration is the simultaneous production of electricity and heat from the same energy source. This technique increases the system's overall energy efficiency and reduces energy losses. The heat produced can be used to power industrial processes or to heat buildings.
- Electrification involves replacing fossil fuels with electricity to power industrial processes. This technique reduces CO₂ emissions and atmospheric pollutants. The electricity used can come from renewable or low-carbon sources.
- Heat recovery is the technique of recovering waste heat from industrial processes and reusing it for other purposes. This technique reduces primary energy consumption and energy costs. Recovered heat can be used to preheat fluids or raw materials, to generate electricity or to power heat pumps.

According to the International Energy Agency (IEA, 2023), the industrial sector accounted for 37% of global final energy consumption and 33% of global energy-related CO₂ emissions in 2022.

Industrial energy use increased by 97% between 2000 and 2022, from 84 exajoules (EJ) to 166 EJ. This growth was mainly driven by increasing production in energy-intensive industrial sub-sectors such as steel, chemicals, cement, aluminum and pulp and paper.

Energy use in the industrial sector varies around the world, depending on the level of economic development, industrial structure, energy efficiency and energy mix. In 2022, Asia was the most energy-intensive region in the industrial sector, accounting for 63% of global consumption, followed by Europe (12%), North America (10%), Africa (5%), Latin America (4%) and Oceania (3%). China was the biggest consumer of energy in the industrial sector, accounting for 43% of global consumption, ahead of the United States (7%), India (6%), Russia (4%) and Japan (3%).

2.2.3.3 Agricultural Use

Energy is an essential factor in the development and productivity of the agricultural sector. Energy can be used at various stages of the agricultural value chain, from the production of inputs (seeds, fertilizers, pesticides) to the consumption of food products (cooking, preserving), via agricultural production (irrigation, mechanization, greenhouses), transport, storage, processing and distribution. Energy can be supplied by a variety of sources, depending on availability, cost, and environmental impact. Energy sources can be divided into two categories: renewable and non-renewable. The choice of energy sources for the agricultural sector depends on a number of factors, such as energy demand, climatic conditions, existing infrastructure, public policies, and stakeholder preferences. There are advantages and disadvantages to each energy source, which need to be assessed in terms of energy performance, economic profitability, energy security, and environmental sustainability.

Renewable sources offer advantages such as reduced greenhouse gas emissions, diversification of the energy mix, access to energy in remote rural areas and local job creation. However, they also present drawbacks such as intermittency, variability, high initial cost and the need for technological adaptation. In addition, non-renewable sources offer advantages such as availability, reliability, competitive cost and ease of use. However, they also present drawbacks such as import dependency, price volatility, accident risks and negative environmental and health impacts

The agricultural sector can use energy efficiently and sustainably by adopting practices and technologies that reduce energy consumption per unit of production or service (energy efficiency), substitute non-renewable sources with renewable ones (energy transition) and minimize losses and waste throughout the agricultural value chain (circular economy). Some examples of energy use in the agricultural sector:

- Solar irrigation is a technique that uses solar pumps to extract water from groundwater or rivers and deliver it to crops. This technique reduces the consumption of diesel or conventional electricity for irrigation, improves food and water security and cuts operating costs.
- Methanization is a process that transforms organic waste (manure, crop residues) into biogas (a mixture of methane and carbon dioxide) and digestate (residual organic matter). Biogas can be used to generate electricity or heat, or to power vehicles. Digestate can be used as an organic fertilizer. This technique recovers agricultural waste, reduces greenhouse gas emissions and improves soil fertility.
- Solar drying is a technique that uses solar energy to dry agricultural produce (fruit, vegetables, cereals, spices). This technique reduces the consumption of wood or fossil fuels for drying, prolongs the shelf life of products and preserves their nutritional quality.

According to the Food and Agriculture Organization of the United Nations (**FAO, 2023**), the global emissions due to agriculture were estimated at 5.4 gigatons of CO₂ equivalent in 2022, accounting for 11.1 % of the total anthropogenic emissions. The main sources of emissions from agriculture were enteric fermentation (39.8 %), manure management (16.2 %), synthetic fertilizers (14.3 %), rice cultivation (10.1 %) and biomass burning (6.1 %). Agriculture consumed 13.9 exajoules of final energy globally in 2022, or 2.8% of all final energy consumption. Agriculture's main energy sources included oil products (41.7%), electricity (24.3%), waste and biofuels (19.1%), natural gas (10.2%), and coal (4.1%).

As reported by (Eurostat, 2022) the EU's final energy consumption by agriculture, forestry and fishing was 1.3 exajoules in 2022, accounting for 2.5 % of the total final energy consumption³. The main sources of energy used by this sector were oil products (54.8 %), electricity (23.4 %), biofuels and waste (15.3 %), natural gas (5.1 %) and renewable energies (2.1 %).

The World Bank (2022) asserts that the renewable energy sector has a great potential to revolutionize the income of farmers in India, as they can use solar pumps for irrigation, biogas plants for cooking and heating, and biomass gasifiers for power generation. The government has launched several schemes to promote the adoption of renewable energy by farmers, such as KUSUM, PM-KUSUM, and PMUY.

2.2.3.4 Transport Sector

Exchanges of goods and merchandise developed between peoples with the development of human civilization, where sea transport was preferable to the transport of heavy goods, after the use of animals, of course, land transport came after the discovery of steam engines, to enter the era of modern

machines at the beginning of the 20th century represented in cars, air transport and the use of liquid fuel. Indeed, electricity joined the transport sector in electric trains and subways, etc.

The COVID-19 epidemic led to a 9.5% drop in energy consumption in 2021, although the International Energy Agency (IEA, 2023) reported that energy consumption in the transport sector reached 104.7 exajoules (EJ) in 2022. As a result, transportation-related CO₂ emissions rose by 3% in comparison to the previous year. From 1990 to 2022, the average annual increase in transportation emissions was 1.7%. The main energy sources used by the transportation sector were oil products (87.4%), biofuels (5.4%), electricity (3.9%), natural gas (2.8%), and hydrogen (0.5%). Some examples of energy use in the transportation sector are as follows:

- The electric vehicle is a vehicle that uses electricity as an energy source to power an electric motor. This reduces CO₂ emissions and atmospheric pollutants. The electricity used can come from renewable or low-carbon sources.
- Biofuel is a liquid or gaseous fuel produced from organic plant or animal matter. This fuel reduces dependence on petroleum products and improves energy security. Biofuel can be blended with conventional fuel or used pure.
- Hydrogen is a gas that can be produced from water or biomass by electrolysis or gasification. This gas can be used as an energy source to power a fuel cell or an internal combustion engine. Hydrogen helps reduce CO₂ emissions and atmospheric pollutants. The hydrogen used can come from renewable or low-carbon sources.

The following table summarizes the key renewable energy sources and their uses

Table 2.1. Renewable Energy Sources and their Use

Energy sources	Energy conversion and usage options
Hydropower	Power generation
Biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Solar home systems, solar dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generators, windmills, water pump
Wave and tide	Numerous design, barrage, tidal stream

Source: (Panwar, Kaushik et Kothari, 2011)

2.2.4 Development of Energy: Global Production and Consumption

Energy is essential to the functioning and development of human societies. It enables us to carry out a wide range of activities, including the production of goods and services, transport, heating, lighting, and communication. However, energy also poses many challenges, particularly in terms of supply, distribution, cost, safety, environmental impact, and social justice. It is therefore important to know the history of the global energy crisis as well as, the current state of energy production and consumption in the world, in order to understand the issues and prospects linked to this strategic sector.

2.2.4.1 Energy Generation Worldwide

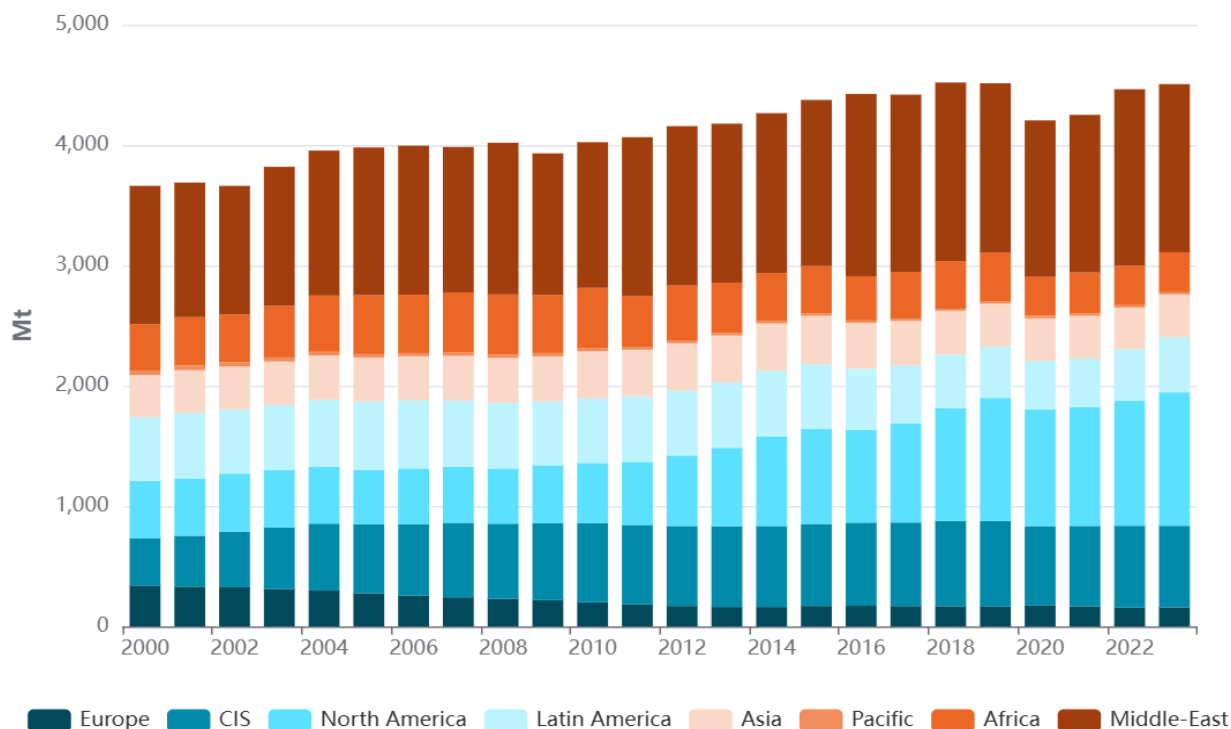
A. Oil Production

In 2022, 93.9 million barrels of oil were produced a day globally. With approximately 95 million barrels generated, oil output in 2019 touched a record high. The next year marked a noticeable fall, however, as a result of the coronavirus epidemic and its effects on the need for transportation fuel. **(Statista, 2023)**. In other words, global crude oil output increased by a record 5.4% in 2022, far more than the 1.6% annual improvement from 2010 to 2019 and the 1.3% average growth rate from those years.

In 2023, worldwide crude oil generation reached around 4.5 billion metric tons, marking the highest level ever recorded. This was nearly one billion metric tons higher than the oil produced in 1998 **(Statista, 2024)**.

According to **(EnerData, 2024)**, in 2023, the Middle East accounted for 31.4% of global crude oil production, maintaining its position as the leading producing region. North America followed, contributing 26.8% to global output, with the United States representing 18.3% and Canada 8.5%. Russia remained a key player, accounting for 12% of the total production. Other regions, including Europe, Africa, Latin America, and Asia-Pacific, also contributed to global oil production but held smaller shares (Figure 2.1).

Figure 2.1. Global Oil Production from 2000 to 2023



Source: World Energy & Climate Statistics – Yearbook 2024

With production of about 18 million barrels per day (B/D) in 2022, the U.S. maintained its position as the top oil producer in the world, which it had held since 2018 (Table 2.2). This made up almost one-fifth of the oil supply in the planet. Saudi Arabia, the world's second-largest oil producer behind the United States, produced 12 million B/D, or almost 13% of the world's oil supply, ranking it in second place. With 11 million B/D, Russia placed third in 2022. More than half of the world's oil supply is generated by these top three oil-producing behemoths, along with Canada in fourth place and Iraq in fifth. More than 70% of the world's oil is created by the top 10 oil producers, which also include the nations placed 6th to 10th: China, UAE, Iran, Brazil, and Kuwait. Particularly, between 2021 and 2022, all ten of the largest oil producers increased their output; as a result, the world's output climbed by 4.2% annually (IEA - Oil Marker Report, 2023).

Table 2.2. Oil Generation(mb/d) by Country 2022

Country	2022 Production	YoY change	Share of World Supply
United States	17,770	+6.5%	18,99%
Saudi Arabia	12,136	+10.8%	12,9%
Russia	11,202	+1.8%	11,9%
Canada	5,576	+3.0%	5,9%

Iraq	4,520	+10.2%	4,8%
China	4,111	+2.9%	4.4%
UAE	4,020	10.4%	4.3%
Iran	3,822	4.6%	4.1%
Brazil	3,107	3.9%	3.3%
Kuwait	3,028	12.0%	3.2%
Mexico	1,944	0.9%	2.1%
Total World	93,848	+4.2%	100%

Source: (IEA, 2023)

B. Natural Gas Generation

Referring to (Statista, 2023) Global natural gas production rose by 23% between 2010 and 2020, from 3,130 billion cubic meters to 3,850 billion cubic meters. This increase reflects growing energy demand, particularly in emerging and developing countries.

The United States has been the world's leading producer of natural gas since 2011, overtaking Russia, which had held this position since 2009. In 2020, the United States produced 947 billion cubic meters of natural gas, almost a quarter of the world's total. This performance is due to the development of shale gas, which accounts for more than half of US production.

Russia is the world's second-largest producer of natural gas, with 693 billion cubic meters in 2020, or around 18% of global production. Russia has the world's largest proven reserves of natural gas, estimated at 37.4 trillion cubic meters in 2020. Russia is also the world's leading exporter of natural gas, mainly to Europe and Asia.

Iran is the world's third largest producer of natural gas, with 254 billion cubic meters in 2020, or around 7% of global production. Iran also has the world's second-largest proven reserves of natural gas, estimated at 34 trillion cubic meters in 2020. Iran mainly uses its natural gas for domestic consumption and for reinjection into its oil fields.

China is the world's fourth-largest producer of natural gas, with 205 billion cubic meters in 2020, or around 5% of global production. China has seen strong growth in natural gas production in recent years, thanks to the exploitation of conventional gas, unconventional gas (shale gas, coal seam gas) and synthetic gas (coal gasification). China is also the world's leading importer of natural gas, in liquefied form (LNG) or by pipeline.

The United States is the biggest producer of natural gas on the entire planet. China generated around 5.5 percent of the world's natural gas in 2022, compared to the United States about 24.2% production (Table. 2.3). Future demand for natural gas is anticipated to increase. The energy industry's usage of natural gas has been hailed as a way to help cut greenhouse gas emissions.

The United States is the leading producer of natural gas worldwide. In 2032, it accounted for approximately 25.5 percent of global natural gas production, an increase from 19.3 percent in 2010. This growth is primarily due to advancements in fracking and horizontal drilling technologies (Statista, 2024).

Table 2.3. Top 10 Nations Producing Natural Gas by Generating Share

Country	2019	2020	2021	2022
United States	23.1%	23.7%	23.1%	24.1%
Russia	17%	16.6%	17.4%	15.3%
Iran	6.1%	6.5%	6.4%	6.4%
China	4.5%	5%	5.2%	5.5%
Canada	4.3%	4.3%	4.3%	4.6%
Qatar	4.5%	4.4%	4.4%	4.4%
Saudi Arabia	2.8%	2.9%	2.9%	3%
Norway	2.9%	2.9%	2.8%	3%
Algeria	2.2%	2.1%	2.5%	2.4%
Indonesia	1.7%	1.6%	1.5%	1.4%

Source: (Statista, 2023)

C. Coal output

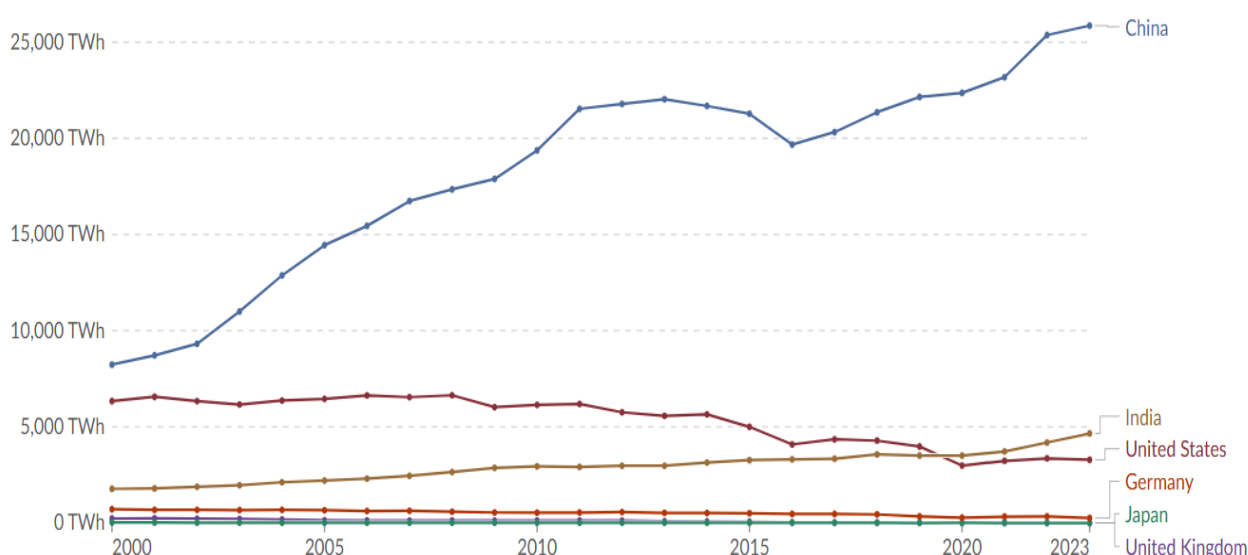
Based on (IEA, 2022), the Covid-19 pandemic's effects on the demand for power and steel caused a 4% decrease in worldwide coal output in 2020 compared to 2019 to reach 7.8 billion tonnes. China, which produces more than half of the world's products, experienced a 0.7% decrease in production, but output fell faster in other important producers including India, the USA, and Australia. Supported by economic growth and better coal prices, global coal production increased by 3.9% in 2021 as opposed to 2020 to exceed 8.1 billion tonnes. India had a record growth of 11% while China's production rose by 4%. Following the decrease in 2020, output in the United States and Australia also somewhat increased. Global coal output is expected to rise by 0.9% in 2022 compared to 2021, hitting

8.2 billion tonnes. India, China, and South Africa are predicted to raise their combined production by 7.8%³, which will boost growth.

As mentioned by (Ritchie, Roser et Rosado, 2020), global coal production has grown rapidly and continuously since the start of the industrial revolution, from less than 10 TWh per year in 1800 to over 15,000 TWh per year in 2019. This growth has been mainly driven by the growing demand for electricity, which accounts for around 40% of global coal consumption. Coal production reached its historic peak in 2013, with over 16,000 TWh produced that year. Since then, it has fallen slightly but remains at a high level.

The top three countries in world coal production are ranked as follows: China, India, and the United States. The output of each of these countries reached in 2023 respectively 25,861 TWh, 4653 TWh, and 3288 TWh (Figure 2.2).

Figure 2.2. Coal Production Worldwide from 2000 to 2023 (in terawatt-hours)



Source: (Our World in Data, 2024)

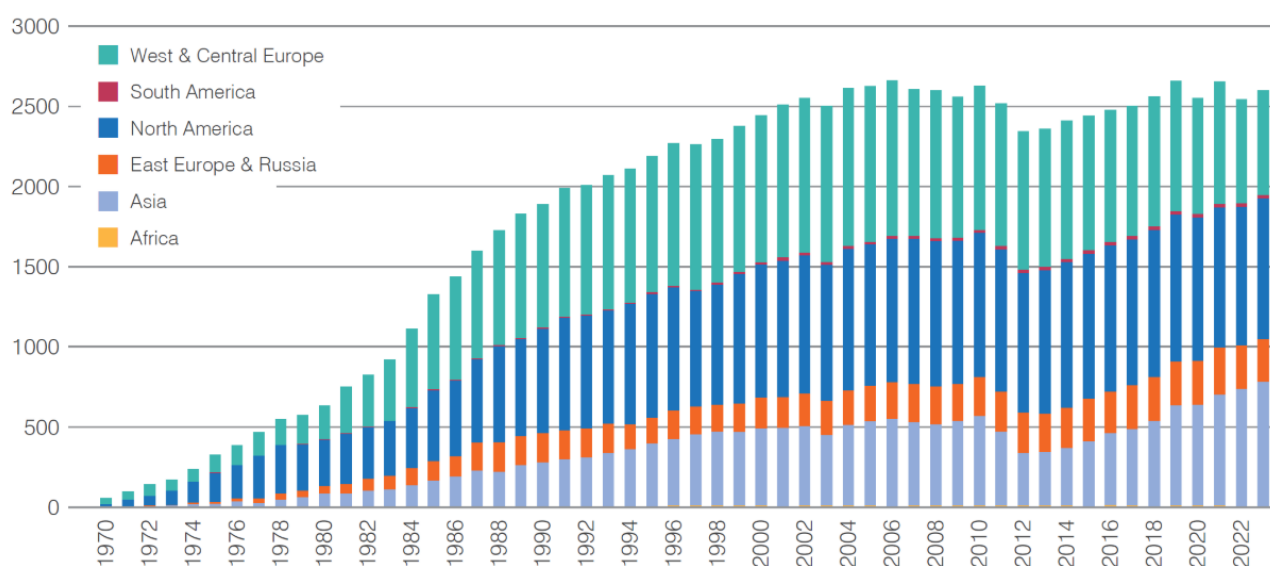
D. Nuclear energy production

According to the (World Nuclear Institute, n. d.) global nuclear power generation rose from 2507 terawatt-hours (TWh) in 2000 to 2610 TWh in 2022, an increase of 4.11%. However, nuclear power's share of the global electricity mix fell from 16.8% to 10.3% over the same period, due to the faster growth of other energy sources, notably renewables.

Global nuclear power generation in 2020 was 2,634 TWh, down 6.97% from 2019, due to lower electricity demand caused by the Covid-19 pandemic (Shen, Alberini et Timilsina, 2022).

The (Figure. 2.3) indicates that nuclear electricity production increased steadily from 1970 and reached its highest point around 2006. Following this peak, production levels have largely stabilized, showing only minor variations. In terms of world leaders in nuclear power generation, the United States occupies 1st place. It has a total nuclear capacity of 91.5 GW, generated by 93 reactors in 30 of the country's 50 states. Followed by France, which produces a larger share of nuclear power, two-thirds of its electricity is generated from nuclear sources using 56 operational reactors, which collectively produced 338.7TWh in 2020. China ranks 3rd, with a net installed capacity of 50.8 GW thanks to 51 nuclear reactors (**World Nuclear Institute, n. d.**).

Figure 2.3. Nuclear Power Generation Worldwide (TWh)



Source: World Nuclear Association

E. Renewable Energy Generation

Renewable energies have grown rapidly in recent years, accounting for around 31% of total production in 2022. Among renewable energies, hydroelectricity remains the most widely used, accounting for around 19% of total production in 2022, followed by wind power at around 8% and solar power at around 4%. Other renewable sources, such as biomass, geothermal, and tidal power, will account for around 2% of total production in 2022. Nuclear power has seen a slight increase in recent years, accounting for around 11% of total production in 2022. This increase is due to the commissioning of new reactors, notably in China, Russia, and the United Arab Emirates.

According to (**IRENA, 2024**), the worldwide renewable energy capacity reached 3,870 gigawatts in 2023, with solar energy leading the pack at 1,419 gigawatts. The remaining capacity was primarily attributed to renewable hydroelectricity and wind energy, with total capacities of 1,268 gigawatts and

1,017 gigawatts respectively. Other renewable sources included 150 gigawatts of bioenergy, 15 gigawatts of geothermal power, and 0.5 gigawatts of marine energy.

Asia increased its renewable capacity by 327.8 GW to reach 1 961 GW (50.7% of the global total) by 2023, accounting for a large portion of new capacity (69.3%). China contributed +297.6 GW of this growth. In North America and Europe, capacity increased by 34.9 GW (+7.0%) and 71.2 GW (+10.0%), respectively. Africa's GDP increased by 2.7 GW (+4.6%), maintaining its steady expansion. Australia played a major factor in Oceania's 5.5 GW (+9.4%) rise in installed capacity, while South America sustained its upward trend with a 22.4 GW (+8.4%) expansion in capacity. Additionally, the Middle East had its greatest increase, adding 5.1 GW of new capacity in 2023 (+16.6%). With a total capacity share of 980 GW, the G7 nations (except the EU) contributed about 25.3% of the world capacity share. With a combined capacity of 3 084 GW, the G20 countries except the EU and AU have a total capacity of 3 084 GW, or 79.7% of the worldwide share. In 2023, the G20 and G7 nations represented about 87.2% and 14.7% of additional capacity, respectively (IRENA, 2024). The table below illustrates the renewable energy capacities by sources in 2023

Table 2.4. Renewable Energy Capacities in 2023

Renewable Energy	Capacity	Leaders Countries
Solar energy	Solar photovoltaic power was responsible for nearly the entire increase in solar energy capacity, with solar PV growing by 345.5 GW and concentrated solar power (CSP) adding just 0.3 GW.	In 2023, Asia saw a significant expansion in solar capacity, adding 237.7 GW compared to 110.7 GW in 2022. China and India accounted for the majority of this growth, contributing 216.9 GW and 9.7 GW respectively. Japan also added 4.0 GW, which was slightly less than its increase in 2022. Outside of Asia, the United States increased its solar capacity by 24.8 GW, while Germany and Brazil added 14.3 GW and 11.9 GW respectively.
Wind energy	In 2023, wind power experienced its largest growth in	China contributed nearly two-thirds of this expansion with an addition of 75.9 GW, while the United States saw an increase of 6.3 GW.

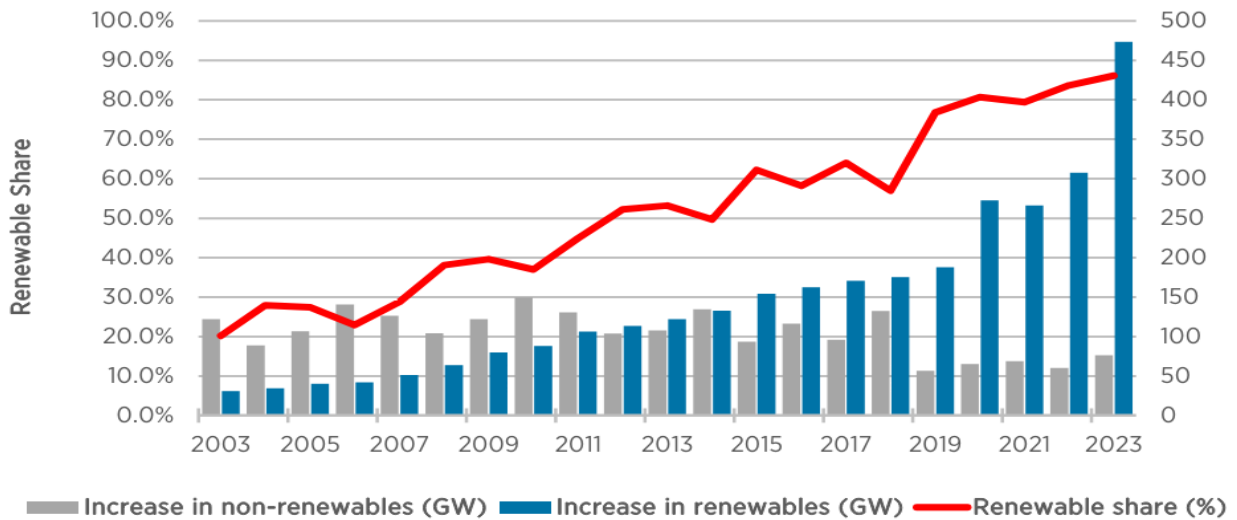
	the past decade, increasing by 116.0 GW.	The remaining capacity growth was primarily seen in Brazil, India, Canada, and several European countries. Offshore wind made up about 1.9% of the total renewable power capacity and 7.1% of the total wind capacity.
Hydropower	Renewable hydropower has seen a modest increase in recent years, adding 7 GW of capacity.	The largest contribution to this growth came from China's 5.4 GW. Other countries that expanded their capacity by more than 0.5 GW include Australia, Nigeria, and Colombia.
Bioenergy	The expansion of bioenergy capacity slowed in 2023, increasing by 4.4 GW compared to 6.4 GW in 2022	China saw the largest growth with an increase of 1.9 GW. Other significant increases occurred in Japan with 1.0 GW, Brazil with 0.4 GW, and Uruguay with 0.3 GW.
Geothermal energy	In 2023, geothermal capacity saw a slight increase (208 MW)	The majority of this growth comes from Indonesia (58 MW), Kenya (35 MW), and Chile (32 MW).

Source: Realized by the researcher using data from (IRENA, 2024)

In comparison to 2022, the expansion of renewable power capacity in 2023 rose and remained far above the long-term trend (Figure 2.4). China and the United States accounted for a larger portion of this increase than in prior years. Nonetheless, in comparison with 2022, the majority of other nations also accelerated the growth of their renewable capacity in 2023.

In 2023, the contribution of renewable energy in total capacity growth increased to 86%, up from 84% in 2022. Additionally, from 40.4% in 2022 to 43.2% in 2023, the share of renewable energy in total power capacity increased by about three percentage points (IRENA, 2024).

Figure 2.4. Renewable Share of Annual Energy Capacity Growth

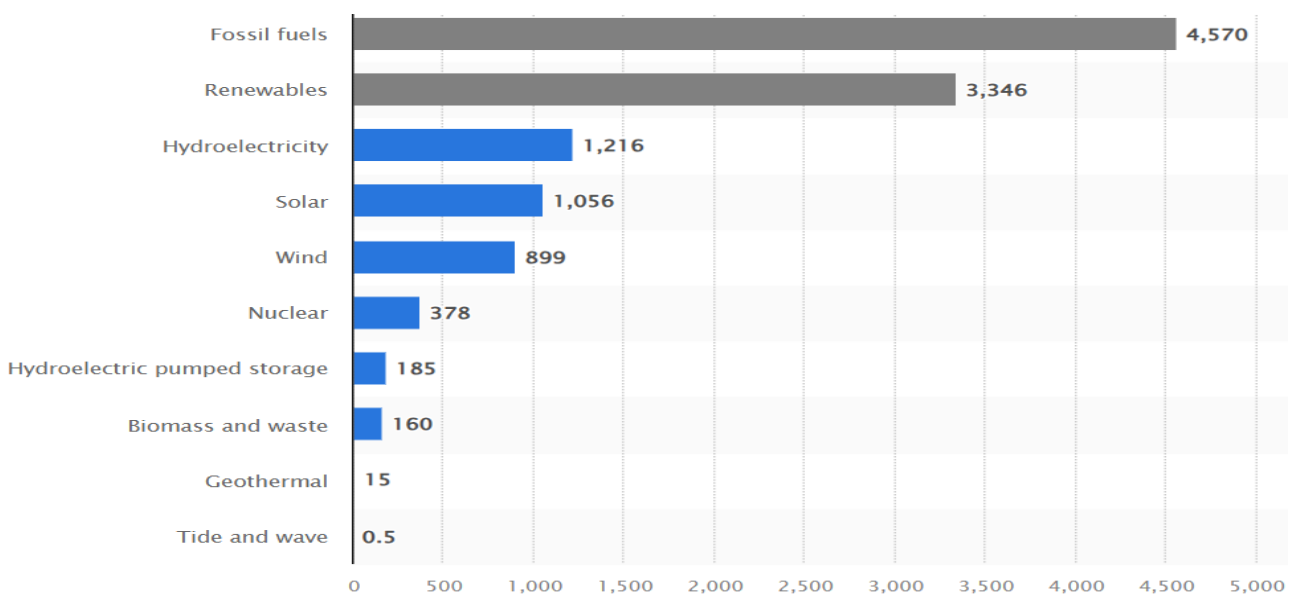


Source: (IRENA, 2024)

F. World electricity production

Globally, renewable energy sources generated more than 3.3 terawatts of electricity in 2022. This was still far less than the combined 4.57 terawatt capacity of all fossil fuel-based energy sources, though (Figure 2.5). Globally, coal remains the most significant source of energy generation representing around 35.8% of the world's energy mix in 2022, with natural gas following in second with 22%. In 2021, the USA, China, and India consumed the greatest amount of coal for the production of energy (Statista, 2024).

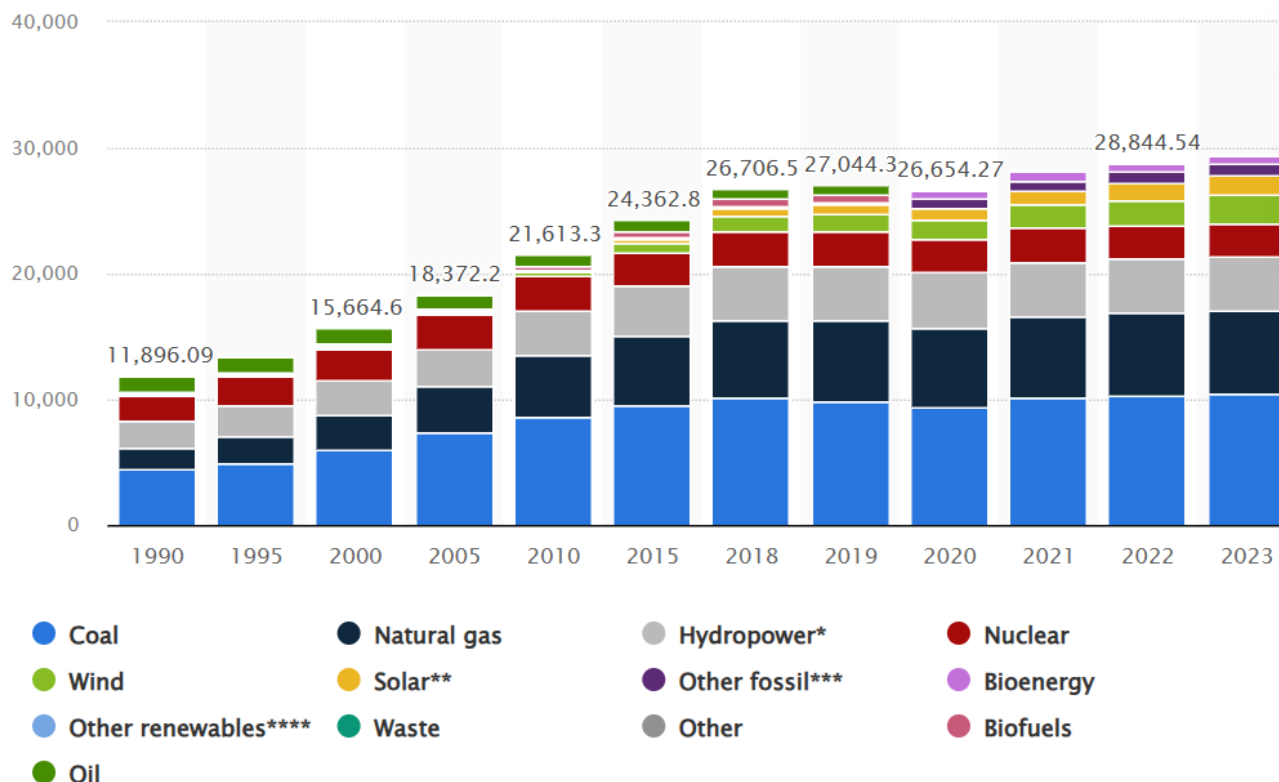
Figure 2.5. World Electricity Generation by Source 2022 (GW)



Source: (Statista, 2024)

According to (Statista, 2023), global electricity production rose by 162.1% between 1990 and 2022, from 11,127 TWh to 26,662 TWh. This increase reflects growing energy demand, particularly in emerging and developing countries. Coal has continued to be the world's top source of energy generation for the past three decades. Over 10,500 terawatt-hours of coal were used to generate electricity worldwide in 2023 (Figure 2.6). About 60% of the world's power was produced that year using coal, natural gas, and other fossil fuels.

Figure 2.6. Global Electricity Generation 1990-2023 (TWh)



Source: (Statista, 2024)

2.2.4.2 World Energy Consumption

A. Oil Consumption

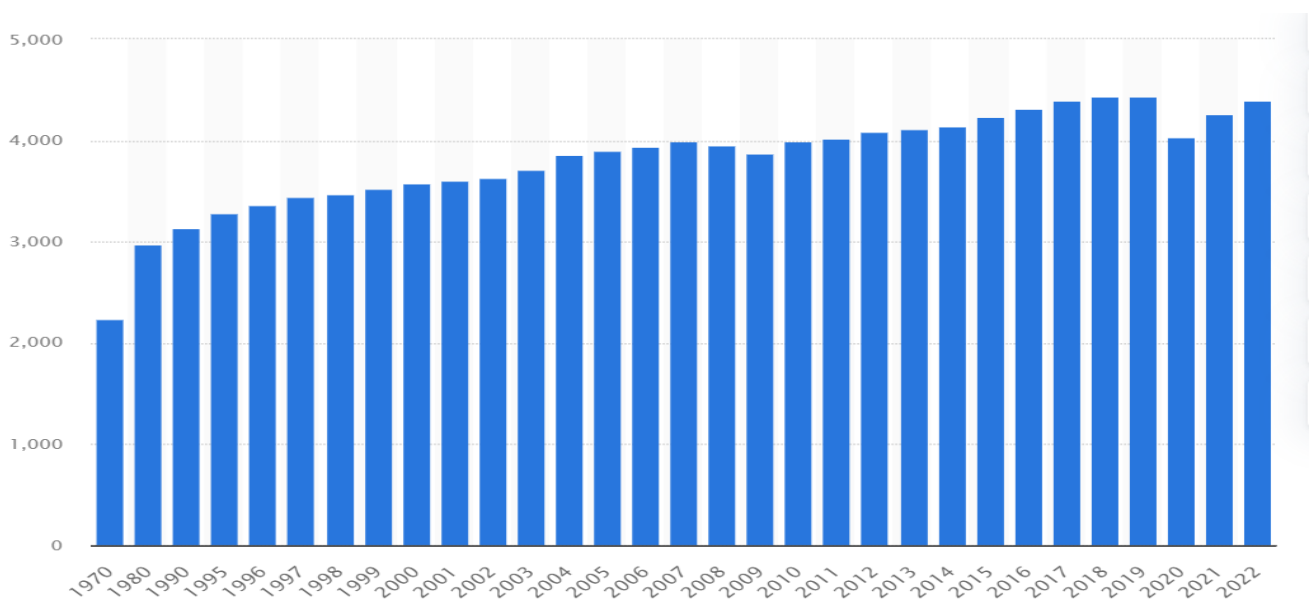
According to the International Energy Agency (IEA, n. d.), world oil consumption has followed the evolution of global energy demand, which has been influenced by several factors, such as population growth, economic development, technological progress, energy and environmental policies, and geopolitical events.

Global oil consumption rose steadily between 1990 and 2008, from 3.141 billion metric tons to 3.958 billion metric tons. This increase was driven by strong growth in emerging countries, notably China and India, which experienced rapid urbanization and intensive industrialization. These

countries have increased their demand for oil to power their vehicles, factories, and power plants. Due to the global financial crisis, which brought about a slump in the economy in many regions of the world, worldwide oil consumption decreased in 2009 to 3.867 billion metric tons. mainly to the recession in business and industrial activity, the drop in air travel and foreign commerce, as well as consumer energy conservation efforts, there was a decrease in the demand for oil. Between 2010 and 2019, the world's oil consumption increased once again, setting a new high of 4.441 billion metric tons in 2019. The worldwide economic recovery, particularly in emerging and developing nations, which continued to result in an increase in their demand for oil, served as an underpinning for this recovery. The surge in unconventional hydrocarbons, such shale oil or tar sands, which allowed the United States and Canada to lessen their reliance on imports, also resulted in an increase in the world's oil supply at the same time.

In light of the coronavirus pandemic, which resulted in unbeatable health and economic crises globally, global oil consumption decreased once again in 2020, to 4.037 billion metric tons (Figure 2.7). Because of the containment and social isolation policies put in place by governments to stop the virus's spread, there has been a sharp decline in road, rail, and air travel as well as in industrial and commercial activity, which has resulted in a sharp decline in demand for oil. Global oil consumption in 2022 reached 4.394 This recovery is being driven by the deployment of coronavirus vaccines and the gradual lifting of health restrictions around the world. Oil demand is stimulated by the global economic recovery, particularly in the transport and industrial sectors (Statista, 2024).

Figure 2.7. Global Oil Consumption 1970 - 2022 (in Million Metric Tons)



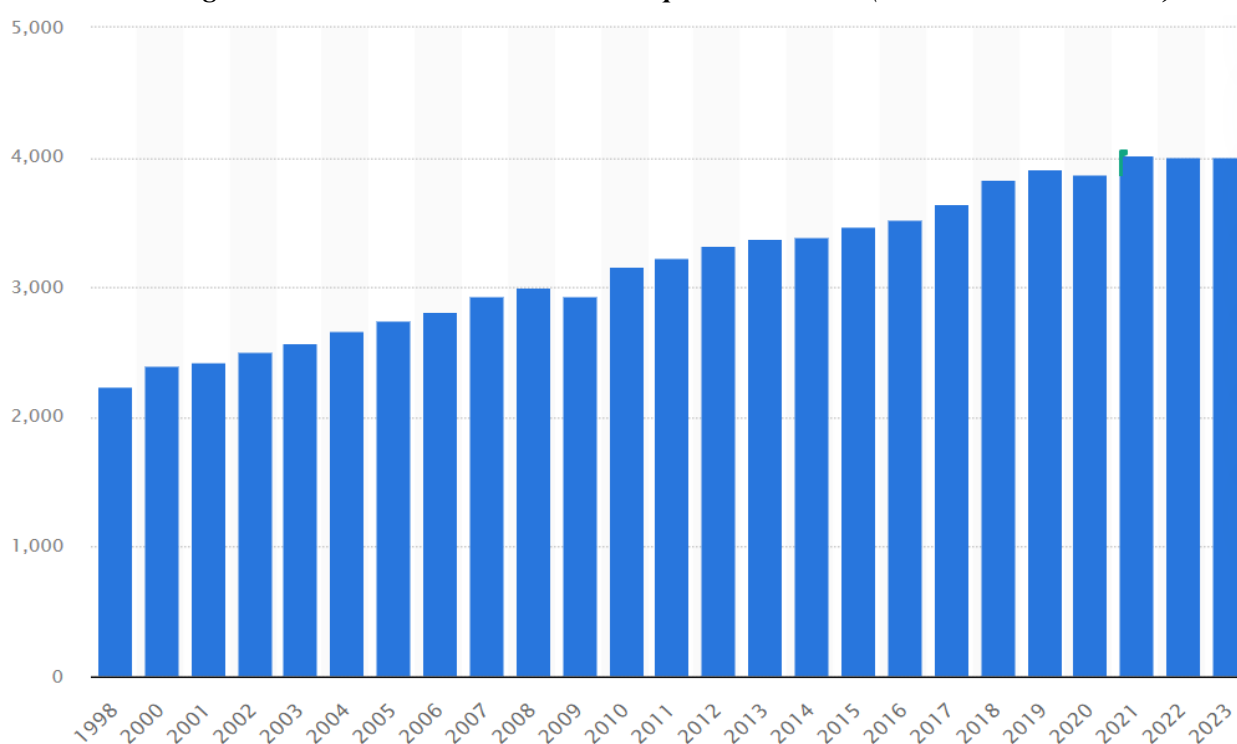
Source: (Statista, 2024)

B. Natural gas consumption

Over the past 20 years, the world's consumption of natural gas has grown. The amount of natural gas consumed worldwide in 2023 reached approximately 4 trillion cubic meters. (Statista, 2024).

The use of natural gas has decreased in different regions of the world in 2023, most notably in Europe (-5.6%), North America (-1.9%), and Asia (-0.8%). Several causes might account for this reduction, including the health crisis, competition from renewable energy sources, energy efficiency initiatives, and weather conditions. By contrast, natural gas consumption rose in other regions, such as the Middle East (+4.7%), Africa (+3.5%) and Latin America (+2.9%).

Figure 2.8. Global Natural Gas Consumption 1998-2023 (in Billion Cubic Meters)



Source: (Statista, 2024)

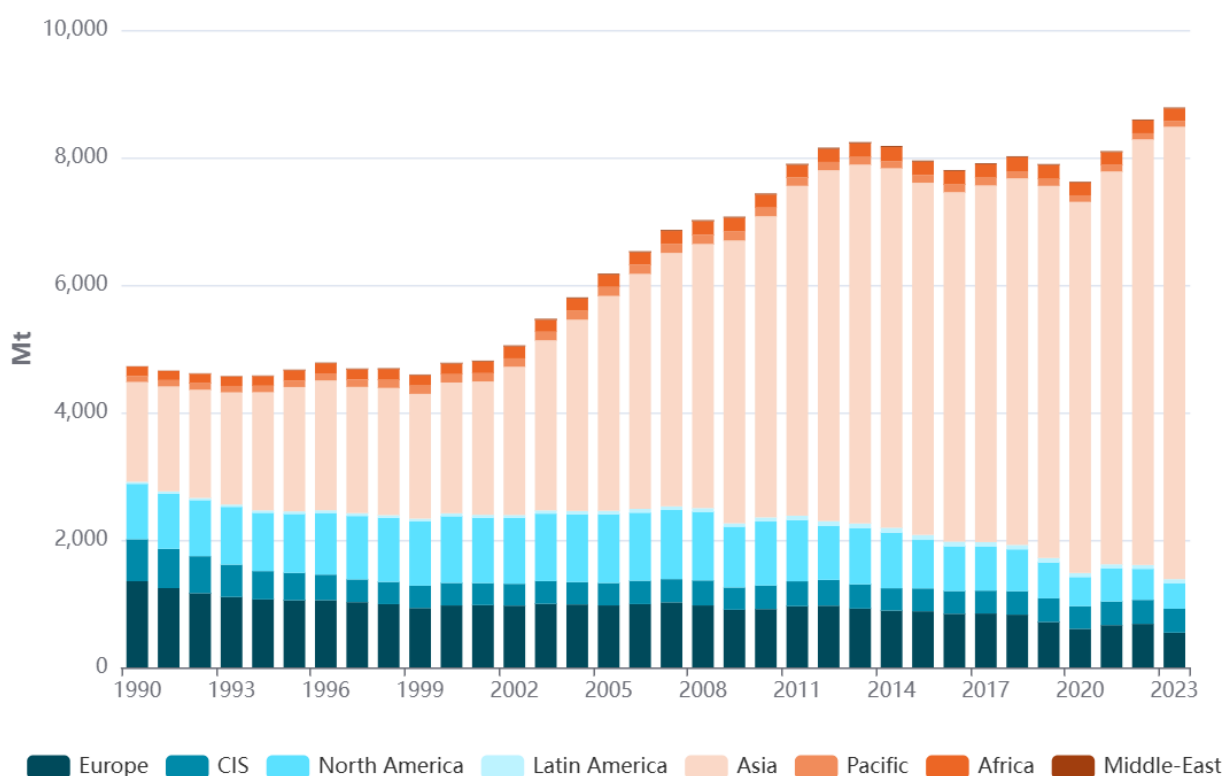
C. Coal Global Consumption

The use of coal has climbed in emerging nations over the past decade while declining in industrialized ones. The Organization for Economic Co-operation and Development (OECD)'s 38 member nations had a 3.9% average yearly decline in coal usage over the past 10 years. The average yearly growth rate of coal use in non-OECD nations was 1.4% (Forbes, n. d.). The European Union (EU) and the OECD both saw a decline in consumption. The average yearly diminution of coal usage in the EU over the past ten years has been 4.2%. However, by 2022, the EU's coal consumption had

turned around and climbed by 2.0%. The invasion of Ukraine by Russia and the substitution of coal for Russian natural gas in EU nations are the causes of the current situation.

In 2023, global coal consumption grew by 2.2%, slowing from 6% in 2022 but remaining above the 2010-2019 average. Non-OECD countries, led by China (+6.9%), India (+9.9%), and Vietnam (+25%), drove demand, while OECD nations saw declines due to weak economic growth and rising renewables. The U.S. (-18%), EU (-22%), Japan (-8.9%), and South Korea (-2.8%) reduced coal use, with Australia and South Africa also experiencing declines.

Figure 2.9. Coal Global Consumption, 1990-2023 (Mt)



Source: World Energy & Climate Statistics – Yearbook 2024

In the Asia Pacific area, six of the top 10 coal users in the world are located. China still controls the majority of the world's coal production and consumption, and it probably will for many years to come. In 2024, the top 10 coal users worldwide were listed below in the following Table:

Table 2.5. Top 10 Consumers of Coal 2024

Rang	Country	Billion Cubic Feet	Rang	Country	Billion Cubic Feet
01	China	4.3T	06	Japan	210.6B

02	India	966.3B	07	South Africa	202.3B
03	US	731.1B	08	South korea	157.1B
04	Germany	257.5B	09	Poland	148.8B
05	Russia	230.4B	10	Australia	129.6B

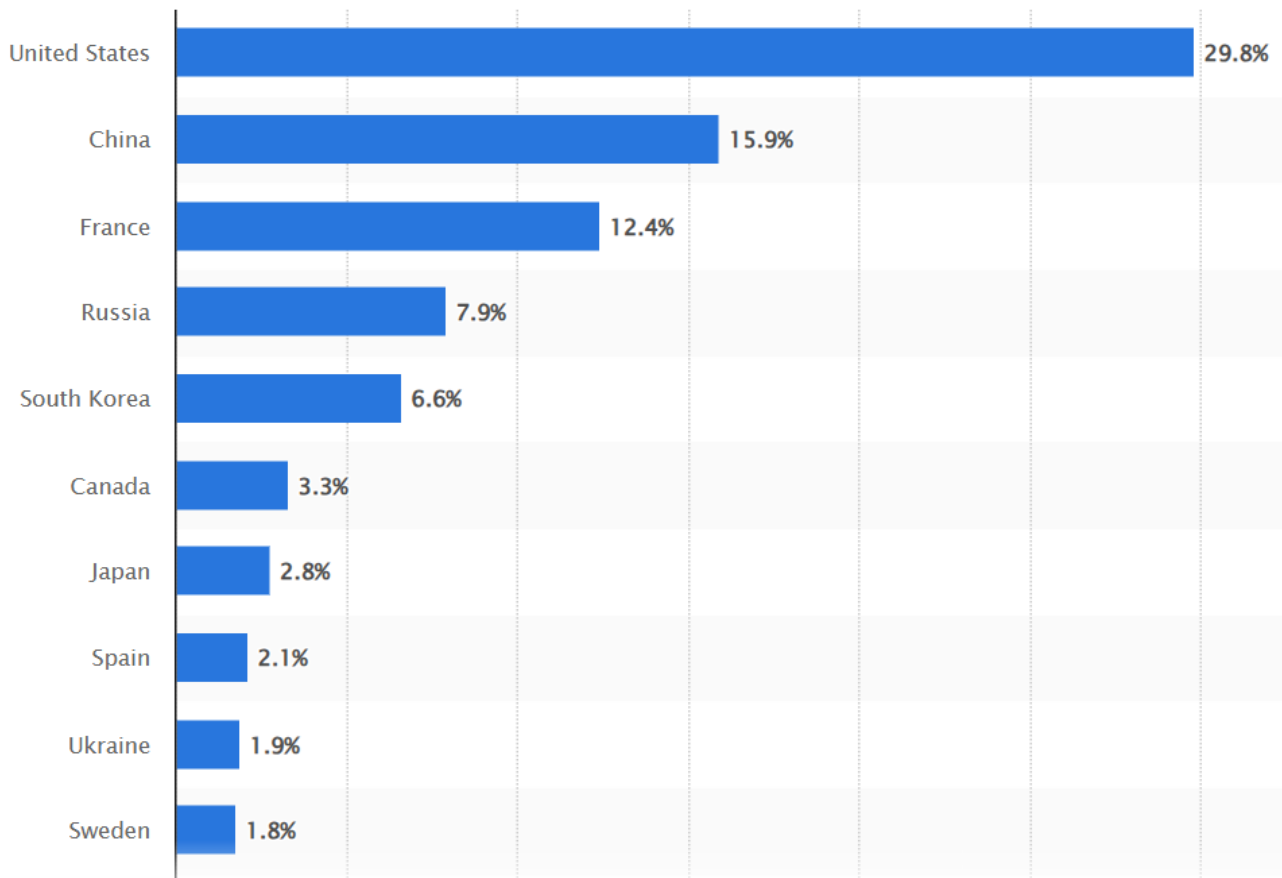
Source : World Population Review

D. Nuclear global consumption

According to (Statista, 2024) global nuclear energy consumption reached 24.13 Exajoules in input equivalent in 2022, down from 25.33 Exajoules in 2021. Nuclear power accounts for around 10% of global electricity production.

In 2023, the United States was the world's leading consumer of nuclear energy, making up nearly 30% of global nuclear power usage. That year, U.S. nuclear energy consumption reached 7.3 exajoules. The USA has the largest number of operating nuclear reactors in the world, with a rate of 29.8% in May 2023. China is the second largest consumer of nuclear energy, accounting for 15.9% of global consumption in 2023. China also has a record number of nuclear reactors under construction and planned in the world, with 21 and 45 units respectively by May 2023. China is expected to overtake the USA as the world's leading producer of nuclear power. France is the world's third-largest consumer of nuclear energy, accounting for 12.4% of global consumption in 2023. Other countries consuming nuclear power are Russia (7.9%), South Korea (6.6%), Canada (3.3%), Ukraine (1.9%), Sweden (1.8%), and various other countries, which together will account for 31.6% of global consumption in 2023 (Statista, 2024).

Figure 2.10. Globally Distributed Nuclear Energy Consumption in 2023, by Nation

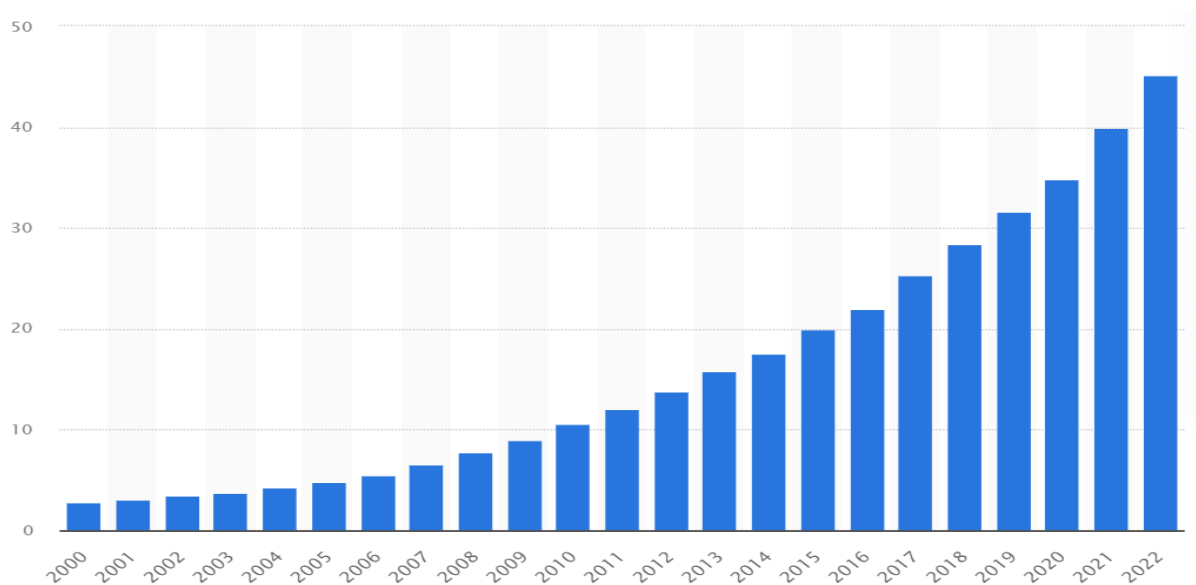


Source: (Statista, 2024)

E. Renewable Energy Consumption

Global consumption of renewable energy has increased significantly over the past two decades. According to (Statista, 2024), renewable energy consumption reached almost 45.18 Exajoules in 2022, up 6.8% in 2021 (Figure. 2.11). Despite its rapid growth, renewable energy consumption still lags far behind that of coal, natural gas, oil, and other energy technologies. Indeed, the share of renewables in final energy consumption was just 14% in 2022, compared with 81% for fossil fuels and 5% for nuclear power.

Figure 2.11. Renewable Energy Consumption 2000-2022



Source: (Statista, 2024)

Around half of the world's final consumption of renewable energy comes from modern sources of bioenergy, such as biofuels, biogas, and solid biomass used to generate electricity and heat. In particular, bioenergy accounts for a significant share of renewable energy consumption in the transport (63%), industry (55%), and residential (49%) sectors (IRENA, 2022). However, bioenergy also presents environmental and social risks, such as deforestation, competition with food crops and greenhouse gas emissions.

Among other renewable energy sources, hydropower is the most widely used for electricity generation, with an installed capacity of 1,350 gigawatts (GW) by 2022, representing 54% of total renewable energy. Hydropower is particularly well developed in China, Brazil, Canada, the United States and Russia. However, hydropower also faces challenges such as its impact on aquatic ecosystems, local populations and the climate (IEA, n. d.).

Wind power is the second most important renewable energy source for electricity generation, with an installed capacity of 743 GW by 2022, or 28% of total renewable energy. Wind power has grown rapidly in recent years, thanks in particular to falling costs and improved performance. The main wind power-producing countries are China, the United States, Germany, India and Spain. Wind power offers advantages such as reduced greenhouse gas emissions, job creation and diversification of the energy mix (EIA, n. d.).

Solar photovoltaics (PV) is the renewable energy source that has dominated growth in installed capacity in recent years. By 2022, installed solar PV capacity had reached 627 GW, or 24% of total

renewable energy. Solar PV has benefited from the sharp drop in solar module costs, as well as the development of rooftop and off-grid installations. The main countries producing solar PV are China, the United States, Japan, India, and Germany. Solar PV offers opportunities such as access to electricity in rural areas, reduced dependence on fossil fuels, and technological innovation (EIA, n. d.).

Other renewable energy sources include geothermal, tidal, wave, and solar thermal. These sources have a smaller installed capacity but offer significant potential for future development. For example, geothermal energy can provide continuous, low-carbon heat and power. Tidal and wave energy can harness the power of the oceans to generate renewable electricity. Solar thermal energy can provide heat for heating, cooling, and domestic hot water.

F. world electricity consumption

According to the International Energy Agency (EIA, n. d.) global electricity consumption rose by 175% between 1974 and 2019, from 8,900 terawatt-hours (TWh) to 24,500 TWh. This growth was mainly driven by the industrial sector, which saw its electricity consumption triple over the same period, reaching 10,000 TWh in 2019, or 41% of global consumption. The industrial sector includes manufacturing, construction, mining, and extraction activities.

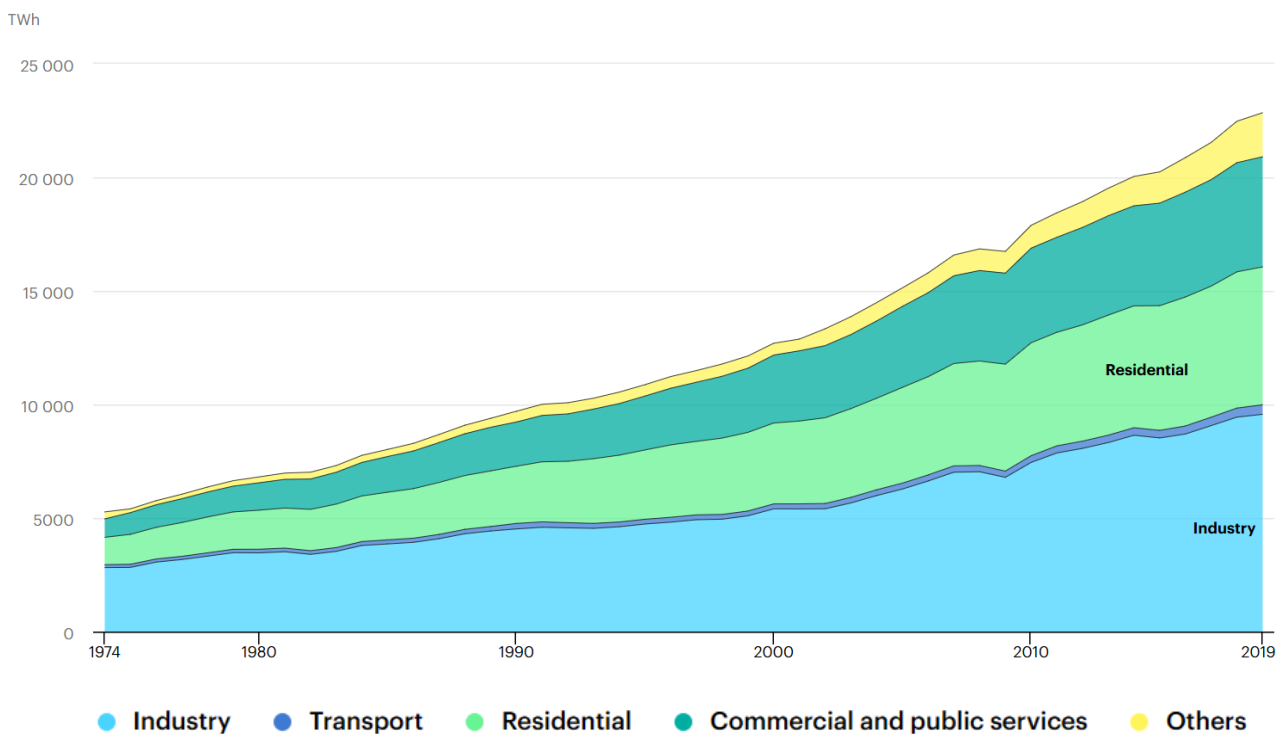
The residential sector is the second largest consumer of electricity, with a share of 27% in 2019. The residential sector includes households and collective dwellings. Electricity consumption in the residential sector rose by 250% between 1974 and 2019, from 1,800 TWh to 6,500 TWh. This increase is due to population growth, urbanization, rising living standards, and the spread of household appliances.

With a share of 22% in 2019, the third-biggest power consumer is the tertiary sector (Figure. 2.12). The tertiary sector includes industries that provide both private and public services, such as trade, hotels, education, healthcare, administration, and defense forces. Between 1974 and 2019, there was a 370% increase in the tertiary sector's electricity usage, from 1,100 TWh to 5,200 TWh. Economic growth, tertiarization of operations, and digitalization of services can all be used to explain this trend.

The fourth-largest electricity consumer was the transport sector, with a contribution of 2% in 2019. The transportation industry encompasses air, marine, rail, and road transportation. Between 1974 and 2019, the transportation sector's electricity usage increased by 160%, from 200 TWh to 600 TWh. The development of electric vehicles, which will make up around 2% of the global vehicle fleet in

2019, as well as the expansion in rail traffic, especially in developing nations, should be attributed to this increase.

Figure 2.12. Global Final Electricity Consumption by Sector



Source: (IEA, 2021)

2.2.5 Facing the Global Energy Crisis: Impacts and Consequences

The world is dealing with serious issues and profound repercussions as a result of the global energy crisis. This crisis highlights the pressing need for sustainable energy solutions. It is driven by depleting fossil fuel sources, geopolitical conflicts, and environmental deterioration.

2.2.5.1 Wood Crisis in England Drives First Industrial Revolution

The energy crisis is a result of the Industrial Revolution, which was a turning point in human history (Ashton, 1997). During that time, an economy focused on mass production, mechanization, and technological innovation replaced one that was agrarian and artisanal. In addition to unprecedented economic growth, it also brought about significant cultural and social transformation. Furthermore, it caused environmental deterioration, rising demand and costs, and an ongoing lack of energy resources.

During the 16th and 17th centuries, England experienced strong demographic and economic growth, which led to an increase in energy demand. The main source of energy at the time was wood,

used for heating, industry, and shipbuilding. Wood came from forests, which covered around 15% of English territory in 1086.

However, English forests have undergone progressive deforestation, due to several factors. On the one hand, forest land was cleared to make way for agriculture, which was more profitable and more useful for feeding the population. Secondly, wood was overexploited to meet the growing needs of industry, particularly metallurgy and textiles, which used charcoal as fuel. Furthermore, wood was massively consumed for the construction of warships, which were essential for England's defense and expansion (**Wrigley, 1972**).

The consequence of this deforestation was a shortage of wood, which manifested itself in price inflation and dependence on imports. The price of wood increased tenfold between 1540 and 1620. Wood had to be imported increasingly from the Baltic, which represented a high cost and a strategic risk for England. Indeed, if the English fleet was destroyed by an enemy, the latter could block timber supplies and prevent ships from being rebuilt (**Wrigley et Wrigley, 1990**).

Faced with this energy crisis, England had to find solutions to its dependence on wood. The main solution was to turn to coal, which was abundant and cheap in England. Coal gradually replaced wood as the energy source for heating, industry and even iron production. Coal underpinned England's economic and technological growth, and set the stage for the industrial revolution.

The Industrial Revolution is the process that enabled the transition from an economy based on agriculture and crafts to one based on industrial production, mechanization, and technological innovation. It took place between the 18th and 19th centuries, mainly in Europe and North America. It brought unprecedented economic, social, and cultural growth, but also a transformation in energy consumption and production. It accelerated the demand for fossil fuels, notably to power steam engines, internal combustion engines, and electricity. It has also encouraged the development of new energy sources, such as gas and oil. However, it has also had harmful consequences, such as air, water, and soil pollution, as well as the emission of greenhouse gases responsible for climate change.

2.2.5.2 Global Oil Crisis And its Repercussions

On October 6, 1973, during the Yom Kippur War, Egypt and Syria unexpectedly attacked Israel. This was the beginning of the 1973 oil crisis (**Pollack, 1974**). They set out to reclaim the areas that had been lost in the Six-Day War of 1967. After three weeks of fighting, Israel, with support from the United States and other Western nations, was able to hold off the Arab attack. However, the Arab members of OPEC (Organization of Petroleum Exporting Countries) decided to use their influence

on the world oil market as a means of political pressure. They announced a gradual reduction in their oil production and an embargo on deliveries to the United States and other countries supporting Israel. They also raised the price of a barrel of oil from 3\$ to 12\$ between October 1973 and January 1974.

The oil crisis had major economic and social consequences worldwide (**Issawi, 1978**). It led to a sharp rise in the cost of energy, affecting all sectors of activity and all households. It also led to galloping inflation, stagnant growth, high unemployment, and deteriorating trade balances. The crisis revealed the fragility of the international monetary system based on the US dollar, which was linked to gold until 1971. It also heightened tensions between industrialized and developing countries, which were demanding greater participation in global economic decision-making and a better distribution of wealth. The crisis also had an impact on the environment, raising awareness of the limits of natural resources and the risks associated with pollution (**Mitchell, 2014**). It also had major political and strategic repercussions. It weakened the United States' position as a world leader and ally of Israel. It strengthened the power and cohesion of Arab oil-producing countries, which used their revenues to finance their economic and social development, as well as their support for nationalist and revolutionary movements in the Third World. It also encouraged the search for a peaceful solution to the Arab-Israeli conflict, which led to the Camp David Accords in 1978 and the peace treaty between Egypt and Israel in 1979. It also encouraged Western countries to reduce their dependence on oil and diversify their energy sources, notably by developing nuclear power, renewable energies, and energy efficiency. However, these efforts were undermined by the second oil crisis of 1979, triggered by the Iranian revolution and the Iran-Iraq war.

The 1979 crisis was the second oil crisis to affect Western economies after that of 1973. It was triggered by the Iranian revolution, which overthrew the US-backed Shah regime and established an Islamic Republic led by Ayatollah Khomeini. The revolution led to a drop in Iranian oil production, from 6 million barrels per day in 1978 to 1.5 million in 1979 (**Zulkifli et Haqem, 2022**). It also led to regional instability, culminating in the Iran-Iraq war in 1980. These events created a climate of uncertainty and tension in the oil market, leading to a further surge in prices. The price reached 39\$ a barrel in February 1981. This increase reinforced the negative effects of the 1973 crisis on Western economies, which entered a phase of stagflation, which meant stagnant growth accompanied by high inflation.

The 1979 crisis had far-reaching economic, social, and political consequences. On the economic front, it accentuated the slowdown in growth and unemployment in industrialized countries, particularly in Europe. It also aggravated trade and financial imbalances between oil-exporting and oil-importing countries. It encourages the emergence of new economic players, such as the Gulf

States and emerging countries, which are taking advantage of rising oil prices to expand. It also encourages consumer countries to diversify their energy sources and reduce their dependence on oil. On the social front, the crisis increased inequality and insecurity in Western societies. It reduced the purchasing power of households, which had to cope with the rising cost of energy and imported goods. It has also led to a rise in social discontent and demands, manifested in strikes, demonstrations, and riots in several countries. It is also contributing to the emergence of new social movements, such as environmentalists and alter globalists, who denounce the harmful effects of the capitalist system and globalization. Politically, the 1979 crisis altered international balances of power and national political orientations. It weakened the position of the United States, which lost its strategic ally in Iran and had to face up to the rise of radical Islamism in the region. It also strengthens the role of the Organization of the Petroleum Exporting Countries (OPEC), which controls a large part of the world oil market. Finally, it favored the election or accession to power of conservative or liberal leaders in several Western countries, such as Ronald Reagan in the United States, Margaret Thatcher in the United Kingdom, and Helmut Kohl in Germany, who advocated a policy of fiscal austerity and economic liberalization (**Bangura, Mustapha et Adamu, 1983**).

2.2.5.3 Fukushima Nuclear Crisis

According to the (**World Nuclear Association, n. d.**) the Fukushima nuclear crisis in 2011 was the worst nuclear disaster since Chernobyl in 1986. It was triggered by a magnitude 9.0 earthquake followed by a tsunami, which damaged the reactors at the Fukushima Daiichi nuclear power plant on Japan's northeast coast. This situation resulted in radioactivity leaking into the air, water and soil, affecting the health and environment of local and regional populations. It also had a major impact on power generation in Japan and on the safety of nuclear energy worldwide. In terms of energy, it has led to a drop in electricity production in Japan, which was 30% dependent on nuclear power before the disaster. It also caused a shortage of electricity in the country, which had to resort to economic measures and massive imports of fossil fuels to meet demand. Finally, it called into question Japan's energy policy, as the country decided to gradually reduce its share of nuclear power and develop renewable energies.

In social terms, the nuclear crisis affected the health and environment of local and regional populations. It resulted in radioactivity leaking into the air, water, and soil, exposing residents to the risk of cancer, malformations, and psychological disorders. It also led to the evacuation and displacement of over 160,000 people, who lost their homes, jobs, and communities. It also generated mistrust of the authorities and experts, who were accused of minimizing or concealing the seriousness of the situation (**Maeda et Oe, 2017**).

On the political front, the nuclear crisis raised global awareness of the risks associated with nuclear energy. It prompted several countries to review their nuclear policy and tighten up their safety standards. Some countries, such as Germany and Switzerland, have even decided to phase out nuclear power in the medium to long term. Other countries, such as France and China, have maintained their choice of nuclear power, but have put in place action plans to improve the safety of their facilities. It has also stimulated public debate on the pros and cons of nuclear power, particularly in terms of cost, environmental impact, and waste management (**Bernardi et al., 2018**).

2.2.5.4 The Global Energy Crisis Caused By The Covid-19 Pandemic.

The global energy crisis of 2021-2023 is an unprecedented situation affecting all sectors of the economy and society. It is the result of a combination of several factors, the main ones being:

- The strong economic recovery following the Covid-19 pandemic, which has led to an increase in global demand for energy, particularly electricity. According to (**World Energy Council, n. d.**), global electricity demand rose by 6% in 2021, the highest increase on record.
- Russia's invasion of Ukraine in February 2022, led to an escalation in geopolitical tensions and a reduction in gas supplies from Russia, the world's leading exporter of natural gas. Europe, which relies heavily on Russian gas for power generation and heating, was particularly hard hit by this crisis (**Brunk et Hakimi, 2022**).
- Tensions in the gas, coal, and oil markets, leading to soaring prices for these fossil fuels. The price of natural gas has reached historic levels on the world's main markets, sometimes exceeding 100 euros per megawatt-hour in Europe. Coal prices also reached record levels, particularly in Asia, where it is widely used for power generation. Oil prices have followed the same trend, topping 100\$ a barrel in October 2022 (**Kuik et al., 2022**).

These factors have had many and varied consequences for countries and regions around the world. Among the most important are:

- Rising inflation and slower economic growth, due to higher production and transport costs, as well as reduced purchasing power for households and businesses. According to the International Monetary Fund (**IMF, n. d.**), global inflation is set to reach 5.9% in 2022, the highest level since 1980. The IMF has also downgraded its forecast for global growth in 2022, from 5.9% to 3.9%.
- Worsening poverty and social inequality, particularly in developing countries, where rising energy and food prices are taking a heavy toll on the budgets of the most vulnerable households (**Clemente-Suárez et al., 2021**). According to the (**World Bank, 2023**), the

energy crisis could push a further 150 million people into extreme poverty by 2022. The energy crisis also threatens the progress made towards universal access to affordable and reliable energy services.

- Negative environmental and climate impacts, linked to rising greenhouse gas (GHG) emissions from increased fossil fuel combustion. According to the (IEA, 2023) global energy-related CO₂ emissions are set to rise by 5% in 2021 and 3% in 2022, reaching record levels. The energy crisis is thus jeopardizing international efforts to limit global warming to 1.5°C, in line with the Paris Climate Agreement.

2.2.6 Comparative Analysis of Renewable Energy Policies: EU, China, USA

Various policies have been crafted and put into action to advance the adoption of renewable energy. These encompass pricing laws, quota requirements, production incentives, tax credits, and trading schemes (Lipp, 2007). The efficacy of these support measures, either individually or in combination, in fostering RE development remains a topic of ongoing discourse, particularly as more nations pursue RE strategies. While many countries share similar objectives in energy policy, such as diminishing reliance on imported fossil fuels, curbing the environmental impact of the energy sector, and fostering industrial growth, the specific policies adopted to achieve these goals can diverge significantly, often influenced by unique national contexts shaped by distinct cultures and histories. Nevertheless, two policies, the Feed-in Tariff (FIT) and the Renewable Portfolio Standard (RPS), have emerged as prominent methods for promoting renewable energy, sparking debates over their effectiveness and potential trade-offs. Certain countries and regions are currently deliberating on RE policy frameworks, evaluating which model best aligns with their particular circumstances and objectives. As (Ekins, 2004) notes, "no optimal model has emerged, and probably none will emerge in contexts shaped by different histories and cultures. But there is a huge scope for analysis and comparison of different experiences to illuminate, in any particular context, how this improvement in delivery can be achieved." Consequently, we delve into a comparative examination of RE policy experiences in three leading areas: the European Union (EU), China, and the United States of America (USA).

2.2.6.1 European Union's Policy on Renewable Energy

The Renewable Energy Power EU Plan, which was adopted in May 2022, (EUR-Lex n. d.), and the Renewable Energy Directive 2018/2001/EU, which was amended in 2018, are the primary documents pertaining to the growth of renewable energy in the European Union. The European Commission initially enacted the regulation on the development of renewable energy in 2008. The

regulation aimed to raise the proportion of renewable energy sources in the overall energy production to 20% by 2020. (**Karaeva, Magaril et Al-Kayiem, 2023**). The European Commission updated the directive in 2018 and established a new target: by 2030, 32% of energy must come from RES (Official Journal of the European Union, 2018). The EC raised its stake to 40% in 2021. The Recovery Plan, which went into effect in May 2022, states that by 2030, RES should account for 45% of all energy consumed in the European Union (**European Commission, 2022**).

Results for 2020 show that almost 40% of the energy used in the EU came from renewable energy sources (**EUR-Lex n. d.**), demonstrating both the success of the energy strategy and the accomplishment of the 2009 target. In the area of renewable energy, the main focuses of European energy policy are hydropower, solar energy, bioenergy, offshore renewable energy, and onshore wind energy. Nearly every potential path for the growth of renewable energy in the European Union is covered under the current energy strategy.

The development of renewable technologies and the expansion of their use's geographic reach are facilitated by substantial state backing and an emphasis on the implementation of investment projects. Tax incentives, quota requirements with green certificates, feed-in tariffs, feed-in premiums, tendering programs, grants and investment subsidies, loan guarantees, and soft loans are some of the most significant financial tools used to support renewable energy. The European Commission has tightened the criteria for assessing and choosing investment projects in the energy sector. Projects' environmental aspects are prioritized, and green energy initiatives are given preference (**Karaeva et al, 2022**). Furthermore, the governments of the EU Member States provide incentives to energy producers as well as to their end consumers, which doubles the industry's growth by raising both the supply and demand for green energy.

Scientists and specialized authorities identify a number of obstacles to the growth of the renewable energy sector, even if it is developing at the highest rate in the world in Europe. It takes longer for businesses to pass basic administrative processes due to bureaucracy and a low degree of digitization of project approval procedures in the energy sector; this has a detrimental impact on the time and financial expenses of project implementation (**Schumacher, 2017**).

Furthermore, diverse tax policies for renewable energy enterprises and a shortage of experts in certain Member States contribute to uneven rates of renewable energy development. In spite of all the support measures put in place, certain EU nations are unable to independently carry out significant initiatives aimed at decarbonizing their economies and advancing renewable energy because they lack the necessary technologies, resources, and expertise. The overall lack of manpower in the European

Union makes it difficult to always recruit the finances and experts needed to remedy this issue from other Member States (**Khatiwada et al, 2022**).

2.2.6.2 United States Policy on Renewable Energy

The US Environmental Protection Agency (US-EPA), which outlines the aims, goals, and objectives of energy development, is the primary document on the subject in the United States. This legislation provides an extensive overview of various energy domains, encompassing energy efficiency, renewable energy sources, oil and gas, coal, tribal energy, nuclear matters, and safety protocols, vehicles and motor fuels (including ethanol, hydrogen, and electricity), energy tax incentives, hydropower, geothermal energy, and climate change technologies. The current energy strategy places an emphasis on reducing harmful environmental effects, developing green energy, and renouncing the use of coal as a fuel for energy production.

Large-scale plans for the growth of the renewable energy sector have been highlighted by the presidential administration's goal of having 100% carbon-pollution-free electricity by 2035 signaling ambitious intentions for advancing the renewable energy market. The State and Local Energy and Environment Program's Guide to Action, which was most recently updated in 2022, contains the majority of the strategies for developing renewable energy. Information about energy efficiency policies, renewable portfolio standards, combined heat and power policy considerations, and electric utility policies are all included in the document. The document encompasses sixteen green energy policies in total (**Karaeva, Magaril et Al-Kayiem, 2023**).

Furthermore, a number of programs are being put into place to encourage the growth of renewable energy: the Landfill Methane Outreach Program (LMOP), which encourages the use of landfill gas as a renewable, green energy source; AgSTAR, a program designed to reduce methane emissions from livestock waste and encourage the development of bioenergy; and Renewable Energy–Power America’s Lands, which aims to encourage and support the implementation of Renewable Energy Sources projects on currently and formerly contaminated land and mining sites (**Susskind et al., 2022**).

The US government has created and put into practice an extensive number of mechanisms to promote the renewable energy industry at different levels. The United States employs financial support for green energy projects, subsidies, and compensation as well as Feed-In Tariffs and financial incentives utilized in the European Union. Examples of these tools include Renewable Portfolio Standards, Output-Based Environmental Regulations, and Interconnection Standards. These instruments are designed to decrease the amount of dangerous substances and greenhouse gas

emissions into the atmosphere while also raising the percentage of energy use that businesses obtain from renewable energy sources. Emission limitations incentivize businesses to purchase "green" energy to carry out their operations (**Newell, Pizer et Raimi, 2019**).

Overall, the US government's approach to the advancement of renewable energy is comprehensive, encompassing nearly every potential avenue for growth. It should be mentioned that there is a long list of programs and resources available to assist businesses and organizations using renewable energy, in addition to incentives for consumers and businesses to utilize renewable energy. The low competitiveness of energy derived from renewable energy sources in the domestic market is one of the major obstacles that the renewable energy industry faces, notwithstanding all the steps taken and ambitious tasks undertaken. Furthermore, adverse utility pricing structures, administrative roadblocks in environmental permitting, and absence of transmission can be distinguished (**Sharpton, Lawrence et Hall, 2020**).

2.2.6.3 China's Policy on Renewable Energy.

China, as one of the globe's leading energy consumers and greenhouse gas emitters, has experienced rapid economic growth in recent decades. Consequently, the government has had to introduce new energy legislation to accommodate this growth and high energy consumption rates (**Shokri et Heo, 2012**).

Presently the Chinese government mostly offers pricing incentives, tax incentives, and subsidies. Natural gas, electricity, and renewable energy sources are increasingly used to meet China's expanding energy needs. For the first time in 2016, global investment in electricity surpassed that in oil and gas, and electricity security is steadily rising on the policy agenda. These developments can be attributed to the size of China's projected electricity consumption and the difficulty of decarbonizing the power supply (**Wang, Tang et Pan, 2017**). However, cost reductions for renewable energy alone won't guarantee stable supply or effective decarbonization.

China's coal production capacity and demand, however, are still very high. Presently, China burns one out of every four tons of coal used worldwide to generate energy. Although China's coal fleet is still 10 times larger than its gas-fired fleet and is relatively new and highly efficient, the government is pushing for the conversion of industrial and residential sectors to gas in order to reduce emissions and improve air quality. New onshore wind and solar photovoltaic (PV) systems are significantly less expensive than new combined-cycle gas turbines (CCGTs) at the current gas pricing (**Liu, 2019**).

The promotion of renewable energy technologies in China has advanced significantly in recent years thanks to these policy instruments. China has various types of policies on renewable energy. Some major policies are enacted at the national level by the central government, while other policies are passed locally and regionally.

The government initiated the first renewable energy incentives by providing biogas subsidies for rural areas. In 1980, small hydropower systems in rural regions were also eligible for this type of subsidy, and in 1987, wind power development received it as well. Additionally, environmental concerns prompted the 1990 passage of new legislation that prioritized solar and wind energy. When the Price Policy Act was implemented in 1994, electrical network operators were mandated to buy electricity produced by renewable energy sources at a higher price and with a reasonable benefit from five renewable energy providers. The air pollution prevention law of 2000 and the electricity law in 1995 were two further laws that promoted the use of renewable energy. They attempted to catch up to more developed nations until the year 2000, at which point they made significant strides in the development of innovative renewable energy technology. Following that, in 2003, the Renewable Energy Promotion Act was passed. The PRC law on renewable energy was the other major policy, and it had a significant impact on the expansion of renewable electricity.

Moreover, similar to other nations, tax incentives have a noteworthy impact on renewable energy technology in China. For example, the value added tax is waived for small hydro power units, and income tax is not applied to producers of renewable energy. Additionally, certain components of renewable energy equipment, such as wind turbines and solar power generators, are free from customs charges (Shokri et Heo, 2012).

The following table summarizes the comparative analysis of renewable energy policies for the European Union, China and the United States.

Table 2.6. Comparative Analysis of Renewable Energy Policies: EU, China, USA

Element	The Union European	China	USA
Population (2022)	447,370.51	1,412,175.00	333,287.56
CO2 emission (Gt) (2022)	3.6	11.4	4,941
Electricity Supply Mix (2022)	Fossil fuels: 38.7% Nuclear power: 21.9% Renewables (including hydro): 39,4%;	Coal 63% Hydro 14% Wind 9% Nuclear 5% Solar 5% Gas 3%	Coal 19% Nuclear/ 18% Natural Gas 40% Renewables (including hydro): 22%
Main documents outlining RE policy	-The Renewable Energy Directive 2018/2001/EU - RE Power EU Plan	- The People's Republic of China" from 2005 and its subsequent amendment in 2006. - The People's Republic of China" from 2020 -China 13th 5-year plan for 2016–2020 includes geothermal, solar, wind, hydro, and ocean power	-The US Environmental Protection Agency -The State and Local Energy and Environment Program's Guide to Action
Main goals of RE policy	By 2030, RES are projected to comprise 45% of the total energy mix.	By 2030, RES are expected to account for 26% of electricity generation	By 2030, RES are expected to account for 80% of electricity generation.
Principal directions of RE	Wind and wave generated energy offshore; onshore wind power;	Solar energy (PV and solar thermal) ; wind energy; bioenergy; energy efficiency; geothermal energy; hydropower	Solar energy, both PV and solar thermal; wind power; geothermal

	Hydropower and ocean; solar energy both PV and solar thermal; biomass; geothermal energy; energy efficiency; Minimizing the reliance on imported fossil fuels; onshore wind energy;		energy; – biomass; low-influence hydropower; energy efficiency.
Principal government instruments	Tax incentives; quota obligations with green certificates; feed-in tariffs; feed-in premiums; tendering schemes; grants and investment subsidies; loan guarantees; soft loans.	Tax incentives; grants and investment subsidies; Support for Biogas Projects; Solar Photovoltaic Integration Program for Buildings; Wind Energy Concession Program; Notice on the elimination of the local content requirement for the acquisition of equipment for wind power projects.	Renewable portfolio standards (RPS); public benefits funds for renewable energy; output-based environmental regulations; feed-in-tariffs; property assessed clean energy; net metering; grants and investment subsidies.
Barriers	Excessive bureaucratic processes and limited digitalization in administrative tasks for renewable energy initiatives; Lengthy generation chains; Shortage of technicians, workforce, and materials; Varying tax structures across EU member countries.	Dominance in the industry and control over the market; Inflexibility in power grid systems hinders meeting renewable energy demands; Regional protectionism; reliance on power generation methods; uptake of renewable technologies; The costly shift towards energy sources.	RES have higher production costs compared to traditional fossil fuel-based energy; Unfavorable electricity tariff structures; Administrative hurdles and complexities in obtaining environmental permits; Insufficient transmission infrastructure to support renewable energy integration.

Source: Realized by the researcher using data from: World Bank, Statista 2024; (Shokri et Heo, 2012), and (Karaeva, Magaril et Al-Kayiem, 2023).

2.3 Economic and Political Challenges of Renewable Energy in Algeria

In Algeria, on a global scale, the energy sector is one of the main drivers of climate change. Algeria, a large Mediterranean country with a population of over 45.4 million in 2022 (**World Bank, n. d.**), has considerable energy capacity, particularly in the hydrocarbons sector. Faced with a changing climate that requires long-term action and programs to protect its environment, The hydrocarbons sector is considered a vital energy sector, albeit with limited long-term prospects. Within this sector, key petroleum products include fossil fuels, crude oil, and natural gas, all categorized as non-renewable energy sources. Concurrently, Algeria is at the forefront of a new era of energy transition, embarking on a comprehensive strategy aimed at fostering sustainable development. In alignment with this vision, the nation is exploring alternative energy sources known as renewable energy to diversify its energy portfolio and reduce dependency on traditional fossil fuels.

2.3.1 Algeria's Energy Sector: A Current Overview

Algeria was Europe's third-largest supplier of natural gas, behind Russia and Norway, prior to the crisis in Ukraine. It is a prominent producer and exporter of fossil fuels, occupying second place in the region after Nigeria in terms of crude oil output and ranked 17th worldwide (**Tahchi, 2024**). Algeria ranked tenth in the world among producers of natural gas, accounting for 2.4% of worldwide production in 2022 (**BP Statistical Review, 2023**). The nation had 4.5 billion cubic meters of natural gas reserves, or 2.4% of the world's total reserves, before the revisions made by BP in 2021 (**Abada et Bouharkat, 2018**). Algeria now ranks second in terms of gas supply to Europe, behind Norway, according to the Gas Exporting Countries Forum October 2023 monthly report (**GECF, 2023**). Algeria (20%), Russia (17%), and Norway (54%) continue to be the top three suppliers. Significantly, Algeria maintained stability year over year and kept up its gas supply to Europe during the crisis in Ukraine, despite drops in imports from Russia and Norway.

The Algerian market is largely dominated by Sonatrach, a state-owned entity controlling 80%, while foreign companies manage the remaining 20%. To attract more foreign investment, Algeria has passed a new law aimed at making the sector more enticing. This law seeks to alleviate Sonatrach's tax burden by 20%, reducing it from 85% to 65%. (**Sonatrach Annual Report, 2022**)

Through the state-owned enterprises that oversee the abundant fossil fuel resources in the nation, the state continues to control Algeria's economy. In addition to placing restrictions on imports and foreign engagement in the country's economy, the Algerian government has halted the privatization of state-owned businesses and industries (**Boukhatem et Oei, 2024**). Thus, a very clear import

substitution policy has been implemented to boost the nation's economy and lessen its unchecked susceptibility to foreign influence.

Additionally, in 2022, Sonatrach, the national oil corporation of Algeria, reported the discovery of several onshore oil and gas resources that are anticipated to begin production in the next few months (**Tahchi, 2024**). An estimated volume of 96,815.30 billion m³ of in situ shale gas, with 20,020 billion m³ of technically recoverable proven reserves and 121 billion m³ of probable reserves of shale oil and condensates, including 5.7 billion barrels of technically recoverable proven shale oil reserves, further highlights this potential. Algeria has the third-largest technically recoverable shale gas resources in the world, according to an assessment conducted in 2019 by the International Energy Agency (**EIA, 2019**).

According to the Atradius Country Report 2019, and Oxford Economics data, oil and gas revenues accounted for about 60 percent of the budget in 2018. Starting in 2014, oil prices experienced a significant decline, impacting public finances. However, in 2021, these prices rebounded, reaching a peak in 2022 following the shock caused by the war in Ukraine. During this period, Algeria's reserves decreased from \$178 billion in 2014 to \$88.6 billion in 2018, resulting in a budget deficit of approximately 9% of GDP in 2018 (**World Bank, 2020**). In 2022, Algeria's GDP growth rate was 4.7%, while the inflation rate stood at 9.7%. Additionally, public debt, which was 10.5% of GDP before the "Arab Springs" in 2010, rose to 52.3% in 2020 and is projected to increase further to 70.3% in 2023. Despite these challenges, Algeria's external debt remains extremely low, at around 2% of GDP (**IMF, 2022**).

Algeria experienced a significant economic shock in 2020 due to the COVID-19 pandemic and a sharp decline in hydrocarbon exports. The country's real GDP contracted by 4.6%, a stark contrast to the positive growth of 0.8% in 2019, which was more than four times the regional average. This drastic downturn was primarily attributed to the plummeting revenues from fuel exports, which constituted over 96% of merchandise exports in 2019. Consequently, Algeria faced substantial fiscal and current account deficits, with the fiscal deficit more than doubling from -5.6% of GDP in 2019 to an estimated -12.6% in 2020. The current account balance, including grants, worsened from -10.0% to -14.8% of GDP. Managing these deficits exacerbated the country's external vulnerabilities, as reflected in the decline of gross international reserves held by the Central Bank of Algeria from over \$61.5 billion in 2019 to \$44.6 billion in 2020, and further to \$21.9 billion in 2021 (**World Bank, 2022**).

In an effort to become more energy independent, Algeria has started to diversify its energy industry recently by utilizing solar energy. Even with its great potential, renewable energy still makes up a small portion of the energy balance, particularly when it comes to power generation (**Stambouli et al., 2012**). According to **Ghezloun, Chergui et Oucher (2011)**, legislative support and encouragement for the introduction of hybrid alternatives, such as electricity generation by the private sector, is the only requirement for Algeria's energy mix to develop its potential for renewable energy.

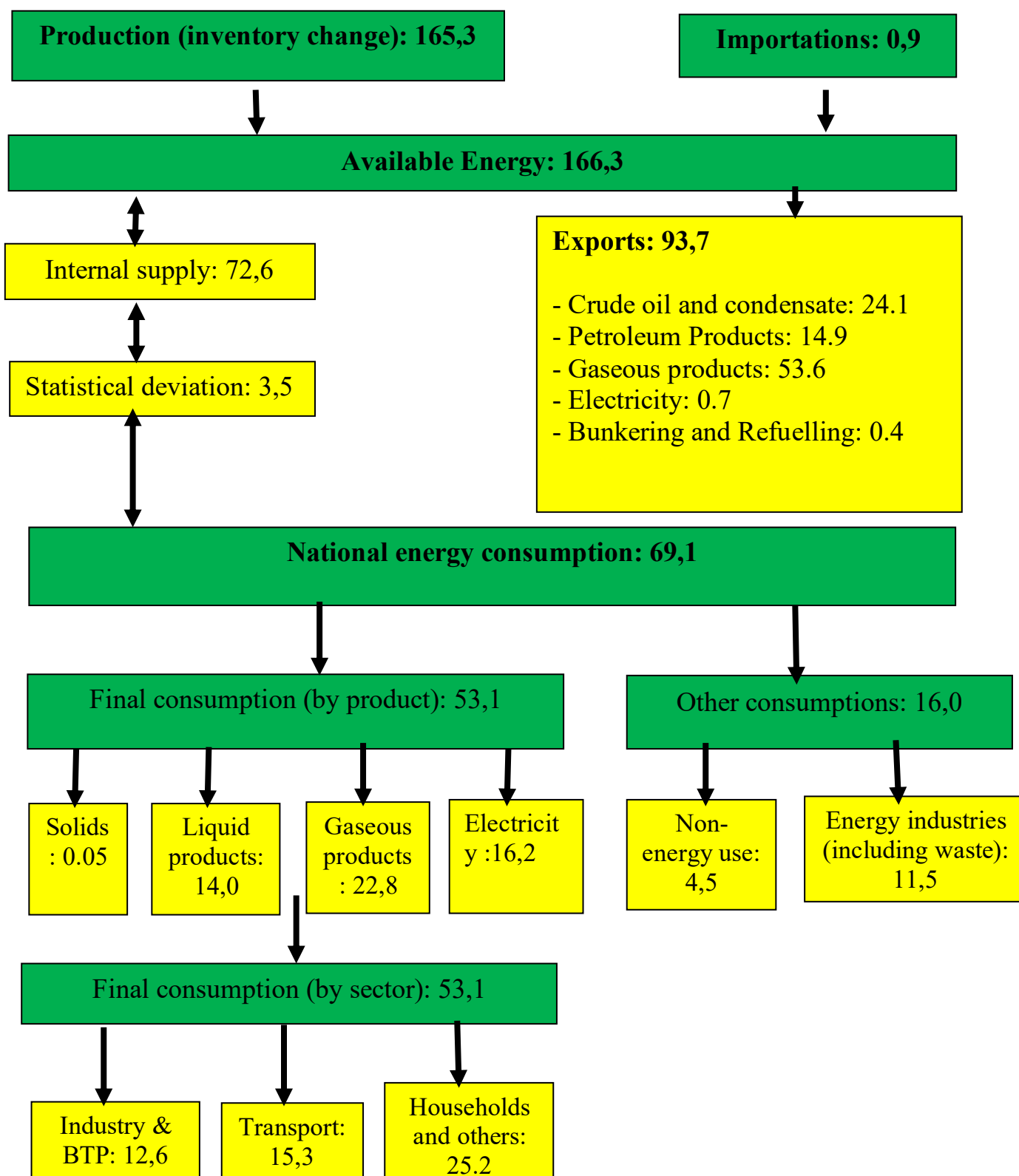
However, in order to achieve a mutually beneficial plan in which, on the one hand, a greater share of gas is released for export, ensuring the stability of its balance sheet, and, on the other hand, the energy required for the development of the nation's production structure is guaranteed, the government is working to develop the photovoltaic industry and, more broadly, the renewable energy sector. According to the latter perspective, diversification of the production structure not only aims to diversify the sources of energy supply, but it also advances the development of industrial sectors and sectors other than the conventional hydrocarbon-based sectors (**World Bank, 2015**).

Algeria's energy needs are entirely met by its production, which is virtually exclusively derived from fossil fuels. Over 93% of the installed power capacity comes from natural gas, which is the main energy source. Hydropower dominated the renewable energy share in the energy mix until recently, accounting for only around 3.4% of the total share of renewable energies.

According to (**Algeria's Energy Balance, 2022**) the main results and highlights of the 2022 energy balance are summarized in (Figure. 2.13):

- A significant drop (-31.3%) in imports of energy products, which reached 0.93 Mtoe in 2022, following the suspension of imports of petrol and diesel and the optimization of refining facilities;
- Drop (-2.9%) in energy exports (including bunkering and victualling) compared with 2021 levels, to 93.7 Mtoe, driven by gaseous products as a result of lower demand from foreign customers;
- Increase (+2.8%) in national energy consumption, from 67.2 M toe in 2021 to 69.1 M toe in 2022, driven by the rise in final consumption, which accounts for 77%;
- Increase (5.9%) in final energy consumption to 53.1 M toe, driven mainly by natural gas (8.3%), electricity (5.9%), LPG (8.4%), and petroleum products (including LPG) (3.4%).

Figure 2.13. Summary of Energy Flows (M Toe) in 2022



Source: Ministry of Energy and Mines- National Energy Balance 2022

2.3.1.1 Assessing current Energy Dynamics: Production and Consumption analysis

A. Primary Energy Production

According to the Ministry of Energy and Mines, Primary energy production reached 165.4 M toe in 2022, slightly up (0.6%) on the 2021 production level of 164.4 M toe (**Algeria's Energy Balance, 2022**), as shown in the table below:

Table 2.7. Primary Energy Production in Algeria

Product	Units	2021	2022	Evolution	
				Quantity	(%)
Natural Gas	K Tep	99,260	95,857	-3,403	-3.4
	10 ⁶ m ³	105,037	101,436		
Crude oil	K Tep	47,084	50,437	3,353	7.1
	K Tonnes	42,688	45,727		
Condensate	K Tep	8,712	9,063	350	4
	K Tonnes	7,696	8,006		
LPG field	K Tep	9,222	9,833	611	6.6
	K Tonnes	7,816	8,333		
Primary electricity	K Tep	160	164	4	2.6
	GWh	662	681		
Wood	K Tep	2	18	15	625
	10 ³ m ³	13	91		
Total	K Tep	164,442	165,372	930	0.6

Source: Ministry of Energy and Mines- National Energy Balance 2022

The increase in production was driven by higher output of all products, with the exception of natural gas, where output fell (-3.4%).

For crude oil, the rise in production is due to the increase in Algeria's OPEC quotas in application of OPEC+ decisions, from an average of 911 kb/d in 2021 to over one million b/d in 2022. It also follows the commissioning of the Hassi Messaoud South fields and the good performance of other fields.

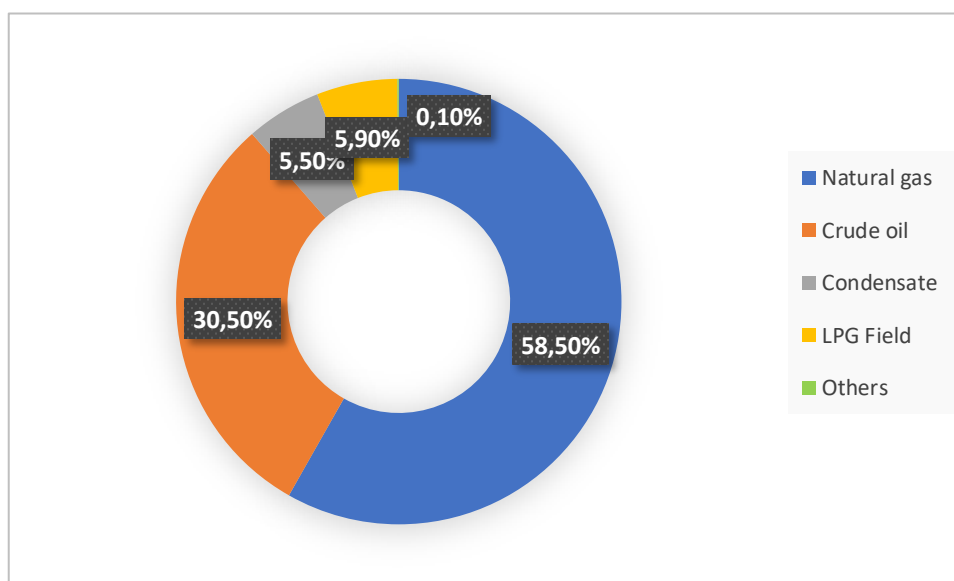
Primary electricity generation (ENR) reached 681 GWh, up slightly (2.9%) in 2021, following an increase in production:

- Hydropower plants (76%), up from 9 GWh in 2021 to 16 GWh in 2022, driven by a moderate increase in rainfall compared to the year before;
- Wind turbines (51%), up from 11 GWh in 2021 to 16 GWh in 2022;

Despite this increase, the share of renewable power generation remains very modest, not exceeding 1% of national electricity production, which is still dominated by natural gas at 99%.

The structure of primary commercial energy production remains dominated by natural gas at 58%, followed by oil (31%), as illustrated in the graph below:

Figure 2.14. Structure of Primary Energy Production



Source: Ministry of Energy and Mines- National Energy Balance 2022

As per the (IRENA, 2021), Algeria ranks third in Africa in terms of renewable energy capacities. Algeria has made achievements in the direction of renewable energy. Following their significant 20-year plan for solar development that stipulates that 20% of renewable energy must be installed by 2030, with 70% coming from CSP, 20% from PV, and the remaining 10% from wind power. containing one of the first Integrated Solar Combined Cycle (ISCC) plants in the world (the 150 MWe ISCC Hassi R'mel is a hybrid of a 25 MWe equivalent CSP solar field and a combined cycle).

B. Final Energy Consumption

▪ By Product

Final energy consumption is set to rise to 53.1 M toe in 2022, compared with 50.2 M toe in 2021, an increase of 5.9% thanks to higher consumption of virtually all energy products, mainly natural gas

and electricity (Algeria's Energy Balance, 2022). Final consumption trends, by product, are detailed below:

Table 2.8. Final Energy Consumption by Product

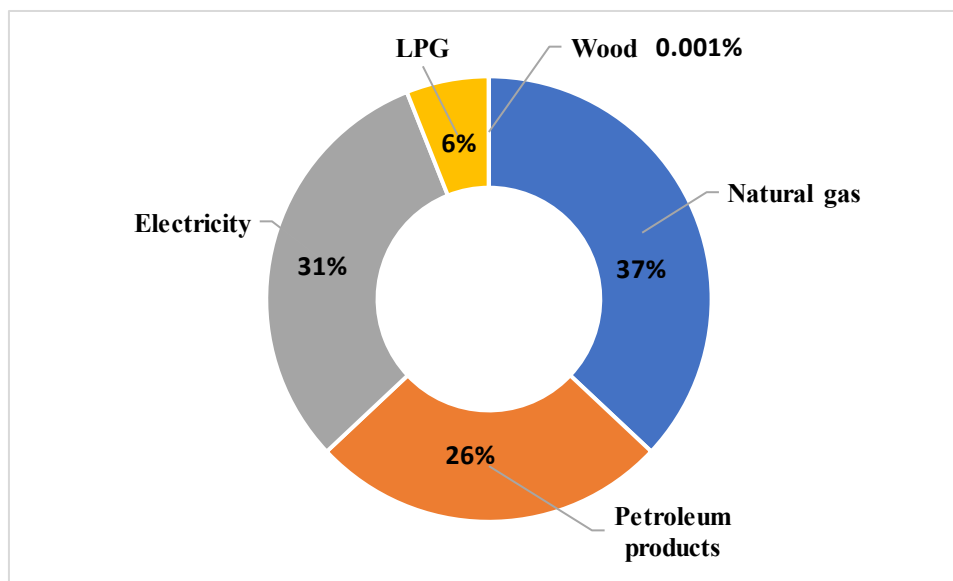
Product	Units	2021	2022	Evolution	
				Quantity	(%)
Petroleum products	K Tep	13,686	13,999	312	2.3
	10 ⁶ m ³	13,099	13,402		
Natural Gas	K Tep	17,930	19,421	1491	8.3
	K Tonnes	18,974	20,552		
Electricity	K Tep	15,348	16,219	871	5.7
	K Tonnes	63,442	67,207		
LPG	K Tep	3,157	3,422	266	8.4
	K Tonnes	2,675	2,900		
Steel coke	K Tep	47	27	-20	-42.4
	GWh	68	39		
Wood	K Tep	2	18	15	612.8
	10 ³ m ³	13	91		
Total	K Tep	50,171	53,106	2935	5,9

Source: Ministry of Energy and Mines- National Energy Balance 2022

The previous table shows the following:

- Significant rise (8.3%) in final natural gas consumption to 19.4 M toe, driven by increased demand from Sonelgaz customers, including those in the residential sector (9.4%), thanks to the rise in the gas penetration rate to 64% in 2022 at the national level. The number of Sonelgaz subscribers, in particular BP subscribers, rose by 6.1% compared with 2021, to 7.3 million subscribers in 2022, i.e. almost 420 thousand new customers;
- Increase in final electricity consumption (5.7%), from 15.3 M toe in 2021 to 16.2 M toe in 2022, driven by the growing needs of manages (6.6%), including the number of Sonelgaz customers, which rose by 5.0% to 11.5 million subscribers, and more particularly those of BT;
- With regard to the breakdown of final consumption by product, and as illustrated in the graph below, natural gas accounts for the largest share (37%), followed by electricity (31%) and finally petroleum products (26%).

Figure 2.15. Structure of Final Energy Consumption by Product



Source: Ministry of Energy and Mines- National Energy Balance 2022

▪ By Sector

By sector of activity, final consumption in 2022 was characterized by:

- Increase in demand from the "Household and other" sector (7.6%) from 23.4 M toe in 2021 to 25.2 M toe in 2022, driven mainly by the residential sub-sector (6.5%);
- Continued growth (5.4%) in consumption in the "transport" sector since the lifting of COVID19 restrictions, rising from 14.5 M Tep in 2021 to 15.3 M Tep in 2022, driven by land-based fuels, thanks to the upturn in road transport (passengers and goods). Final consumption of petroleum products in this sector is essentially made up of diesel (62%), gasoline (24%), and LPG/C (12%);
- Increase (3.1%) in consumption in the "Industries and Construction" sector to 12.6 M toe in 2022, in line with the upturn in economic activity, driven in particular by the ISMME and building materials sub-sectors;

Details of final consumption by sector of activity are given below.

Table 2.9. Final Consumption by Sector (K Tep)

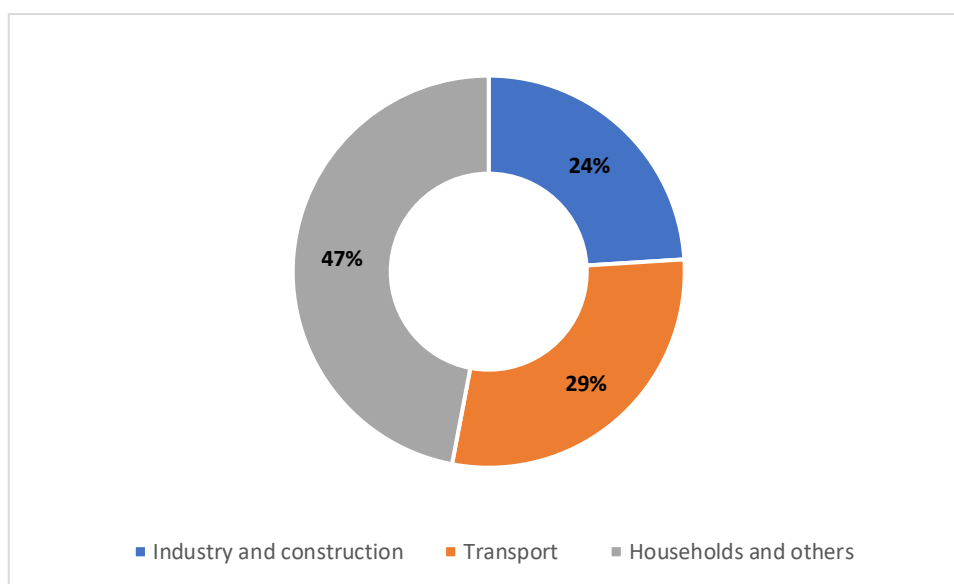
Sectors	2021	2022	Evolution	
			Quantity	(%)
Industry and construction	12.220	12.596	375	3,1
Transport	14.520	15.297	777	5,4

Households and others	23.431	25.214	1783	7,6
Total	50.171	53.106	2935	16,1

Source: Ministry of Energy and Mines- National Energy Balance 2022

The structure of final consumption remains dominated by the "Household & other" sector (47%), followed by the transport sector (29%), and finally the "Industry and construction" sector with a share of 24%, as illustrated in the graph below:

Figure 2.16. Structure of Final Energy Consumption by Sector



Source: Ministry of Energy and Mines- National Energy Balance 2022

2.3.1.2 Electric Power Generation and Consumption Patterns in Algeria

Understanding Algeria's electric power output and consumption trends is crucial to understanding the country's energy infrastructure and consumption patterns. Making educated decisions about energy regulations, investments, and infrastructure development is made easier for stakeholders and politicians when these trends are analyzed. It enables the integration of renewable energy sources and the identification of prospective areas for energy efficiency improvement. In order to guarantee a sustainable and dependable energy supply that satisfies the nation's expanding wants while reducing environmental effects, it is imperative to comprehend these dynamics.

2.3.1.2.1 Algeria's Electricity Generation

Algeria's electricity production is managed by the national electricity company (SPE) and includes gas turbines, steam turbines, combined cycle, diesel, hydropower, and renewable energy sources. Since 2013, renewable energy plants have been overseen by SKTM. The national grid consists of

three systems: (1) **RIN**, covering northern regions with around 40 power stations connected by 220 kV and 400 kV transmission lines; (2) **PIAT**, powered by Adrar and In Salah Turbine Plants, linked through a 220 kV network; and (3) **RIS**, comprising 26 isolated southern locations supplied by diesel and turbine generators (**Bouraiou et al., 2020**).

Table 2.10. Renewable And Conventional Generated Power (1980-2022)

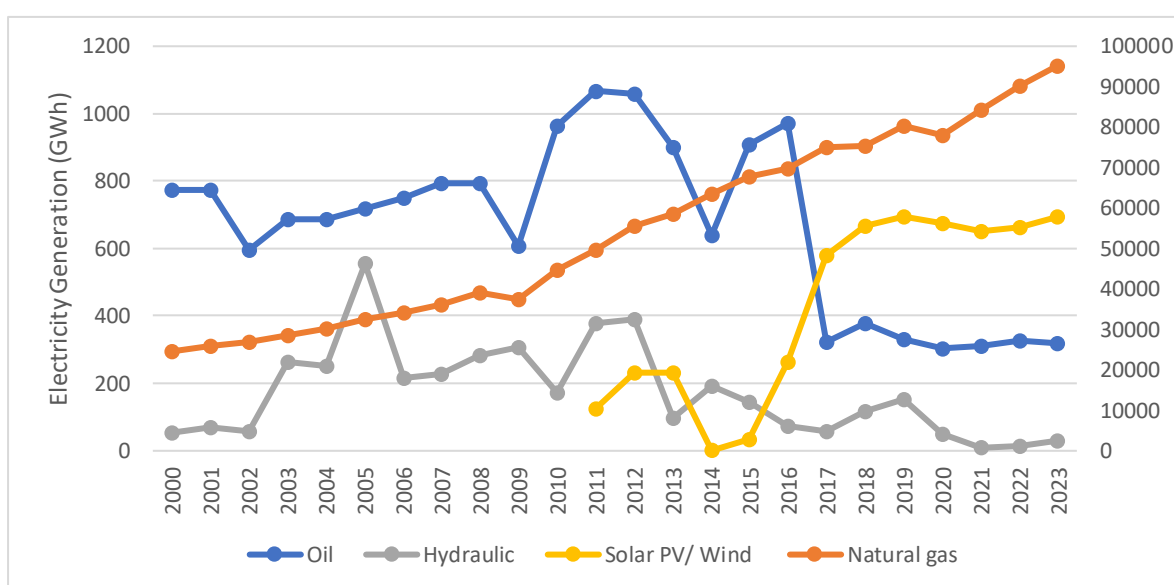
National production	RES		Non-RES				Total
	Hydraulic	wind and solar	Steam turbine	Gas Turbine	Combined Cycle	Diesel	
1980	251	-	3621	2223	-	125	6220
1990	135	-	8397	6704	-	216	15452
2005	555	-	16624	15679	386	281	33525
2010	173	-	9692	19564	15341	403	45173
2011	378	124	9654	22055	15701	464	48252
2012	389	232	9422	24975	18623	416	53825
2013	99	231	9582	17400	27685	227	54992
2014	193	1	10221	20211	28444	248	59317
2015	145	33	10227	26970	26122	276	63818
2016	72	264	11511	24441	29664	281	66233
2017	56	579	9992	20752	29204	314	60897
2018	117	666	10682	36580	28244	374	76663
2019	152	693	7638	34672	38045	326	81526
2020	50	673	4496	29315	39027	277	73838
2021	9	653	3970	29380	45614	277	79903
2022	16	665	3 724	33 971	47134	243	85753
2023	29	694	4 336	22 949	50 849	139	78 996

Source: Realized by the researcher using data from MEM, and (Bouraiou et al., 2020)

Between 2000 and 2023, Algeria's electricity generation was overwhelmingly dominated by natural gas, which experienced continuous and robust growth, increasing from around 24,585 GWh to over 95,000 GWh (Figure. 2.17). This confirms the country's strong dependence on its vast natural gas reserves for power production. In contrast, oil-based generation, which remained relatively stable until the mid-2010s, saw a sharp decline after 2015, falling to less than 400 GWh by 2020, reflecting a strategic shift away from oil in the national energy policy. Hydropower, which was the primary

renewable source before 2011, contributed modestly and inconsistently, with several short-lived peaks (notably in 2005 and 2012) that suggest sensitivity to climatic variability and limited infrastructure. Solar and wind energy began contributing meaningfully from 2011 and expanded rapidly after 2015, following the launch of Algeria's updated National Renewable Energy Program (MEM, 2011). However, this growth quickly plateaued after 2018, with generation stabilizing below 60,000 GWh, revealing persistent challenges in scaling up renewable infrastructure. Despite its immense solar potential and institutional reforms, Algeria has struggled to convert renewable ambitions into significant outputs. By 2023, renewables still represented only a minor share of the national energy mix, leaving natural gas as the dominant and growing source of electricity.

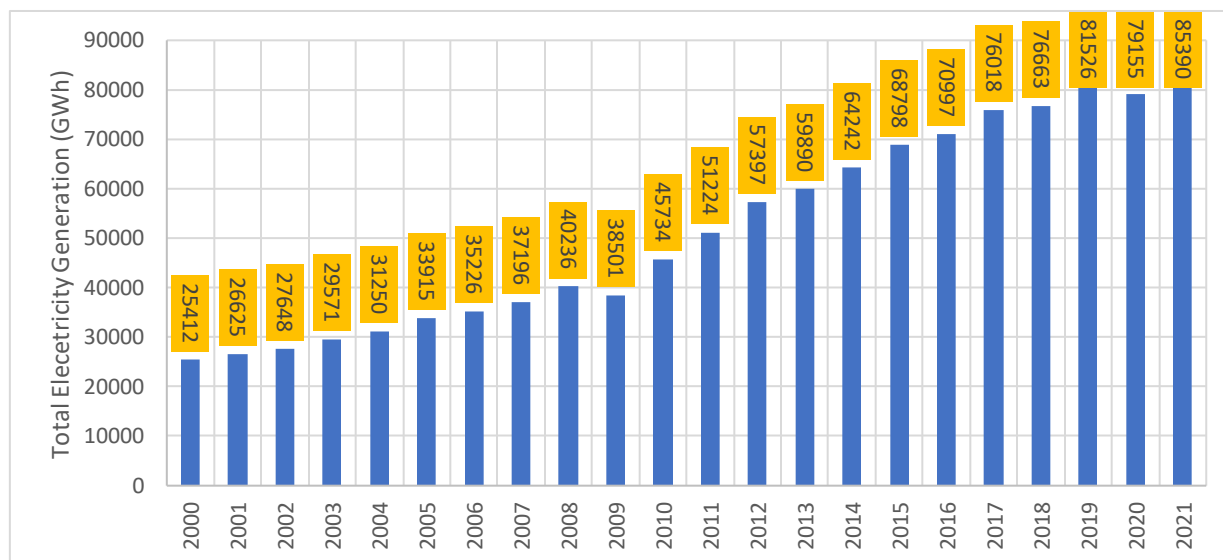
Figure 2.17. Evolution of Electricity Generation Sources in Algeria



Source: Realized by the researcher using data from the International Energy Agency (IEA)

Total electricity generation in 2021 was attained 85.390 GWh (Figure. 2.18). The heavy reliance on natural gas and the absence of renewable energy sources underscores the necessity for Algeria to explore and invest in alternative, low-carbon electricity generation options. Transitioning towards a more diverse and sustainable energy mix could help the country mitigate its environmental impact and move towards a greener future; given Algeria's favorable conditions for renewable energy, such as abundant solar irradiation, the country has significant potential to diversify its electricity generation and reduce its carbon footprint (IEA, n. d.).

Figure 2.18. Total Electricity Production in Algeria (GWh)



Source: Realized by the researcher using data from the International Energy Agency (IEA)

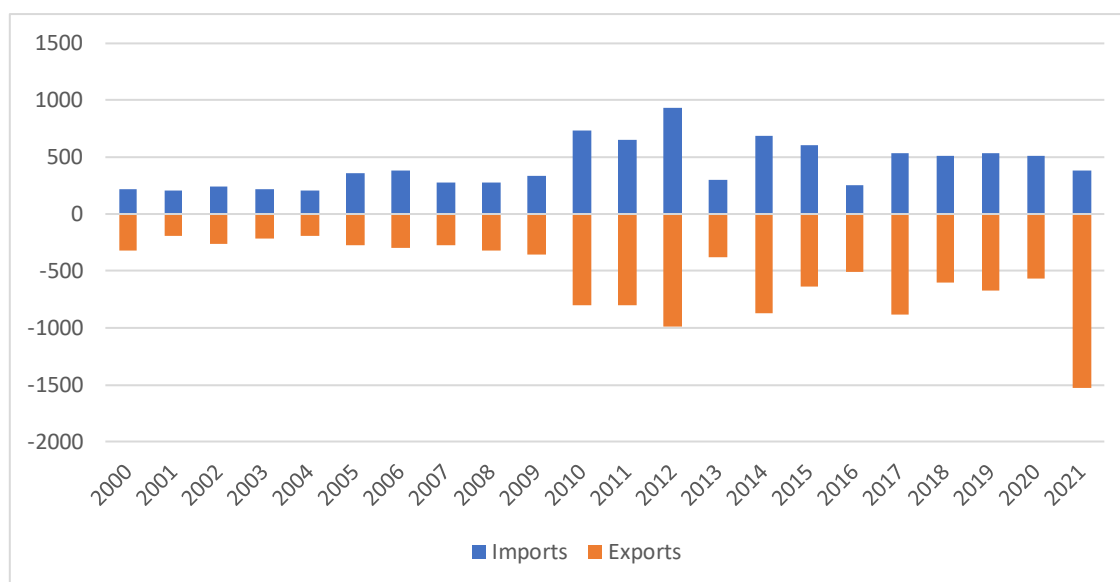
Algeria, as a developing country with an economy in transition, faces significant challenges in the energy sector, particularly with regard to the production and management of electricity. In this context, electricity imports and exports play a crucial role in meeting national energy needs, as well as in regional integration and international energy cooperation.

Algeria is a major player in the North African energy market, with vast hydrocarbon and renewable energy resources. However, despite its production capacity, the country has faced persistent challenges in terms of domestic energy supply, particularly due to the growth in domestic demand and structural constraints in the electricity sector. Against this backdrop, electricity imports have played a crucial role in bridging the gap between supply and demand, ensuring the stability of the electricity grid and meeting consumer needs. At the same time, electricity exports offer Algeria an opportunity to sell its surplus production on the international market, strengthening its position as a regional energy supplier and revenue generator.

Over the last two decades, the trend in electricity exports in Algeria saw a 379% change from 2000 to 2021 (EIA). the country has increased its electricity export capacity, taking advantage of its investment in energy infrastructure and its strategic geographical position. (Figure. 2.19) illustrates an exponential fluctuation over the last 2 years with electricity exports surging from 573 GWh in 2020 to 1529 GWh in 2021, marking a rate of increase of +166.65%. Exporting electricity is economically beneficial for Algeria, the best way to generate revenue and contribute to trade balance improvements.

Simultaneously, imports decreased from 512 GWh in 2020 to 378 GWh in 2021, representing a rate of -26.17%, indicating the necessity to broaden the array of supply sources to address the increasing energy demand. These patterns underscore the swiftly evolving energy scenario in Algeria and underscore the necessity of implementing efficient strategies to optimize resource utilization and enhance economic gains.

Figure 2.19. Imports and Exports of Electricity in Algeria



Source: Realized by the researcher using data from the International Energy Agency (IEA)

2.3.1.2.2 Algeria's Electricity Consumption

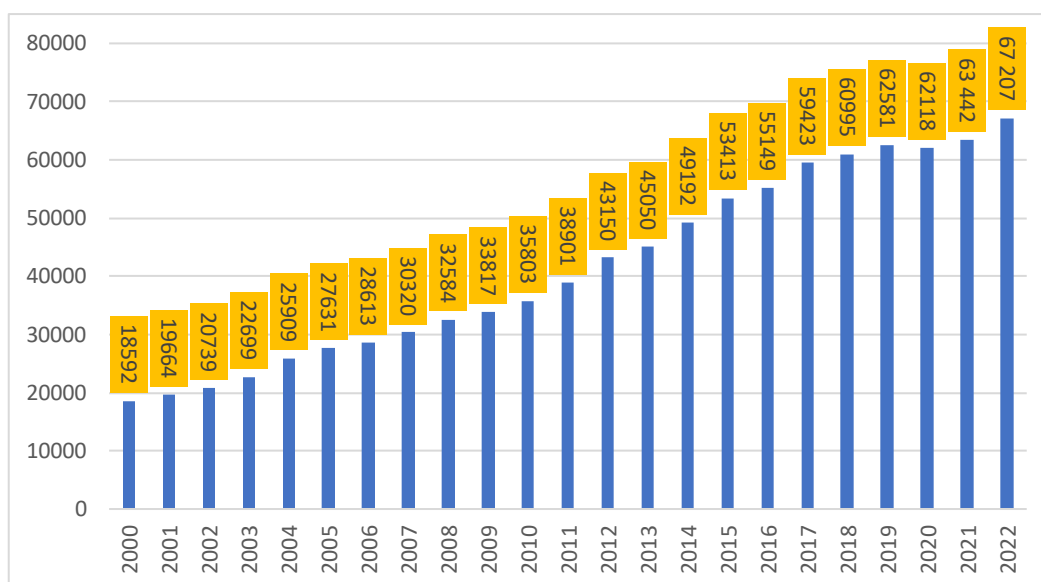
Electricity demand in Algeria has risen sharply in recent years, driven by a rapidly growing population and economic development, and by subsidized energy tariffs for both electricity generation and final consumers (SDG7, 2022).

According to the recent data of the Ministry of Energy and Mines, the primary outcomes and notable aspects of the 2022 report include A rise (+2.8%) in domestic energy consumption from 67.2 M toe in 2021 to 69.1 M toe in 2022, fueled by increased final consumption, representing 77% of the total.

From the graph below, it can be seen that electricity consumption in Algeria has grown steadily throughout the period (2000-2022) with a trend of 261.54%, due to several factors, the most important of which is the increase in the population and private individuals' need for electricity. Because of the expansion in the use of household appliances. This consumption rose from 18592 (GWh) in 2000 to around 67207 (GWh) in 2022, nearly quadrupling the amount consumed in 2000. National electricity

consumption peaked in 2022, at 67207 (GWh), compared with 63442 (GWh) in 2021, reflecting an increase of an estimated 5,94%. since 2000, consumption has been constantly rising, except for a slight drop in 2020 compared with 2019. This decrease is mainly due to the Coronavirus health crisis and its repercussions, in particular the economic shutdown, in addition to travel and movement restrictions.

Figure 2.20. Electricity Consumption in Algeria (GWh)



Source: Realized by the researcher using data from the International Energy Agency (IEA)

The electricity sector is one of the largest consumers of energy, accounting for 38% of Algeria's total energy demand, with the residential sector accounting for over 39% of total electricity demand followed by the industrial sector for a portion of 34% (EIA, 2022).

(Figure. 2.21) shows that the principal sectors that drive the main source of electricity demand (the residential sector, and the industrial sector) have developed to varying degrees, especially during the COVID-19 pandemic.

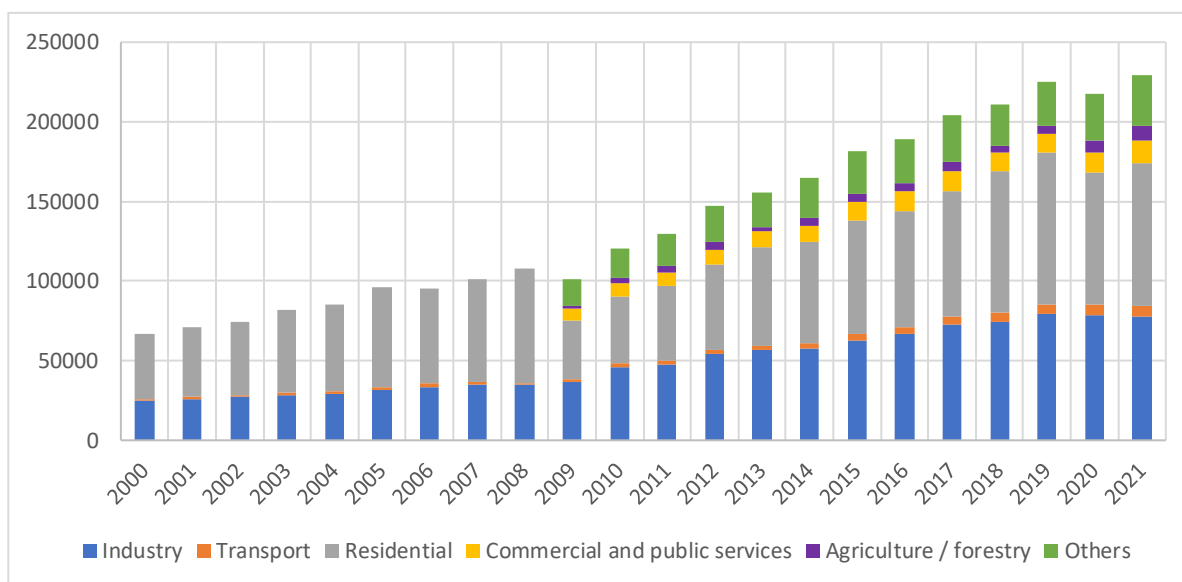
From 2009 to 2018, all sectors saw a slight annual increase in electricity demand, which is logical in view of the continuing demographic growth.

During the COVID-19 pandemic, and more specifically during the two years 2019, 2020, electricity consumption in the residential sector increased compared with previous years, reaching a peak of 95518GWh in 2019, compared with a slight fall in consumption in the industrial sector. This is explained by the slowdown in economic and industrial activity and the fact that people were spending more time at home as a result of measures taken by the public authorities, including social distancing measures and travel restrictions, which led households to work from home and pursue their

studies online during the pandemic. This led to increased demand for electricity to power electronic devices such as computers, tablets and communications equipment.

Household consumption remains dominant in the post-COVID-19 period, at 89835 GWh in 2021 compared with 83165 GWh in 2020, an increase of 8.02%.

Figure 2.21. The Evolution of Electricity Consumption (TJ) in Algeria by Sector



Source: Realized by the researcher using data from the International Energy Agency (IEA)

2.3.1.3 Algeria's CO₂ Emissions: Trends and Implications for Climate Policy

In 2022, Algeria's carbon dioxide (CO₂) emissions amounted to 177.079 megatons, signaling a decline of 1.717 megatons (Table. 12), equivalent to a decrease of 0.96%, compared to the preceding year, placing Algeria 153rd in the 184 country CO₂ emissions ranking, in which countries are ranked from least to most polluting. This reduction underscores Algeria's commitment to environmental stewardship and carbon mitigation efforts. Despite this decrease, Algeria maintains its stance as a significant contributor to global emissions, reflecting the ongoing challenges faced in transitioning to a more sustainable energy landscape.

consequently, Algeria has pledged to cut its emissions of greenhouse gases (GHGs) by 2020–2030. Since 2014, a regulatory framework based on feed-in tariffs has established an incentive system. Moreover, a 1% tax on oil revenue was to be used to fund a Renewable Energy Fund. Even with all of these initiatives, the RE Program takes a while to take off.

Algeria has reaffirmed its commitment to decrease its GHG emissions by 7% by 2030, as outlined in the Paris Climate Agreement of 2015. This global initiative seeks to cap the Earth's average

temperature increase below 2°C. However, with adequate international assistance, Algeria aims to achieve a GHG reduction of up to 22% by 2030. Despite these goals, renewable electricity generation has yet to reach a threshold enabling a substantial impact on the reduction of carbon dioxide emissions derived from energy sources (WHO, 2015).

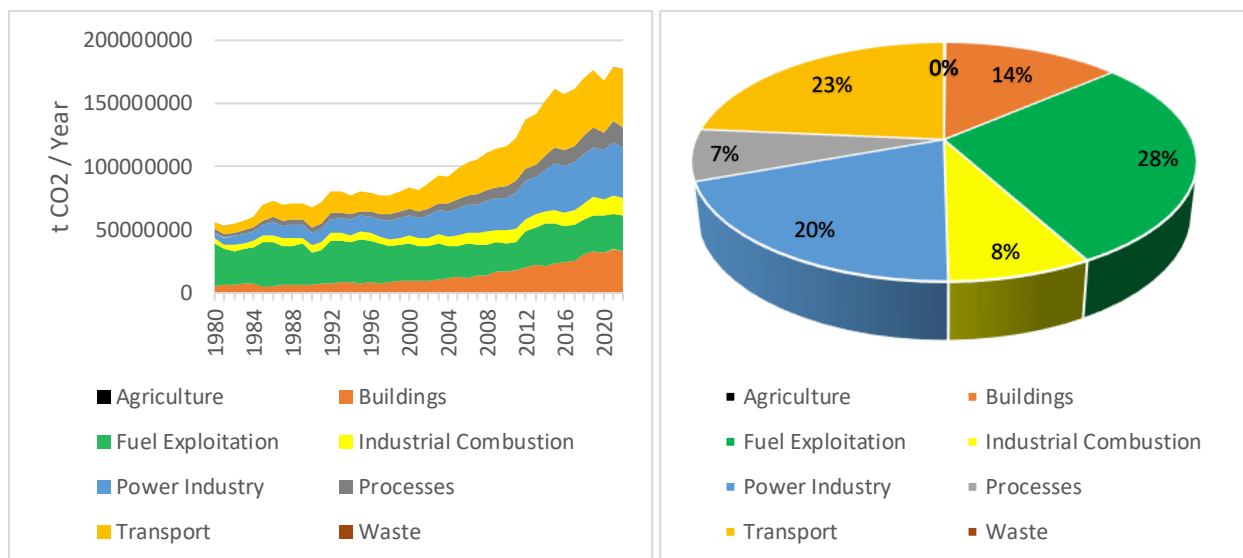
Table 2.11. Algeria's CO2 Emissions from 1980 to 2022

Year	t CO2	Year	t CO2	Year	t CO2	Year	t CO2
1980	56609307	1991	72011255	2002	86476120	2013	141545821
1981	53228631	1992	79912588	2003	92911576	2014	151970471
1982	54861463	1993	80201916	2004	92480062	2015	161328158
1983	57423779	1994	77639672	2005	98171708	2016	157928519
1984	60508276	1995	80180230	2006	103187446	2017	161370191
1985	69807569	1996	79068132	2007	105792949	2018	170433740
1986	72660596	1997	77513166	2008	110619573	2019	176235463
1987	69802697	1998	77682053	2009	114004543	2020	167634215
1988	70492707	1999	80908238	2010	116363774	2021	178796419
1989	70936217	2000	83584347	2011	122711358	2022	177079421
1990	67921639	2001	81974541	2012	137269925		

Source: Our World in Data

According to the data presented in the next figure, the sector primarily responsible for CO2 emissions in Algeria is Fuel Exploitation, constituting 28% of the total emissions. This sector encompasses emissions resulting from the extraction, processing, and transportation of fossil fuels, including oil and natural gas. Following closely is the Transport sector, contributing 23% to the country's CO2 emissions, while the Industrial sector accounts for 20%. Additionally, the Buildings sector, which covers emissions from residential and commercial buildings, including heating, air conditioning, and lighting, represents 14% of the total emissions. (Figure. 2.22) underscore the importance of understanding the country's environmental performance and the key sectors driving greenhouse gas emissions. Such insights are invaluable for policymakers, researchers, and other stakeholders in formulating effective strategies for emission reduction and climate change mitigation.

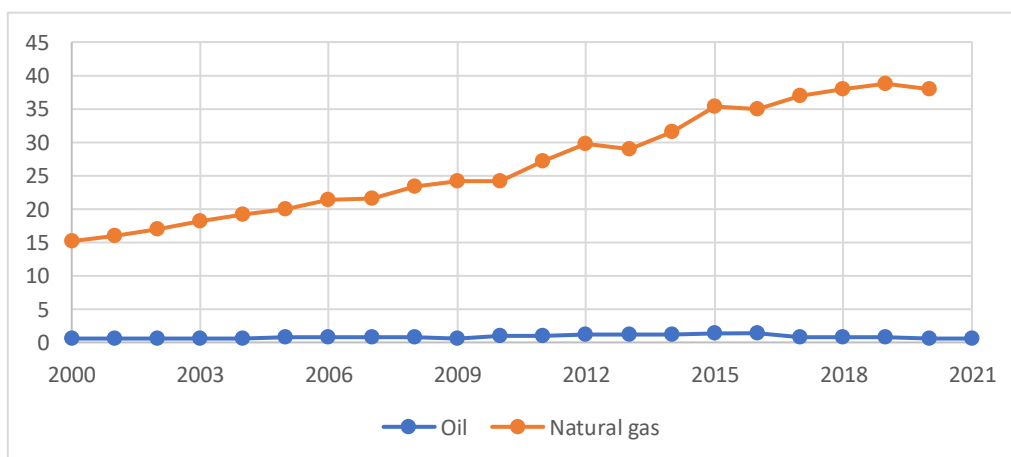
Figure 2.22. CO2 Emissions by Sector in Algeria



Source: Our World in Data

Power generation, comprising both electricity and heat production, emerges as a notable driver of global CO2 emissions, with around 30% of total energy-related CO2 emissions in 2021 attributed to this sector. This significant contribution can largely be attributed to the combustion of fossil fuels like coal, oil, and natural gas within thermal power plants worldwide. In Algeria, emissions from power generation primarily stem from natural gas, accounting for approximately 98.5% of total emissions in 2021, with only a minor share of 1.5% coming from oil (Figure. 2.23). Over the years, the evolution of emissions from power generation sources in Algeria has seen a substantial shift, with a notable increase in reliance on natural gas since 2000. This evolution underscores the need for concerted efforts to transition towards cleaner and more sustainable energy sources to mitigate the impact of power generation on climate change.

Figure 2.23. CO2 Emissions by Source in Algeria



Source: Realized by the researcher using data from the International Energy Agency (IEA)

2.3.2 Assessing the Impact of Policy Decisions on Renewable Energy Integration

As early as 1999, Algeria introduced regulatory measures to incorporate the development of renewable energies and energy efficiency into its energy model. An initial renewable energy development program was launched in 2011, and updated in 2015. This provided for the installation of 22 GW of capacity by 2030, with 13.57 GW dedicated to photovoltaic technologies.

In 2017, regulatory texts were put in place to launch auctions and investor tenders for RE projects. A first national call for tenders was launched in 2018, for PV power plants. The conditions under which this tender was launched did not allow the project to be completed. These experiences were rich in lessons and led to the arrangement of regulatory and organizational measures to increase the chances of success for future projects.

2.3.2.1 Governance's Framework: Policy and Regulation Perspectives

Today, the Algerian government has created a Ministry of Energy Transition and Renewable Energies. The latter has all the prerogatives needed to develop projects in the field of renewable energies and energy transition in Algeria (Executive Decree no. 20-322 of Nov. 22, 2020). The new ministry has set a target of 15,000 MW of renewable energy capacity to be installed by 2035. With this in mind, an initial project for 1,000 MW of IPP photovoltaic power plants was launched on December 23, 2021.

Several energy policies aimed at facilitating the adoption of renewable energy sources have been enacted since 2004. To give concrete expression to the government's political will to promote renewable energies and build infrastructure to generate electricity from renewable energy sources, a range of laws, executive Decrees and ministerial orders have been adopted (**CEREFÉ, 2023**).

Law N°. 99-09, July 28, 1999, concerning energy control: this legislation was implemented in 1999 to raise awareness of energy efficiency by developing conserving energy and maximizing effectiveness techniques; creating a comprehensive framework for national energy consumption; preventing air pollution and reducing carbon dioxide and monoxide emissions to promote renewable energy sources and environmental protection.

Law N°. 02-01, February 5, 2002, regarding pipelined public gas distribution and power. concerns the public distribution of piped gas and electricity in Algeria. It establishes a legal framework for the feed-in tariff, encouraging the development of renewable energies and cogeneration. The law aims to diversify the national energy mix and promote investment in gas and electricity infrastructures.

Executive Decree N°. 2004-92, March 25, 2004, regarding the diversification of power generation costs. Elaborates on the procedures outlined in Law 02-01 (5 February 2002) to implement a feed-in tariff system, aiming at promoting the growth of renewable energy sources and broadening Algeria's energy portfolio. This tariff structure entails offering an additional payment per unit of electricity generated (kWh) to qualifying renewable energy and co-generation facilities, in addition to the standard electricity tariff in Algeria. It establishes specific tariff rates, varying based on the type of generation technology, set at certain percentages above the prevailing market electricity price. The eligible technologies include hydropower, wind, solar, solar thermal from solar-gas hybrid systems, energy waste, and steam/water cogeneration.

Law N°. 04-09, August 14, 2004, expands upon the general commitments provided by Law No. 99-09 concerning the Management of Energy, setting foundations for a necessary “national program to support renewable energy within the context of sustainable development”, provides the framework for the comprehensive Renewable Energy and Energy Efficiency Program (2011–2030) of the Ministry of Mines and Energy, which was launched in March 2011 and sets detailed numerical objectives for renewables. This strategy was created and approved in 2004 to address three primary aspects of renewable energy: full certification to the energy technology source, so that it may be promoted both domestically and globally; a nationwide observatory aimed to pushing renewable energy; a framework of financial incentives to support projects advancing the development of renewable energy technologies.

Law N°. 04-20, December 29, 2004, pertaining to the mitigation of significant risks and the handling of disasters within the context of sustainable development. The Law defines the framework that governs Algeria's efforts to prevent disasters and manage their risks. This law specifically covers risks associated with climate change as well as climate-related regions (such as flooding and forest fires) and other tragedies unrelated to climate change.

Executive Decree N°. 2005-375, September 26, 2005, establishing the National Agency on Climate Change, establishing its goals, and outlining the parameters of its functioning. Introduces the formation of a new National Agency on Climate Change (ANCC) under the supervision of the Minister of Environment, aimed at safeguarding the environment by aiding in the incorporation of climate change impact considerations into development strategies. Furthermore, the ANCC is tasked with investigating, consolidating, and fostering public involvement in issues related to (a) greenhouse gas (GHG) emissions and sequestration, and (b) adaptation to and mitigation of diverse socio-economic impacts of climate change. In line with this objective, the ANCC is obligated to conduct capacity-building activities, establish and manage a climate change database, compile meteorological

data, produce regular reports, and coordinate responses to climate change across various governmental and industrial sectors.

Presidential Decree N°. 06-206 of June 7, 2006, in terms of the ratification of the Stockholm Agreement on Persistent Organic Pollutants, which was adopted in Stockholm on May 22, 2001

Ministerial order of December 15, 2007, concerning the National Agency of Climate Change's organizational structure.

Presidential Decree N°. 07-94, March 19, 2007, relates to the ratification of the Montreal Protocol, which was adopted in Beijing on December 3, 1999, and deals with substances that damage the ozone layer.

Ministerial order, February 21, 2008, fixing the technical rules connection to the electricity transmission network and the rules of the system electric.

Interministerial Order, April 19, 2008, adopting the technical regulation on the "Photovoltaic Module (PV) with crystalline silicon for terrestrial application".

Law N°.09-09, December 30, 2009, carries the 2010 law, which includes Article 64 establishing the National Fund for Renewable Energy and Cogeneration (FNER).

Executive Decree No. 10-258, October 21, 2010, which delineates the authorities of the Planning and Environment Minister

Executive Decree No. 2011-33, January 27, 2011 about the creation, structure, and administration of the Algerian Institute of Renewable Energy.

The Algerian Institute of Renewable Energy (IAER) is established under the jurisdiction of the Minister for Energy. It delineates the IAER's obligations, which involve overseeing institutional requirements and collaborating with both public and private entities for the enhancement of renewable energy and energy efficiency. Additionally, it involves promoting research in these fields and offering consultancy services to support the development of renewable energy and energy efficiency projects, and engaging in national and international agreements related to these areas. Moreover, mandates the Institute to offer skills training in renewable energy and energy efficiency for engineers, technicians, and other relevant stakeholders, covering topics such as engineering systems development, safety protocols, energy auditing, and renewable energy management, as well as energy efficiency modeling. Finally, specifies the composition and roles of the Institute and its constituent parts.

Law N°.11-11, July 18, 2011, provides the law pertaining to additional finance for 2011, specifically Article 40, which amends Article 63 of Law No. 09-09.

Executive Decree N°. 1-423 December 08, 2011, establishes instructions for the management of the account N°. 302-131, entitled "National Funds for Renewable Energies and Cogeneration." Modifies the operational guidelines of the National Fund for Renewable Energy and Cogeneration, originally set forth in accordance with the Finance Act of 2010, with the intention of raising the funds' revenue. The distribution of oil royalties undergoes a change from 5% to 1%, while allowing for additional contributions. Authorizes the Minister of Finance, in conjunction with the Minister of Energy, to jointly administer the allocation of funds from this reserve, with the primary objective of funding activities and projects to promote renewable energy and cogeneration.

The National Climate Plan April 28, 2013, the National Climate Plan outlines a mitigation and adaptation program that intends to achieve equitable social development and sustainable economic growth while appropriately addressing climate change-related issues. An overview of Algeria's vulnerabilities to climate change is given, along with over 70 initiatives that are suggested. Among them are: adopting a cleaner energy consumption model by using natural gas and liquefied propane instead of liquid fuels; developing an additional 175,000 hectares of forest and reaching 35,000 hectares of forest cover; railway electrification and the expansion of urban public transportation (including the building of the Algiers metro and tramway systems in many areas). The Plan also aims to install 22,000 MW of renewable power capacity between 2011 and 2030, with 12,000 MW allocated for the country's electricity needs and 10,000 MW for export. It also encourages the use of renewable energy sources.

Executive Decree N°.13-218, June 18, 2013, sets forth the conditions for granting allowances associated with diversifying producing power.

Executive Decree N°.15-69, February 11, 2015, defined the guidelines for certifying the source of renewable energy and how those certificates are utilized.

Ministerial order, February 02, 2014, fixing the feed-in tariffs¹ and the conditions of their application for electricity generated from facilities using photovoltaic systems. Establishing a variable feed-in-tariff (FIT) for ground-based solar power systems spanning 20 years, the tariff remains higher than 1MW. The initial five years see a fixed FIT of 15.94 DZD per kWh, followed by a range of 20.08 DZD to 11.80 DZD for the subsequent fifteen years, applicable to installations ranging from

¹ **Feed-in tariff:** is a policy mechanism that guarantees a higher price for renewable energy than the market price, offering long-term contracts to encourage investment in renewable energy technologies.

1MW to 5MW. The Feed-in Tariff (FIT) for installations above 5 megawatts is set at 12.75 DZD per KWh for the first five years and then varies between 12.75 DZD and 9.44 per kWh for the following fifteen years. The FIT is only compensated for a restricted number of hours annually, beyond that, power is sold at a standard rate.

Law No. 14-10, December 30, 2014, bearing the law of 2015, including Article 108 which provides for the merger of the two Funds. The National Fund for the Control of Energy (FNME) and the National Fund for Renewable Energies and Cogeneration (FNER)

Executive Decree N°. 17-98, February 26, 2017, Setting guidelines for the tender process for renewable energy and cogeneration production, as well as their integration into the national electric power supply system.

Executive Decree N°. 20-152, June 8, 2020, creating the national college of renewable energies, environment and sustainable development.

Executive Decree N°. 20-322, November 22, 2020, establishing the responsibilities of the Minister of Energy Transition and Renewable Energies.

Executive Decree N°. 21-95, March 10, 2021, amending and supplementing executive Decree no. 19-280 of October 20, 2019, creating, organizing, and operating the commission for renewable energies and energy efficiency.

Executive Decree N°. 21-106, March 17, 2021, amending and supplementing Decree no. 85-235 of August 25, 1985, creating an agency for the promotion and rationalization of energy use (APRUE).

Executive Decree N°. 21-158, April 24, 2021 amending Executive Decree no. 17-98 of February 26, 2017 defining the tender procedure for the production of renewable or cogeneration energies and their integration into the national electrical energy supply system.

Executive Decree N°. 21-348, September 11, 2021, amending and supplementing executive Decree no. 15-319 of December 13, 2015, setting the operating procedures for the special allocation account no. 302-131 entitled "national fund for energy management, renewable energies and cogeneration".

Executive Decree N°. 23-212, June 7, 2023, amending and supplementing Executive Decree no. 21-239 of May 31, 2021 establishing the remit of the Minister of Energy and Mines.

Executive Decree N°. 23-381, October 28, 2023 establishing the responsibilities of the Minister of the Environment and Renewable Energies.

Executive Decree N°. 23-200, May 31, 2023, amending Executive Decree No. 19-280 of October 20, 2019 establishing, organizing, and operating the Commission for Renewable Energies and Energy Efficiency.

These political laws have been created to change Algeria's energy system and carry out the following operational goals: (a) ensuring that all citizens have access to electricity; (b) encouraging energy efficiency and conservation; (c) protecting the environment; (d) heading the country closer to energy diversification; (e) enhancing regional infrastructure for energy production, distribution, and transportation; and (f) increasing public awareness of the use of renewable energy sources. The table below summarizes the main renewable energy promotion laws:

Table 2.12. Developments of Main Legislation on Renewable Energies

Title	Year	Policy type
Presidential Decree on the creation of the High Energy Council	2022	<i>Policy support: institutional creation</i>
-Transfer of prerogatives from the Ministry of Energy to the MTEER concerning renewable energy projects. -Creation of a new Algerian Renewable Energy Company SHAEMS	2021	<i>Policy support: institutional creation</i>
Creation of the Ministry of Energy Transition and Renewable Energies (MTEER)	2020	<i>Policy support: institutional creation</i>
Creation of the Commission for Renewable Energies and Energy Efficiency (CEREFÉ)	2019	<i>Policy support: institutional creation</i>
Executive Decree N°. 17-98: Call for tenders for the production of renewable energies or cogeneration and their integration into the national electrical energy supply system.	2017	<i>Economic instruments: fiscal/financial incentives</i>
Renewable energy and energy efficiency program 2011-2030 revised	2015	<i>Policy support: strategic planning</i>
Feed-in tariff for solar PV and wind power installations	2014	<i>Economic instruments: fiscal/financial incentives</i>
The National Climate Plan	2013	<i>Policy support: strategic planning,</i>

Executive Decree No. 2011-33, about the creation, structure, and administration of the Algerian Institute of Renewable Energy	2011	<i>Policy support: strategic planning, institutional creation</i>
Renewable energy and energy efficiency program 2011-2030	2011	<i>Policy support: strategic planning</i>
Law No.09-09 National Fund for Renewable Energies and Cogeneration (FNER)	2009	<i>Policy support: institutional creation</i> <i>Economic instruments: fiscal/financial incentives</i>
Ministerial order relative to the adoption of the technical regulation concerning Silicon PV modules for ground application.	2008	<i>Research, development, and deployment (RD&D): research program, technology deployment, and diffusion</i>
Ministerial order relative to the administrative organization of the National Agency of climate change.	2007	<i>Regulatory instrument: codes and standards</i>
Presidential Decree N°. 06-206 about the ratification of the Stockholm agreement on persistent organic pollutants, adopted in Stockholm on May 22nd, 2001.	2006	<i>Regulatory instrument: codes and standards</i>
Executive Decree No. 2005-375 establishes the National Agency on Climate Change, outlining its duties and organizing its structure and functions.	2005	<i>Policy support: institutional creation</i>
Law 04-09 about the promotion of renewable energies in the context of sustainable development	2004	<i>Regulatory instrument: codes and standards</i> <i>Policy support: institutional creation</i>

		<i>Research, development, and deployment (RD&D):</i> research program, technology deployment, and diffusion
Law 04-92 on the diversification of Power Generation Costs (REFIT)	2004	<i>Economic instruments:</i> fiscal/financial incentives
Law 02-01 relative to the electricity and the public distribution of the gas by pipeline	2002	<i>Policy support:</i> strategic planning
Law 99-09 on the management of Energy	1999	<i>Policy support:</i> strategic planning, institutional creation
Executive Decree N°. 85-235 creating an agency for the promotion and rationalization of energy use (APRUE).	1985	<i>Policy support:</i> institutional creation

Source: Realized by the researcher using from data (CEREFÉ, 2023), and Ministry of Energy and Mines

2.3.2.2 Key Contributors to Algeria's Renewable Energy Sector

Algeria has created a strong set of laws to support the growth of renewable energy. This commitment is evident in multiple regulations and strategic initiatives focused on decreasing reliance on fossil fuels and encouraging sustainable energy advancement. Therefore, the government's efforts are aimed at fostering a sustainable energy landscape that aligns with global environmental goals.

Ministry of Energy Transition and Renewable Energies (MTEER): is responsible for the deployment of renewable energy projects in Algeria. It is responsible for issuing invitations to tender to investors for renewable energy projects.

Ministry of Energy and Mines (MEM): this is the historic player in Algeria's energy sector. It owns all energy production, distribution, and transport infrastructures.

Commission for Renewable Energies and Energy Efficiency (CEREFE): A public establishment created in October 2019, reporting to the Prime Minister. Dedicated to promoting renewable energy and energy efficiency at both national and sectoral levels.

Renewable Energy Development Center (CDER): attached to the Ministry of Higher Education and Scientific Research, established on 22 March 1988. This center is responsible for drawing up and implementing scientific and technological research programs and developing energy systems using solar, wind, geothermal, and biomass energy. The CDER is composed of three research divisions that focus on implementing and assimilating several RE projects on a national scale. These three research units include the Unit of Solar Equipment Development (UDES) in Tipaza, established in 1988; the Unit of Applied Renewable Energies Research (URAER) in Ghardaia, founded in 2002; and the Unit of Renewable Energies Research in Saharan Regions (URERMS) in Adrar, established in 2004.

Electricity & Renewable Energy Company (SKTM): serves as a subsidiary of the national electricity and Gas Company (Sonelgaz group), functioning as a power generation enterprise. Established on April 7th, 2013, it was instituted to spearhead Algeria's renewable energy initiatives. Headquartered in Ghardaïa province, SKTM's primary duties entail the operation of isolated electricity networks in the southern regions, encompassing both conventional electricity generation and renewable energies. Moreover, SKTM is tasked with advancing national electrical infrastructure, overseeing the production of isolated Southern Networks, and undertaking engineering, maintenance,

and management responsibilities for the power plants under its jurisdiction. It also oversees the marketing of energy produced for distribution subsidiaries

Electricity and Gas Regulatory Commission (CREG): was put in place by law N°. 02-01 of February 5, 2002, which dealt with pipeline distribution of gas and electricity, is an independent and autonomous body whose main missions are: to provide and monitor public services, to advise public authorities on the organization and operation of the electricity market and the domestic gas market, and to monitor and ensure compliance with the laws and regulations governing the electricity market and the domestic gas market.

SHAEMS: The New Algerian Renewable Energy Company "SHAEMS, Spa", created in 2021, is entrusted by the Minister of Energy Transition and Renewable Energies with the development of the renewable energies program. It is currently responsible for the development, processing and monitoring of the "Solar 1000" project.

SONATRACH (public company): Sonatrach is an Algerian oil and gas company. Created on December 31, 1963. It is a major player in the oil industry. Sonatrach is ranked as Africa's leading oil company.

SONELGAZ (public company): Sonelgaz is an Algerian industrial energy group, Created on July 28, 1969, specializing in the production, distribution and marketing of electricity and the purchase, transport, distribution and marketing of natural gas.

AEC SPA (public company): Algerian Energy Company was born of a partnership between Sonatrach and Sonelgaz, in May 2001, to enable Algeria to seize investment opportunities in the energy markets. AEC's primary objective is to enhance the value of Algerian natural gas.

IAER (public institution): Algerian Institute for Renewable Energies, was established in January 27 2011, the fruit of collaboration between the Ministry of Higher Education and Scientific Research (MESRS) and the Center for the Development of Renewable Energies (CDER). The institute aims to improve access to scientific and technical information, and to facilitate the exchange and sharing of knowledge in the field of renewable energies.

NEAL (New Energy Algeria), the Algeria's renewable energy agency, The national energy companies and the Algerian government established NEAL as a new company to promote the usage, export, and local production of renewable energy. Algeria's plan for creating a renewable energy agency was communicated to US Secretary of Energy Spencer Abraham on June 5, 2002, by former

Minister of Mines and Energy Chakib Khelil of Algeria. The NEAL's energy policy is composed of the following:

- Providing the ideal opportunities for the development of renewable energy sources;
- Guaranteeing the ongoing sustainability of the uses of RES;
- Guaranteeing environmentally sound sustainable energy development programs that cause the least amount of environmental harm;
- Diversifying energy sources and preventing dependence on just one fuel (oil and gas);
- Preventing desertification and combating deforestation in the southern provinces.

The national energy efficiency policy was launched by the public authorities in 2003 through the implementation of the energy efficiency law that was passed in July 1999. This strategy's execution mechanism is made up of four instruments that are outlined within the framework of this law, specifically (**Boudghene Stambouli, 2011**):

PNME: National Energy Efficiency Program;

FNME: National Energy Efficiency Fund;

CIME: Inter-sector Energy Efficiency Committee;

APRUE: Algerian National Agency for the Promotion and Rationalization of Energy Use.

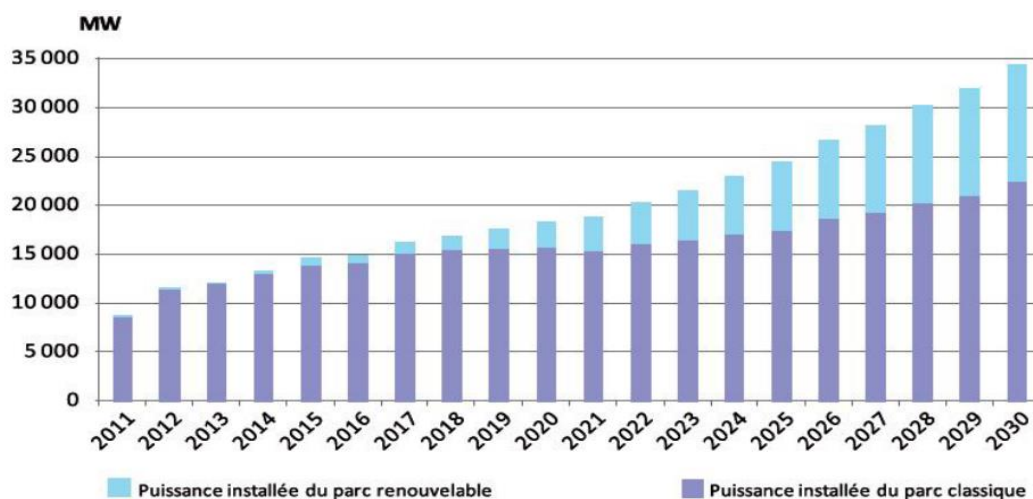
2.3.2.3 Empowering Sustainability: Renewable Energy and Energy Efficiency Program

Algeria's first national program for the development and promotion of Renewable Energy and Energy Efficiency (NREP) was adopted by the government on February 3, 2011. It set a target of 40% renewable electricity generation capacity by 2030. This was based on a previously established estimate of the evolution of installed capacity, presented by the Ministry of Energy and Mines, which forecast an overall annual consumption of 150 TWh/year (**MEM, n. d.**). Quantitatively, the objective was to ensure a renewable electricity production capacity of 22,000 MW, of which 10,000 MW would be dedicated to export.

2.3.2.3.1 Renewable energies component of the NREP

According to the Ministry of Energy and Mines (**MEM, n. d.**), the means of generating electricity for the national market (12GW) were planned based on three main renewable resources (Table. 2.13) and deployed in four stages (Table. 2.14).

Figure 2.24. Estimated Development of the National Power Generation Fleet



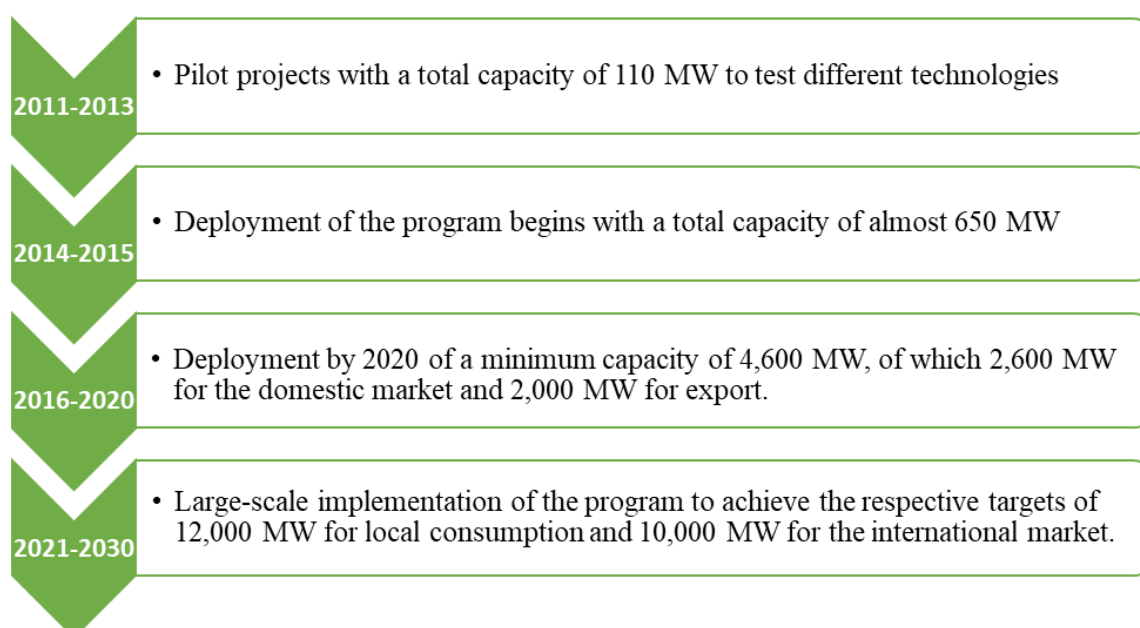
Source: (Renewable Energy and Energy Efficiency Program, 2011, p.09)

Table 2.13. Share of Selected Renewable Resources.

Concentrated Solar Power (CSP)	Solar photovoltaic (PV)	Wind	Total
7200 MW	2800MW	2000MW	12000MW

Source: (CEREFÉ, 2020)

Table 2.14. Program Schedule (2011 Version)



Source: Realized by the researcher using data from (CEREFÉ, 2020)

2.3.2.3.2 Achievements within the Framework of NREP 2011

The planned schedule (Table. 2.14) was never followed from the outset. In fact, of all the pilot projects totaling the planned 110 MW, only three have been completed (CEREFÉ, 2020), with a total capacity of 36.3 MW:

- The Hassi-Rmel hybrid power plant (gas-solar thermal), with 25 MWp of concentrated solar thermal power (CSP) (commissioned in 2011).
- The Ghardaïa photovoltaic (PV) power plant, with the 1.1 MWp photovoltaic (PV) plant in Ghardaïa, encompassing all four PV technologies, with and without solar tracking (commissioned in 2014).
- The 10.2 MWp wind power plant in Kabertène (Adrar), encompassing 12 wind turbines with a rated output of 850 KW each (commissioned in 2014).

For the rest, only a program totaling 343 MWp of solar photovoltaic power plants was launched in early 2014, as an EPC (Engineering, Procurement & Construction) project, by SKTM (Sharikat Kahrab wa Takat Moutadjadida), Sonelgaz's power generation subsidiary, created in April 2013. SKTM's main missions are to operate the isolated power grids in the south (conventional generation) and renewable energies throughout the country. Against this backdrop, ten solar photovoltaic power plants totaling 265 MW and divided into three batches (East, Centre and West) have been built in the highlands, while a further ten have been built as part of the southern batch (78 MW).

2.3.2.3.3 Energy Efficiency Component of the NREP

The Plan seeks to improve energy efficiency in several ways, including: enhancing building thermal insulation; improvement of cogeneration and solar water heating; enhancement of natural gas and LPG fuel; creating techniques for solar cooling; converting simple cycle power plants to mixed cycle power plants wherever suitable; using sustainable energy to desalinate brackish water; converting all mercury lamps with sodium lamps and all mercury lamps with sodium lamps and encouraging the adoption of low-energy lighting.

The energy efficiency component focused on consumption sectors identified as having a significant impact on the country's internal energy demand. These are mainly the following sectors:

A. *Building and Residential*

The program aimed to encourage the implementation of innovative practices and technologies around thermal insulation in existing, under-construction, and planned buildings. This sector alone accounts for over 40% of the country's final energy consumption. In support of this, the aim was also to encourage the mass penetration of high-performance equipment and appliances on the local market, notably solar water heaters and energy-saving lamps (LBCs): the ultimate objective being to improve the interior comfort of homes while using less energy. More than 30 million TOE are expected to be saved by 2030, broken down as follows (CEREFÉ, 2020):

- Thermal insulation: the aim is to achieve a cumulative gain of over 7 million TOE;
- Solar water heaters: Given Algeria's highly favourable potential for direct solar radiation, the development of solar water heaters and their gradual replacement by traditional systems is an alternative that should be supported by the National Fund for Energy Management (FNME). In this case, energy savings of over 2 million TOE are still possible.
- Low-energy light bulbs (LBC): The objective is to gradually ban the sale of incandescent bulbs (conventional energy-guzzling bulbs commonly used by households) on the national market. At the same time, low-energy lamp models will be marketed, with energy savings estimated at almost 20 million TOE;
- Street lighting: the aim is to achieve savings of almost one million TOE, and thus reduce the energy bill of local authorities in charge of lighting.

B. *Transport*

The program was designed to promote the most available and least polluting fuels, namely cGPL and cNG. The aim was to enrich the fuel supply structure in order to reduce the share of diesel, which remains the most polluting fuel, in addition to the fact that a large proportion is imported. This should ultimately result in savings estimated at over 16 million TOE.

C. *Industry*

The aim of the program was to encourage manufacturers to be more sober in their energy consumption. In fact, this sector represents a major challenge for energy management, as its own energy consumption is set to increase with economic recovery, or 30 million TOE of savings are targeted. With this in mind, the following measures are planned:

- Conversion of conventional gas-fired power plants to combined cycle whenever possible;

- Widespread use of energy audits and industrial process control to identify substantial energy-saving potential and recommend corrective action plans;
- Encouraging the adoption of processes that substantially reduce energy wastage in the various industries, with studied support from the State. All in all, the implementation of the national energy efficiency program should gradually reduce the growth in domestic energy demand and generate cumulative energy savings of around 93 million TOE, of which 63 million TOE by 2030 and the rest beyond (**MEM, n. d.**). However, like the renewable energies program, the energy efficiency program has also been delayed in its implementation for reasons of timing, resistance to change, and funding. While the problems of timing and financing are to some extent justified by the urgent need to satisfy the public's demand for housing, those linked to the reluctance of the industrial sector to invest in new, more energy-efficient equipment are partly due to the absence of targeted financial incentives from the State.

2.3.2.3.4 The NREP update for 2015

The 2015 update of the first version of the NREP, published in 2011, was mainly motivated by the significant changes in the world's investment and electricity generation costs based on the various renewable resources (**MEM, n. d.**). Concentrating solar thermal power (CSP) was initially adopted to generate 7200 MW of solar electricity (Table. 2.14), i.e. more than 2.5 times the share of photovoltaics (2800 MWp). However, while in 2011 the costs of generating electricity using these two technologies were more or less the same (\$0.35/KWh), those for solar photovoltaic subsequently fell sharply to less than \$0.15/KWh in 2015, while those for CSP changed little and remained well above \$0.25/KWh. It was this observation that prompted a thorough review of the first version of the program, despite its relatively recent launch. Thus, the share of CSP has been revised downwards (2000 MW instead of 7200 MW) while postponing its effective development beyond 2021, while that of photovoltaic solar power has been multiplied by around 5 (13575 MW instead of 2800 MW), i.e. 62% of the total 22,000 MW planned by 2030. What's more, more than 4,500 MW, 2/3 of it solar photovoltaic, are scheduled for completion before 2020, according to the schedule shown in (Table .2.13).

However, with hindsight, we can see that to date (2020), like the first version of the program, the schedule has not been followed, nor has it even begun to be implemented. Indeed, the only visible activity in the field of renewable energies in the country since 2015 has essentially been dominated by the handover (spread over 2017) of solar photovoltaic power plants totaling 343 MW from the program launched in 2014 by SKTM. In addition, in 2018 Sonatrach commissioned its first 10 MWp

solar photovoltaic power plant at Bir Rebaa Nord (BRN), in the wilaya of Ouargla, as part of its SH 2030 strategy to deploy a total solar energy capacity of 2,300 MW by 2030 (**Bouznit, Pablo-Romero et Sánchez-Braza, 2020**)

Table 2.15. Renewable Energy Goals for Electricity Generation in Algeria's (2015–2030).

Electric Power						
Energy Sources	2015-2020		2021-2030		Total (MW)	%
	MW	%	MW	%		
Photovoltaic	3,000	66.3	10,575	60.52	13,575	61.70
Wind	1,010	22.32	4,000	22.89	5010	22.77
Concentrated solar power	-	-	2,000	11.44	2000	9.09
Biomass	360	7.95	640	3.66	1000	4.55
Cogeneration	150	3.31	250	1.43	400	1.82
Geothermal	5	0.11	10	0.06	15	0.07
Total	4525	-	17475	-	22000	-

Source: Ministry of Energy and Mines

Up to 2017, accomplishments have been somewhat modest when compared to the forecasts. The following table presents information regarding grid-connected power facilities, including 23 photovoltaic (PV) centers and one wind farm, operating on renewable energy. These installations are overseen by the electricity and renewable energy company (SKTM) and cover data on installed capacity and energy production from their launch date until June 2017 (**Bouraiou et al., 2020**).

Table 2.16. The Installed Capacity and Produced Energy from The Establishment Date to June 2017

Location	Province	Surface (Hectare)	Installed Capacity (MW)	Production (GWh)	Establishment date
RIN					
Oued Nechou PV	Ghardaia	05	1.1	4.593	2014
Serdet Leghzel	Naama	32	20	40.715	2016
Oued El Kebrit	Souk ahras	20	15	28.900	2016
Ain Skhouna	Saida	60	30	14.213	2016
Ain El Bel 1&2	Djelfa	120	53	25.134	2016 & 2017
Telagh	Sidi Bel Abbes	30	12	7.417	2016
Lekhneg 1&2	Laghouat	120	60	53.576	2016 & 2017
Labioh Sidi Chikh	El Bayadh	40	23	19.146	2016
El Hadjira	Ourgla	60	30	9.738	2017
Ain El Melh	M'sila	40	20	16.473	2017
Oued El Ma	Batna	-	02	-	2017
RIS					
Tamanrassat	Tamanrassat	26	13	36.410	2015
Djanet	Illizi	06	03	10.729	2015
Tindouf	Tindouf	18	09	28.900	2015
PIAT					
Kabertene (Wind)	Adrar	33	10.2	51.579	2014
Adrar City	Adrar	40	20	59.585	2015
Kabertene (PV)	Adrar	06	03	9.584	2015
In Salah	Tamanrassat	10	05	12.328	2016
Timimoune	Adrar	18	09	23.8222	2016
Reggan	Adrar	10	05	12.557	2016
Zaouiat	Adrar	12	06	15.213	2016
Kounta	Adrar	-			
Aoulef	Adrar	10	05	12.557	2016
Total SKTM (RE)	-	-	354.3	470.318	-

Source: (Bouraiou et al., 2020)

In November 2018, the opening of a 10 MW photovoltaic facility took place in Bir Rebaa, located within Ouargla province. This venture emerged from a collaborative effort between Algerian and Italian oil enterprises, Sonatrach and Eni, and comprises 31,320 photovoltaic panels installed across a 20-hectare site (**Bouraiou et al., 2020**).

In order to make up for the country's considerable lag in the development of renewable energies in relation to the targets set (Table. 2.15), several attempts have been made:

A. Ministry of Energy's 4050 MWp call for tenders

Although the legal and regulatory foundations of the Feed-in-Tariffs procedure had been finalized and discussed at length with potential investors, it has not yet been implemented and has been replaced by a new procedure based on calls for tender (**CEREFÉ, 2020**). The latter was introduced by Executive Decree No. 17-98 of February 26, 2017, defining the tender procedure for the production of renewable energies or cogeneration and their integration into the national electrical energy supply system. Such an initiative was the prelude to a specific legal framework for the launch of a new 4000 MWp solar photovoltaic program, readjusted just afterward to 4050 MWp so that it could be presented in three batches of identical capacities of 1350 MWp each. In the end, this project, which included not only the production of solar photovoltaic (PV) electricity but also a supporting industrial component, never got off the ground and has not been the subject of any calls for investors since, despite the urgency of its implementation.

B. CREG's 150 MWp call for tenders

As a last-ditch attempt to make up for the country's considerable lag in the development of renewable energies about the targets set (Table. 2.15), particularly after the failure of the 4050 MW project mentioned above, the CREG was forced to launch a much more modest call for tenders, for 150 MWp of solar photovoltaic power. An auction bidding formula falling under the CREG's prerogatives was indeed instituted through the same Executive Decree N°17-98 of February 26, 2017, referred to above, in the same way as the call for tenders to investors falling exclusively under the prerogatives of the Ministry of Energy (**CEREFÉ, 2020**).

The specifications relating to the tender in question (150 MWp), were published by the CREG on 18/11/2018 and were aimed exclusively at companies incorporated under Algerian law. It included 15 solar photovoltaic power plants of 10 MWp each, grouped into four lots, two of which were of 50 MWp located in the wilayas of Biskra and Ghardaia, the last two being of the last two being 30 MWp and 20 MWp, located in the wilayas of Ouargla and El Oued respectively. In the end, only eight of

the 93 bidders who initially expressed interest submitted bids by the deadline, which was postponed several times before being finally set for 12/06/2019, following far-reaching changes to the initial specifications. The two planned technical and financial selection stages, the last of which took place on 28/10/2019, almost a year after the tender was first issued, resulted in only one proposal being accepted for the construction of five 10 MWp photovoltaic power plants in the Biskra region, at a transfer price of 8.28 DA per kWh. In conclusion, despite the rather modest level of the call for tenders in question (150 MWp), only a third of the proposed capacity, i.e. 50 MWp, has found takers, with no confirmation to date of the start of work.

C. SKTM/Sonelgaz 50 MWp call for tenders

Launched at nearly the same time (December 2018) as the CREG's 150 MWp project presented previously, this call for tenders, which was also aimed at companies incorporated under Algerian law, was initiated by SKTM to hybridize some of its diesel or gas turbine power plants, used to generate electricity for the Southern Isolated Networks (RIS), with photovoltaic solar power. Nine (9) units were thus selected for the parallel installation of 9 solar photovoltaic power plants totaling 50 MWp, grouped into five lots (Table. 2.17).

Table 2.17. Award Data for SKTM's 50 MWp Market in 2019

Lot N°	Designation	Capacity (MWc)	Amount (DA)	Deadline (month)
1	In Guezzem	6	1 761 543 769,63	09
	Tinzaouatine	3		
2	Djanet	4	1 494 479 058,92	09
	Bordj Omar Dris	3		
3	Bordj Badji Mokhtar	10	2 242 624 058,54	10
	Timiaouine	2		
4	Talmine	8	2 257 920 162,20	09
	Tabelbala	3		
5	Tindouf	11	2 138 859 583,81	09

Source: Algerian Energy Transition 2020-CEREFÉ

2.3.2.3.5 The updated NREP 2020

The energy transition is a central pillar of the government's action plan, focused on economic renewal based on food security, energy transition, and the digital economy. This program aims to

diversify energy sources through renewable energy development and promote energy efficiency as a key complementary measure. The goal is to gradually reduce dependence on fossil resources and foster the emergence of green and sustainable energy, particularly solar energy, which is abundant and locally available. This strategy is based on the following considerations: Preserving and adding value to fossil resources; transforming energy production and consumption models; promoting sustainable development and environmental protection; and optimizing the costs of implementing renewable energy infrastructure (CEREFÉ, 2020).

A. Under the Development of Renewable Energy

Algeria aims to develop a 16,000 MW renewable energy program by 2035, exclusively based on solar photovoltaic energy. Of this capacity, 15,000 MW will be generated by grid-connected power plants, with an initial tranche of 4,000 MW to be completed by 2024. The remaining 1,000 MW will be deployed as off-grid autonomous production by 2030, although details on storage solutions remain unspecified.

The "Tafouk I" project, announced in 2020 for a capacity of 4,000 MWc, has been revised with adjustments, including the removal of the industrial component, a reconfiguration of production lots (eight lots of 500 MW), and a financial restructuring following changes within Sonelgaz. This project will be managed by SADEG, in partnership with Sonatrach.

Additionally, the hybridization of conventional power plants (diesel and gas) with solar photovoltaic systems in southern Algeria is a key priority. The government also plans to develop 1,000 MW of off-grid capacities by 2030, with 500 MW targeted before 2024. This plan includes measures to promote local expertise, strengthen regulatory frameworks (installer certification, accreditation of engineering offices), and establish financial mechanisms to support the development of off-grid renewable energy solutions.

B. Under the Energy Efficiency Policy

The government plans to implement strong measures in energy efficiency, primarily aiming to significantly reduce waste. These measures, to be applied across various sectors, include:

- Widespread use of thermal insulation in new constructions;
- Establishing a national program to convert passenger vehicles to LPG and developing CNG for public transport vehicles;

- Equipping public lighting networks and administrative buildings with low-consumption devices;
- Introducing regulatory frameworks to ban the import and production of energy-intensive equipment;
- Expanding investment incentives to support local manufacturing of equipment and components dedicated to energy efficiency.

This strategy reflects a comprehensive approach to promoting sustainable energy use across the country.

2.3.3 Exploring Algeria's Renewable Energy Potential

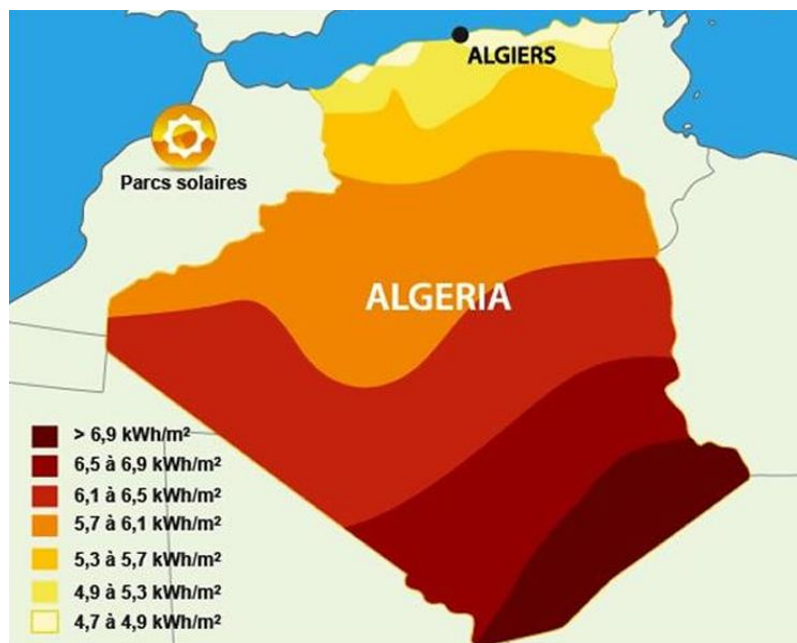
Algeria possesses significant prospects for generating energy from renewable sources such as solar, wind, hydro, geothermal, and bio-energy (Zahraoui et al., 2021). The nation is prioritizing the expansion of solar power generation by the year 2030. With its substantial renewable energy potential, particularly in photovoltaic capacity, Algeria is poised to contribute to Africa's energy transition.

2.3.3.1 Solar Energy

The origins of solar energy in Algeria begin in 1954, with a solar furnace built by the French to produce ceramics. Solar energy stands as Algeria's richest natural asset. It is essential for Algeria to harness this significant resource. Even capturing a mere 1% of this energy would provide more than the global power demand (Z. Jacobson, 2009).

Due to its geographical location, Algeria has one of the largest solar deposits in the world, particularly in the Sahara region (Maammeur et al., 2017), which is widely confirmed by the World Energy Council (WEC) and presented in (Figure 2.25). The country benefits from optimal solar power production conditions, characterized by abundant sunlight, minimal humidity and precipitation, and vast expanses of flat, unused land conveniently situated near transportation networks and power grids. Consequently, the potential for electricity generation is immense, surpassing both regional and global energy requirements; approximately 10% of the Algerian Sahara desert alone could satisfy the energy demands of the European Union (Stambouli et al., 2012).

Figure 2.25. Solar Potential Distribution in Algeria.



Source: Renewable Energy Development Center (CDER)

Across the majority of the nation, sunshine duration surpasses 3,000 hours annually, reaching 3500 hours in the highlands and Sahara. Daily energy intake per square meter of horizontal surface area averages approximately 5 kWh throughout most regions (Table. 2.18), equating to nearly 1700 kWh/m²/year in the north and 2650 kWh/m²/year in the south. Despite this considerable potential, renewable energy sources currently occupy a peripheral position in Algeria's energy mix, contributing less than 1% to the nation's electricity derived from renewables.

Table 2.18. Solar Potential in Algeria

Areas	Coastal area	High plains	Sahara
Surface (%)	4	10	86
Area (Km ²)	95.27	238.174	2.048.297
Mean daily sunshine duration (h)	7.26	8.22	9.59
Average duration of sunshine (h/year)	2650	3000	3500
Received average energy (kWh/m ² /year)	1700	1900	2650
Solar daily energy density (kWh/m ²)	4.66	5.21	7.26

Source: (Bouraiou et al., 2020)

When contrasting solar capacity with natural gas in Algeria, the nation's solar potential equates to a volume of 37,000 billion cubic meters, exceeding the country's natural gas reserves by over

eightfold. It's noteworthy that solar potential is renewable, unlike natural gas (**Tagrerout et Atmania, 2021**).

Photovoltaic solar energy involves the conversion of sunlight directly into electricity using photovoltaic panels, which entails the direct transformation of photons into electrons within a semiconductor. Apart from the cost advantages associated with low maintenance, this energy form proves particularly suitable for remote locations where grid connection proves prohibitively expensive. Notably, photovoltaic solar energy stands out as a clean energy source, with its modular components facilitating innovative and aesthetically pleasing integration into architecture (**Bouزيد, Ghellai et Mezghiche, 2015**). Algeria's energy strategy prioritizes the acceleration of solar energy development, with plans to initiate multiple solar photovoltaic projects with a cumulative capacity of around 200 MWp per year throughout the 2021-2030 period.

Solar thermal energy entails the conversion of solar radiation into thermal energy, which can serve either directly, such as for heating buildings, or indirectly, by producing steam to drive turbo-alternators for electricity generation. Unlike photovoltaic cells, which harness solar radiation itself, solar thermal methods rely on utilizing the heat conveyed by radiation. Direct solar radiation is concentrated by a collector onto an exchange, where it is then conveyed to a fluid, either being vaporized directly or conveying the heat to a steam generator. All solar thermal systems share several components, including a collector for heat concentration, a heat-transfer fluid or gas for conveyance to an extraction point, an evaporator, a condenser, a turbine, and an alternator.

Boudghene Stambouli (2011), highlights a significant divergence in economic potential between thermal and PV solar technologies. This disparity has been somewhat misleading, as initial assessments of their potentials occurred during a period marked by substantial cost discrepancies and projected variations in costs in the foreseeable future. However, this scenario has undergone substantial alteration due to a notable decline in PV technology prices, resulting in reduced investment costs for power plant investors. Consequently, this trend has led to an expansion in the economically exploitable potential of PV solar, consequently diminishing the potential of thermal solar.

2.3.3.2 Wind Energy

In Algeria, the first attempt to connect wind turbines to the power grid dates back to 1957, with the installation of a 100 kW wind turbine on the Grand Vent site (Algiers). Designed by French engineer ANDREAU, this prototype had originally been installed at St-ALBAN in England. This two-bladed, pneumatic, variable-pitch wind turbine, 30 m high and 25 m in diameter (Figure. 2.26),

was purchased by Electricité et Gaz d'Algérie, then dismantled and installed in Algeria (Guerri, 2011)

Figure 2.26. (Grand Vent) 100 kW wind Turbine

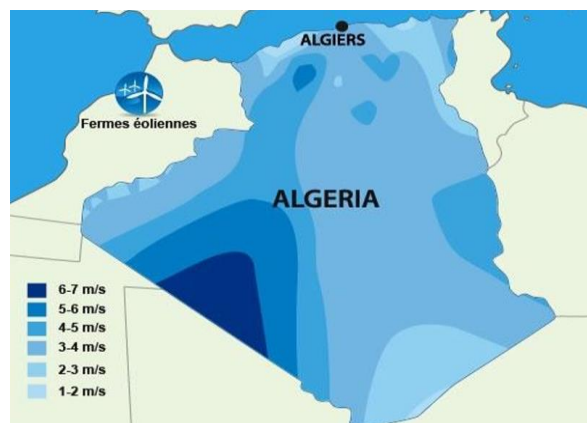


Source: Renewable Energy Development Center (CDER)

Wind power distribution varies across different topographical areas and is heavily influenced by local climate conditions. Algeria's climate exhibits significant variation between its northern and southern regions. The northern half benefits from its strategic location along the Mediterranean, featuring the Atlas Mountains and other elevated plateaus (Boudia et Santos, 2019).

However, wind speeds in the north are generally not as robust as those in the south. Southern regions experience wind speeds ranging from 4m/s to 6m/s, (Figure. 2.27) although they are typically situated at lower latitudes compared to the northern areas. Despite this, more than 70% of Algeria's total land area comprises desert terrain. Adrar stands out as particularly suitable for wind power generation, renowned for its consistent and powerful winds. The presence of strong winds around elevated hills or ridges offers favorable conditions for establishing effective wind power plants.

Figure 2.27. Wind Power Potential in Algeria



Source: Renewable Energy Development Center (CDER)

The wind potential has also undergone assessment by Sonelgaz, the developer, who has currently identified and quantified six pilot projects for electrification and telecommunications. These projects are located in Adrar, Tindouf, Bordj Badji Mokhtar, Bechar, Tamanrassat, and Djanet, as illustrated in the table below. According to preliminary surveys, the Adrar region stands out as the area receiving the highest wind levels in the country (Stambouli, 2011).

Table 2.19. The Annual Average Wind Velocities in the Six Designated Locations

Sites	Adrar	Tindouf	Bordj Badji Mokhtar	Bechar	Tamanrassat	Djanet
Annual Average Speed (m/s)	6,3	5,1	4,6	4,4	3,7	3,3

Source: Renewable Energy Development Center (CDER)

The establishment of nine assessment centers across diverse Algerian regions by Sonelgaz marks a secondary effort aimed at accelerating the adoption of wind energy. These potential wind sites topography and terrain roughness are also undergoing measurement and quantification to enhance the simulation and comprehension of wind flow patterns. Furthermore, the Ministry of the Environment and Spatial Planning has scheduled the development of two wind farms, each with a 20 MW capacity, to be completed by the end of 2012: the first in Tindouf and the second in Adrar (Himri, Belkacem et Himri, 2008).

According to (Tagrerout et Atmania, 2021), Setting up a wind farm in a region with favorable wind resources necessitates meeting additional conditions, including Proximity to the power grid for

interconnection; Access to the transmission path to facilitate the installation of wind power; Handling the intermittent problem that requires coupling this wind resource with other energy sources.

(Tables. 2.20- 2.21) outline the breakdown of photovoltaic and wind installations per province, the installed power allocation across various applications, and the distribution based on resources. The total installed power is recorded as 2.353 MW.

Table 2.20. Distribution per Province of the Photovoltaic/Wind Installations

Provinces	Resource	Installed Power (kW)	Provinces	Resource	Installed Power(kW)
Algiers	Solar/wind	46610	Medea	Solar	5000
Adrar	Solar	234900	M'sila	Solar/wind	45500
Batna	Solar	7500	Naama	Solar/wind	88400
Bechar	Solar	48000	Ouargla	Solar	60600
Biskra	Solar	5000	Oum el Bouaghi	Solar	12500
Blida	Solar	6000	Saida	Solar	40200
Bordj Bou Aferidj	Solar	2000	Setif	Solar	4800
Bouira	Solar	3000	Sidi bel Abbes	Solar	39000
Constantine	Solar	1500	Souk Ahras	Solar	6000
Djelfa	Solar/wind	114700	Tamanrasat	Solar	578500
El Bayad	Solar	78500	Tebessa	Solar	64000
El Oued	Solar/wind	31000	Tiaret	Solar/wind	89500
Ghardaia	Solar	32750	Tindouf	Solar	96150
Illizi	Solar	153850	Tipaza	Solar	2400
Khenchla	Solar	13000	Tizi Ouzou	Solar	6000
Laghouat	Solar/wind	93300	Tlemcen	Solar/wind	54500
Mascara	Solar	1000	Other realizations	Solar	287600

Source: (Stambouli, 2011)

Table 2.21. Distribution of Installed Power per Application and per Resource

Applications	Installed power (W)	Percentage %	PV resource power (W)	Wind resource power (W)
Electrification	1.352.800	57	2.279.960	73.300
Pumping	28.8400	13	97%	3%
Public lighting	48.430	2		
Telecommunication	49.8000	21		

Others	16.5630	7
Total	2.353.260	100

Source: (Stambouli, 2011)

2.3.3.3 Geothermal Energy

In Northern Algeria, there exists a wealth of thermal springs with highly diverse compositions. According to the latest census conducted by the Agence Nationale des Ressources Hydrauliques, over 240 thermal springs have been identified. Approximately one-third (33%) of these springs exhibit temperatures exceeding 45°C (Bouraiou et al., 2020). These springs are spread out from east to west and are predominantly situated at medium altitudes within the country's mountainous regions. In Southern Algeria, despite the depletion of many artesian wells and natural springs around which oases have developed, a significant deep reservoir of thermal water known as the Albiene aquifer persists. Within Algeria's southern territory, the Albian sandstone reservoir registers an average water temperature of 57°C (Stambouli et al., 2012).

In eastern Algeria, there is an abundance of thermal springs that prevail across the region, spanning from Sétif to Constantine and extending as far south as Biskra. Among these springs, the most renowned is Ham mam Meskhoutine in Guelma, recognized for having the highest temperature of any thermal spring globally, reaching 98°C. Moving to western Algeria, specifically in the Oranie region, there are over thirty thermal springs, often characterized by high salt content due to the presence of abundant saline deposits deep underground. The primary geothermal areas in Algeria are depicted in (Table. 2.22)

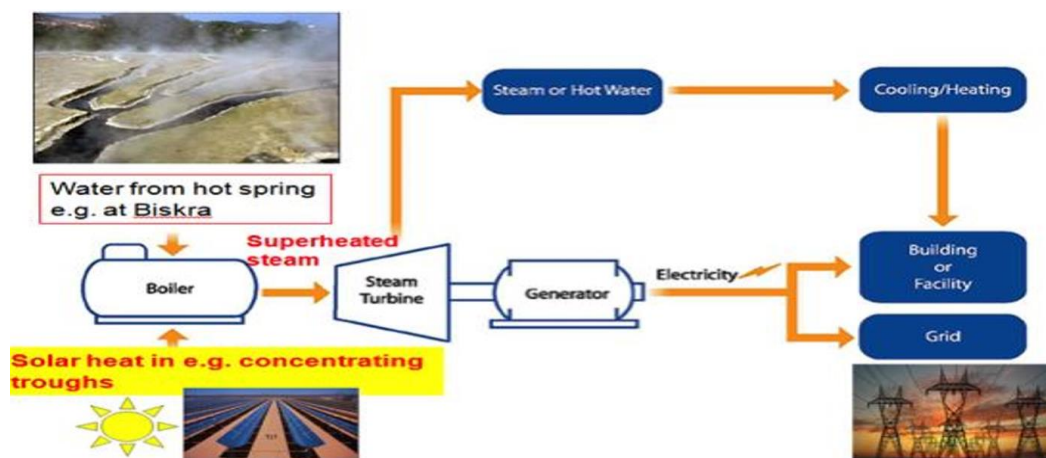
Table 2.22. Location and Temperature of Some Algerian Thermal Springs

Thermal sources	Localization	Temperature
H. Rabi	Saida	49
H. Bouhadjar	Ain Temouchent	66,5
H. Ain Mentila	Relizane	31
H. Righa	Ain Defla	67
H. Melouane	Blida	38,5
H. El Mesrane	Djelfa	42
H. Ksena	Bouira	60
H. Sidi Yahia Al Aidli	Bejaia	58
H. Meskhoutine	Guelma	98

Source: Renewable Energy Development Center (CDER)

According to the Global Energy Network Institute (GENI, 2016), given the abundance of hot springs in the country, there is potential to harness their pressurized heat for productive purposes. This form of energy is readily accessible and eliminates the necessity for additional fossil fuel usage in the process. It is imperative to further develop and implement this method, as illustrated by the following example:

Figure 2.28. Process of Producing Geothermal Energy



Source: Global Energy Network Institute (GENI, 2016)

2.3.3.4 Hydropower

The hydraulic sector encompasses 103 identified dam sites, with over 50 dams currently operational. Despite a significant total water volume estimated at 65 billion m³ across Algerian territory, the country reaps minimal benefits due to factors such as concentrated distribution in specific areas, high evaporation rates, and swift runoff to the sea. Broadly speaking, surface water resources diminish from north to south. Presently, usable and renewable resources stand at approximately 25 billion m³, with surface water resources constituting around two-thirds of this total (Tagrerout et Atmania, 2021).

Hydropower accounted for 251 GWh in 1980, barely 1% of total electricity production. In 2021, this Figure decreased to 9 GWh (MEM, n. d.). The low production of hydroelectricity is explained by the fact that precipitation is low and unevenly distributed across the region.

Table 2.23. Hydropower Plant Installed in Algeria

Plant	Installed capacity (MW)
Darguina	71.5
Ighil Emda	24
Mansouria	100
Erraguene	16
Souk el Djemaa	8085
Tizi Meden	4458
Ghrib	7000
Ighzernchebel	2712
Gouriet	6425
Bouhanifia	5700
Oued Fodda	15600
Beni Behde	3500
Tessala	4228
Total	269208

Source: Renewable Energy Development Center (CDER)

2.3.3.5 Biomass Fuel

Producing fuel via biological processes may entail certain prerequisites. Successful biofuel generation necessitates ample Greenland areas, along with a readiness to incorporate them into the production process. Fortunately, Algeria boasts extensive agricultural lands with pristine soil quality rich in minerals, making it conducive for cultivating energy crops such as soybeans, corn, and wheat. Recognizing the diversity in biofuel feedstock options, Nakheel, an Algerian biotech firm, opted to explore and invest in bioethanol production using dates sourced from the abundant palm trees flourishing in North Africa and the Near East. The renowned Deglet Nour date variety, originating from Algeria, remains the world's largest producer. Primarily cultivated in the Biskra province within the oases of Tolga and M'Chouneche, these dates serve as a raw material for bioethanol. Additionally, biofuel production can capitalize on animal waste, which often contributes to pollution issues but can be mitigated through renewable energy generation. By converting animal or plant waste into a high-calorie energy source, biofuel production contributes to environmental sustainability.

Forest potential in Algeria spans approximately 250 million hectares, accounting for less than 10% of the nation's total land area. This potential is projected at 37 million toe, with an estimated recovery potential of around 10%. Regarding the energy potential of urban and agricultural waste, approximately five million tonnes of such waste remain unrecycled. This untapped energy source equates to around 1.33 million toe per year (**Tagrerout et Atmania, 2021**).

2.3.4 Challenges Hindering Renewable Energy Adoption in Algeria

An overview of the Algerian energy landscape can offer insights into the causes of the deficiencies and delays in implementing the Renewable Energy program. Algeria is presently experiencing a surge in energy demand while grappling with a hydrocarbon sector that has witnessed successive declines since 2007, albeit showing signs of slight recovery in recent times. Total energy consumption increased by 3% in 2022 to 66 Mtoe after 6% growth in 2021 and a 5% drop in 2020. It grew steadily by 5%/year on average from 2010-2019, GDP Constant Prices in Algeria increased to 27688.90 DZD Billion in 2022 from 22079 DZD Billion in 2021. GDP Constant Prices in Algeria averaged 13444.64 DZD Billion from 2000 until 2022, reaching an all-time high of 27688.90 DZD Billion in 2022 and a record low of 4123.50 DZD Billion in 2000. (**World Bank, n. d.**). Consequently, several barriers hinder the progress of renewable energies in Algeria, the most attractive of which are:

A. Energy products with substantial subsidies

The way the government handles issues related to energy development, such as energy production, distribution, and consumption, is reflected in energy policy, which includes components such as Legislation, international treaties, pricing, incentives, taxation, and recommendations for energy conservation. In the medium and long term, pricing is the most effective instrument for managing energy demand. Until 2016, the government's policies tended to focus on augmenting the subsidies for renewable energy sources over reducing subsidies for fossil fuels.

This pattern appears to be financially unsustainable going forward given the declining oil income. Between 2004 and 2014, when oil prices spiked from \$35 to \$130 per barrel, prudent adjustments could have been implemented. Rather, they have resulted in a significant increase in pay (**World Bank, n. d.**). This is a blatant example of the kind of wasted potential that defined that decade. For political reasons, succeeding administrations have refrained from confronting the issues at their root. Rather than solving the problem of sustainable development, they were more likely to simply manage oil profits to ensure social calm.

B. Ineffective planning and policy inconsistency

Similar to certain other nations in the area, Algeria persists in following extremely restrictive energy policies, prioritizing the resolution of one kind of problem over the resolution of others. Instead of concentrating on a single problem, energy price strategy should take trade-offs into account. Every policy package has trade-offs. Unexpected repercussions may arise if a coordinated approach that addresses the issues around electricity, transportation, agriculture, waste and water, and climate change is not implemented. Hasty judgments and reforms have frequently had disastrous outcomes.

The days of high oil prices are long gone, and the rapidly increasing domestic energy consumption will eventually leave little space for exports. Algeria has the capacity to export more than 60 billion m³ of goods by 2040, and it may quadruple by 2030 (Hebri, 2018). However, more pessimistic predictions for gas output indicate that Sonatrach gas exports will drop to about 15 billion m³ year by 2030 in the case of moderate local demand growth, or they will even vanish in the case of larger demand increase (Aissaoui, 2016).

The reduction in oil revenues puts the nation's energy security at jeopardy. Because energy is by its very nature an interconnected problem that affects all facets of social and economic life, other vital areas will also be affected. Probably one of the most important energy-associated industries, agriculture is also the key to solving the nation's problem of food security. Furthermore, water supplies are vital to agriculture. Like a lot of Mediterranean nations, Algeria is dealing with a serious water shortage that could get worse due to climate change and has an immediate impact on the security of food and energy.

Future water resource development will necessitate large energy consumption for the adoption of drip irrigation, wastewater treatment, and saltwater desalination. In order to stop the water deficit from getting worse, the water and energy sectors will need to work together more closely on both planning and execution (Hamiche, Stambouli, et Flazi, 2015).

C. Issues about regional stability

Energy goods that are heavily subsidized encourage smuggling into nearby nations. Contrarily, smuggling provides funding for illicit operations, including occasionally for terrorism and insurrection. Thousands of people have been displaced by regional insecurity, both inside and between neighboring nations. Algerian border security is under stress due to ongoing displacement caused by terrorist activity in Libya and Mali.

D. Mitigating Losses in Energy, Water, and Food Resources

Resource waste is a serious issue that needs to be resolved right away. Ineffective policies waste food and water, and they are strongly related to heavily subsidized energy goods. It would be a gross understatement of the problem to say that the water-energy-food nexus is unsustainable (**Amer et al, 2017**). Algeria faces severe water shortages, but water is nevertheless subsidized. Desalinated water is created using subsidized electricity and is subsequently subsidized. All the natural resources required for food production, processing, packaging, and transportation are also wasted whenever food is thrown away. Therefore, it is evident that subsidies have a number of negative effects and significantly obstruct the path toward sustainable growth.

2.3.5 Crucial Elements to Guarantee the Sustainable Growth of RES in Algeria

The main components of sustainable development include energy security, environmental preservation, economic expansion, and social responsibility. According to research published in October 2005 by Science and Development Network (**SciDevNet, 2005**), North Africa is ideally positioned to take the lead in the lucrative future solar power business. Solar thermal power plants might meet 5% of the world's electricity needs by 2040. Algeria's policy frameworks for sustainable development prioritize extending access, promoting energy efficiency, hastening the spread of new renewable energy sources, and increasing the use of cutting-edge clean fossil fuel technologies—all the while maintaining the option of nuclear power (**Boudghene Stambouli, 2011**).

There are numerous factors to address renewable energy transition questions. According to (**Ahmed belbachir, 2023**), there are three principal purposes:

Starting with, fossil fuels like gas and oil are finite resources. Since these fuels have useful functions, they should be put to better use rather than being burned, such as in the petrochemical sector. As a result, alternative energy sources must be discovered.

Additionally, everyone is concerned about the security of the energy supply. Dependency on fossil fuels can be problematic even in nations where they are readily available.

Lastly, using fossil fuels accelerates global warming. Many human activities are blamed for this change, but the main contributor is the rise in the greenhouse effect produced by CO₂. This gas is released into the atmosphere when fossil fuels burn. An alternate energy source has to be discovered in order to address the climate change challenge. As a result, in addition to the risk involved in hydrocarbon discovery and the requirement to create markets for final energy consumption, an important capital is dedicated to increasing the generating capacity of producing nations.

This leads us to the conclusion that two crucial variables in this equation: finite natural resources and infinite human needs can decide a nation's orientation toward renewable energy sources. There are more factors connected to socio-economic development and economic growth that push countries toward renewable energies as well to the previously listed ones. Considering that a green economy promotes sustainable development, nations with environmental consciousness tend to have greener energy regulations.

In conclusion, to attain sustainable development of renewable energy sources (RES) in Algeria, numerous obstacles and challenges demand urgent attention and consideration:

Public support and awareness: Public and/or professional organizations, as well as the media, should promote this. The public should be given the necessary knowledge regarding energy use and the environmental effects of renewable energy sources.

Research and development: In addition to guaranteeing that future generations of customers have technologies ready to satisfy the rising demands for energy in the twenty-first century, research and development (R&D) is critical to cutting prices.

Structure development: To take Renewable Energy Sources technology to the next level and satisfy the wide range of expanding technical and consumer needs, it will take even more innovation, research, engineering, and infrastructure.

Communication and education: Establishing a network of business, individuals, and establishments, including colleges and universities, to assist educational initiatives encompassing RES technology in all of its forms. The impact of creating high-quality jobs, future technology ownership, and preparing the upcoming generation of RES users for many generations of customers all depend on investments made in education and research.

State involvement: The Renewable Energy Sources approach's competitiveness and future markets depend on investments in technology and policy. At the sub-regional, regional, and continental levels, the government should elucidate energy policies, strategies, development plans, and programs for the Arab world.

Innovation transmission: In order to address the energy crisis, technology could move quickly from the lab bench to the customer. A return to accelerated development and deployment of Renewable Energy Sources technologies is imperative, given the underlying energy concerns of securing our energy sources, promoting environmental improvement, and growing business

(particularly in developing nations) in order to avert a potential tipping point in a catastrophic global warming scenario.

Economic incentives: Implementing a feed-in tariff that guarantees users of renewable energy sources a price per kWh for an extended period of time, with the guaranteed price decreasing annually. Loans with low or no interest rates are available to stimulate the market for renewable energy sources. Through a number of governmental initiatives and policies, the Algerian government has been encouraging the use of renewable energy sources (Boudghene Stambouli, 2011).

2.4 Conclusion

In summary, this chapter has underscored the critical role of energy in driving both economic and social development while highlighting the urgent necessity of transitioning toward sustainable energy sources. By analyzing historical energy crises, the discussion reveals the vulnerabilities of conventional energy systems, emphasizing the risks associated with dependence on fossil fuels. Additionally, a comparative assessment of global renewable energy policies provides key lessons and best practices that can inform Algeria's energy transition strategy.

Furthermore, this chapter analyzed Algeria's energy sector, focusing on production, consumption, and CO₂ emissions. It examined the impact of policy decisions on renewable energy integration, particularly the National Renewable Energy and Energy Efficiency Program. A review of legislation from 1985 to 2022 highlighted key regulatory developments.

Algeria's renewable energy potential was explored, emphasizing solar, wind, geothermal, hydropower, and biomass resources. Despite its advantages, the country faces major challenges, including policy inconsistencies, financial constraints, and regional instability.

Overcoming these barriers requires coordinated efforts through public-private partnerships, technological investments, and policy reforms. The chapter stressed the importance of clear policies, financial incentives, and international cooperation to ensure sustainable renewable energy growth. If Algeria adopts a structured transition strategy, it can emerge as a regional leader in renewable energy.

Chapter Three

Empirical Literature

3.1 Introduction

3.2 Research Method

3.3 Data Origins

3.4 Systematic Search and Study Selection

3.5 Quality Assessment and Data Extraction

3.6 Review and Survey Selected Studies

3.7 Study Impact

3.8 Conclusion

3.1 Introduction

Numerous studies have examined either the relationship between economic conditions and RE, or indicated the relationship between policy decisions and RE. The conclusions of the existing empirical literature vary. Empirical results show either a positive or increasing effect, or a negative or decreasing effect, and this inconsistency in results leads us to investigate this subject further. Examining previous studies carefully is essential to gaining an in-depth understanding. Reviewing the literature helps researchers to develop their knowledge in the field under study, identifying important concepts, experimental approaches, experimental techniques, gaps, and obstacles for further investigations.

This chapter seeks to accomplish all of these goals by providing a thorough analysis of previous and current research that has empirically investigated the relationship between oil prices, economic growth, and policy instruments in the development of renewable energy sources.

3.2 Research Method

In order to obtain circumstantially targeted studies, simple Boolean searches and advanced Boolean searches are performed using the following keywords: economic conditions AND renewable energy generation, (economic growth OR GDP) AND "renewable energy implementation", oil price AND renewable energy production, (policy instruments OR government decisions) AND renewable energy development. Additionally, we confine our focus to the English literature.

3.3 Data Origins

We have crafted a search plan for our systematic review aimed at finding pertinent literature. This plan was customized for different databases: Scopus, CAIRN, Science Direct, Jstore, and Google Scholar. The reasoning behind these choices is to ensure the researcher can comprehensively assess findings from various studies across a diverse array of disciplines, thus offering a broader perspective on researchers' effort

3.4 Systematic Search and Study Selection

The selection criteria adhered to the guidelines outlined in the PRISMA Declaration (**Liberati et al., 2009**). The primary objective of the study was to systematically analyze existing literature concerning oil price (OILP), Gross Domestic Product (GDP) or GDP per capita, policy instruments (Governance indicators, Renewable portfolio standards; Feed in Tarif; Tax incentives *etc.*), and

Renewable Energy Generation (REG) across various disciplines. However, the review was specifically confined to the fields of economics, business, finance, and social sciences. The survey encompassed the period from 2000 to 2024, with a deliberate exclusion of articles published before 2000, except for a handful of seminal works by early pioneers in the conceptualization of the study variables. Additionally, the survey encompassed studies from all countries, with a particular emphasis on Algeria.

3.5 Quality Assessment and Data Extraction

The study exclusively relies on original research articles, books, and review papers. To uphold the survey's quality, meticulous checks were conducted to eliminate duplicates, and article abstracts were thoroughly scrutinized for analysis and refinement, ensuring the academic literature's quality and relevance in the review process. Subsequently, a comprehensive assessment of each research paper was undertaken. In essence, the articles and books selected adhere to the following criteria: firstly, they must be original articles, books, or review articles; secondly, they must be written in English and fall within the fields of economics, business, finance, and social sciences; and finally, the selected articles must have been published between 2000 and 2024.

3.6 Review and Survey Selected Studies

Numerous recent studies have investigated the link between economic conditions (oil prices, economic growth) and renewable energy deployment. The favorable correlation between oil prices and the generation of renewable energy has been highlighted in many studies, for instance, **Dogan et al., 2021** has examined the factors influencing the deployment of renewable energy by utilizing various indicators for RE. For empirical analysis, two econometric methods have been employed: pooled ordinary least squares with robust standard errors and the augmented mean group estimator, both of which consider the cross-sectional dependence present in the dataset. The findings indicate that a 1% increase in energy prices results in a RE increase ranging from 0.07% to 0.99% across different indicators. This suggests that the effects of income and oil prices are relatively minor when RE is measured by consumption compared to when it is measured by production. Additionally, the impacts of these factors vary significantly depending on the choice of RE share and RE levels. Employing an expanded logistic growth model.

In addition, **(Lee et Huh, 2017)** investigate whether international oil prices act as a driver for renewable energy adoption, projecting how policy tools and oil prices might impact renewable energy integration into the electricity sector under various scenarios. The results suggest that higher international oil prices correlate with greater adoption rates. Similarly, the findings of **(Zhao, Zhang**

et Wei, 2021) use a dynamic recursive computable general equilibrium model to analyze the effects of international oil price fluctuations on renewable energy investments and outcomes, as well as on China's macroeconomic stability and environmental health. Their outputs show that an increase in international oil prices can boost renewable energy production and investment, while reducing China's real GDP and exports, and contribute to the atmospheric environment. In contrast, a decline in international oil prices produces the opposite effects. Furthermore, renewable energy policies can alleviate the adverse effects of lower oil prices on renewable energy advancement and environmental quality while bolstering its contribution to GDP.

By concentrating on oil prices, **Omri et al., (2015)** explored the factors influencing renewable energy consumption with a panel of 64 countries. They discovered a modest correlation between the use of renewable energy and real oil prices, a 1% increase in real oil price leads to an rise of about 0.01% in the renewable energy consumption. this suggests that renewable energy serves as a complement rather than a perfect substitute for crude oil, particularly in the short term.

Also, **Öz Durak, (2021)** investigate the relationship between crude oil prices, investment in clean energy, technology firms, and energy democratization. They employ DCC-GARCH models to analyze how market fear, oil prices, and technology company stock returns influence investments in clean energy, spanning from 2009 to 2021 -. Their findings suggest that when oil prices decrease, the volatility index typically reacts by increasing, indicating apprehension in the market about potential oil price spikes. Moreover, investment in renewable energies tends to decline during such periods, aligning with the downward trend in oil prices.

Together with the study of **(Sahu et al., 2022)**, which investigating the impact of fluctuating oil prices on renewable energy utilization in the USA from 1970 to 2019. Two non-linear autoregressive distributed lag (NARDL) models have been developed to assess the effects of both positive and negative oil price shocks on renewable energy usage in the USA. Renewable energy consumption is treated as the dependent variable, while GDP, Brent prices, population density, trade openness, and the price index are regarded as independent variables. The findings indicate that higher crude oil prices, along with increases in GDP and population density, lead to augmented renewable energy consumption in both the short and long term. Moreover, the research demonstrates that any decrease in oil prices results in a short-term reduction in renewable energy usage, with its impact diminishing over the long term.

By the same token, Apergis and Payne conducted several studies on the factors that influence the consumption of renewable energy in various geographical locations. First, They investigate the

factors influencing renewable energy consumption per capita across a panel of seven Central American nations spanning from 1980 to 2010 (**Apergis et Payne, 2014a**). Their analysis reveals a long-term cointegrating relationship between renewable energy consumption per capita, real GDP per capita, carbon emissions per capita, real coal prices, and real oil prices, where the coefficients are positive and statistically significant. Then they looked at 25 OECD countries from 1980 to 2011 (**Apergis et Payne, 2014b**) an initial examination indicates the existence of cross-sectional dependence within the panel dataset. Cointegration and error correction models unveil a sustained connection between renewable energy consumption per capita, real GDP per capita, carbon dioxide emissions per capita, and real oil prices. The long-term elasticity estimates demonstrate positive and statistically significant associations for real GDP per capita, carbon dioxide emissions per capita, and real oil prices. The panel error correction model indicates a reciprocal relationship among the variables. Finally, they examined 11 South American nations from 1980 to 2010 (**Apergis et Payne, 2015**). The three latest studies highlight that the elasticity estimates for real oil prices, real GDP per capita, and carbon emissions per capita, are all positive and statistically significant over the long term, all three studies proved that high oil prices led to a rise in the use of renewable energy sources.

Thus, the Granger causality analysis in quantiles conducted by **Troster et al., (2018)**, validate a unidirectional causality between oil price fluctuations and economic growth in the extreme quantiles of the distribution. Additionally, they uncover indications of lower-tail dependence between oil price fluctuations and variations in renewable energy consumption while examining the causal connection among renewable energy consumption, oil prices, and economic activity in the United States spanning from July 1989 to July 2016.

Furthermore, **Brini, Amara et Jemmali, (2017)** explore the interconnections among renewable energy consumption, international trade, oil prices, and economic growth. The objective is to analyze these dynamic relationships using the cointegration bounds test approach and the ARDL methodology applied to Tunisia from 1980 to 2011. The primary empirical outcomes suggest that a rise in oil prices might correspond to an increase in renewable energy consumption. In addition, a unidirectional link between renewable energies and oil prices in the short term has been demonstrated. Moreover **Eder et al., (2018)** reveal that a 1% change in hydrocarbon prices results in a 1.05% change in renewable energy consumption.

Tambari, Failler et Jaffry, (2023) underline the varying impacts of international oil prices and additional macroeconomic factors on the advancement of renewable energy within both oil-importing and oil-exporting nations in Africa. Employing a panel vector error correction model (P-VECM), the study investigates data from five net oil exporters (Algeria, Angola, Egypt, Libya, and Nigeria) as

well as five net oil importers (Kenya, Ethiopia, Congo, Mozambique, and South Africa). Outcomes indicate that elevated oil prices have a positive influence on renewable energy development in oil-importing countries, primarily by enhancing the economic competitiveness of renewable energy sources. Likewise, **(Ayodele et Alege, 2021)** aim to investigate the influence of fluctuations in oil prices on renewable energy consumption in Nigeria from 1986 to 2017. To fulfill this goal, a Vector Error Correction Model (VECM) was utilized. It was established that the variables demonstrated a prolonged association. Moreover, a one-way causal relationship was identified, originating from renewable energy consumption towards oil price volatility. Furthermore, the impulse response function test indicates a positive impact of oil price volatility on renewable energy consumption in Nigeria. Coupled with, **(Wang, Li et Pisarenko, 2020)** explore that oil price has a positive role in promoting renewable energy. This is confirmed by **(Husaini et Lean, 2022)** and **(Escoffier et al., 2021)**.

Also, **(Murshed et Tanha, 2021)** demonstrate that fluctuations in oil prices affect changes in renewable energy consumption, total final energy consumption, and overall production levels in the case of four net oil-importing South Asian economies, over the period 1990–2018 by using Westerlund (2007) panel cointegration.

As well as, the study of **(Rasheed et al., 2022)** applies FMOLS, cointegration, and the Driscoll-Kraay Regression tests to highlight the relationship between energy consumption (non-renewable and renewable energy), oil prices, and CO₂ emissions in 30 European countries over the period 1997 to 2017. The findings confirm that a rise in oil prices increases RE usage. By the same token, **(Royal, Singh et Chander, 2022)**, aim to investigate the enduring linkage between renewable energy consumption and trade openness, oil rent, oil prices, and carbon dioxide emissions of the G7 nations from 1971 to 2019, utilizing FMOLS and DOLS approach to panel data. The results indicate that oil prices are a key factor influencing REC in the long run.

In contrast to these findings, other research contends that the consumption of renewable energy is unaffected or negatively impacted by increasing oil prices.

Payne (2012) studied the causal dynamics between renewable energy consumption, real GDP, carbon emissions, and real oil prices, and he found that real oil prices had no causal impact on renewable energy penetration, employing the Toda-Yamamoto long-causality test method from 1949 to 2009. Comparatively, For the G7 countries and using Panel cointegration, **Sadorsky (2009a)** provides an empirical model of renewable energy consumption. The results obtained show that

increases in oil prices have a smaller, although negative, impact on the consumption of renewable energy.

In addition, **Mukhtarov et al., (2020)**, examine the influence of economic growth, carbon dioxide (CO₂) emissions, and oil prices on renewable energy consumption in Azerbaijan over 1992-2015. Findings from the estimation indicate a long-term positive and statistically significant relationship between economic growth and renewable energy consumption. At the same time, oil prices have a negative impact on renewable energy consumption. Similarly, **(Mukhtarov, Humbatova et Hajiyev, 2021)** find the same results in the case of Kazakhstan over the period 1992 to 2015, using FMOLS and CCR methods.

Based on data from G-7 countries spanning from 1980 to 2018, **(Guo et al., 2021)** found that in England and Japan, an increase in oil prices has a detrimental effect on renewable energy consumption. Then, **(Deka, Özdeşer et Seraj, 2023)** indicate the factors that contribute to renewable energy consumption. It has been observed that oil prices, inflation rates, and public sector credit negatively impact the development of RE.

Moreover, **(Karacan et al., 2021)** explore the influence of oil prices, income levels, and carbon dioxide emissions on renewable energy consumption in Russia from 1990 to 2015. They employ Vector Error Correction Models and the Canonical Cointegrating Regression method for analysis. The empirical findings suggest that oil prices have a negative impact on renewable energy consumption. This adverse effect of oil prices on the utilization of renewable energy could indicate a challenge arising from elevated oil prices, hindering the shift from conventional to renewable energy sources.

As identified by other studies, there is a positive correlation between economic growth and the development of renewable energy. For instance, **Bamati and Raoofi, (2020)** using the GLS (Generalized Least Square) panel data estimation method, they proved that GDP per capita has a positive impact on renewable energy production per capita for developed and developing countries.

As well as, the outcomes from the panel group Fully Modified OLS (FMOLS) of **(Zeb et al., 2014)** suggest that both GDP and poverty exert a favorable influence on renewable energy production in selected SAARC countries, specifically, Bangladesh, India, Nepal, Pakistan and Sri Lanka, over a period of 1975–2010. Notably, **Chang et al., (2009)** showed that high-economic growth nations can respond to high energy prices by using more renewable energy, whereas low-growth nations are often indifferent to changes in energy prices when it comes to their use of renewable energy.

The study of **(Apergis et Payne, 2010a)** investigates the correlation between economic growth and renewable energy consumption across a panel of twenty OECD countries from 1985 to 2005. The heterogeneous panel cointegration test unveils a sustained equilibrium relationship in the long term among real GDP, renewable energy consumption, real gross fixed capital formation, and labor, with all coefficients showing positive and statistically significant associations. Granger causality analysis reveals a two-way causal relationship between renewable energy consumption and economic growth, persisting both in the short and long term. Similar results were observed regarding the 13 countries within Eurasia over the period 1992–2007, as reported by **(Apergis et Payne, 2010b)**.

Furthermore, **(Apergis et Payne, 2011a)** examine the correlation between economic growth and both renewable and non-renewable electricity consumption across 16 emerging market economies using a multivariate panel framework spanning from 1990 to 2007. The findings suggest the existence of a long-term equilibrium relationship among real GDP, renewable electricity consumption, non-renewable electricity consumption, real gross fixed capital formation, and labor. Additionally, the results from the panel error correction model indicate unidirectional causality between economic growth and renewable electricity consumption in the short term, with bidirectional causality observed in the long term. Moreover, there is bidirectional causality between non-renewable electricity consumption and economic growth, both in the short and long term. Comparative outcomes were found in the case of six Central American countries over the period 1980–2006 **(Apergis et Payne, 2011b)**, also for the case of 80 countries over the period 1990–2007 **(Apergis et Payne, 2012)**.

Pao and Fu, (2013) concluded that economic growth is essential to provide the resources for sustainable development. According to **Ntanos et al., (2018)** there is a stronger correlation between renewable energy consumption and economic growth in countries with higher GDP than in countries with lower GDP. According to **(Inglesi-Lotz, 2016)**, use of renewable energy or its contribution in the overall energy mix has a positive and statistically significant impact on economic growth. **Ohler and Fetters, (2014)** demonstrated that there is a bidirectional relationship between total renewable energy production and real GDP.

The study of **(Tudor et Sova, 2021)** seeks to investigate the diverse impacts of economic and environmental factors associated with renewable energy consumption (REC) stemming from existing policy objectives (such as GDP per capita, carbon intensity, and research and development). This is accomplished through empirical analysis using a comprehensive panel dataset comprising 94 countries and five income-based subgroups, spanning from 1995 to 2019. The findings demonstrate that GDP per capita contributes to the promotion of REC, particularly when it surpasses the threshold of USD 5,000.

Correspondingly, **Sadorsky, (2009b)** identified a mutually influential relationship between renewable energy utilization and economic growth across 18 emerging economies. In the long run, estimated that a 1% increase in real income per capita corresponded to an approximate 3.5% rise in renewable energy use per capita in these economies.

According to **(Bowden et Payne, 2010)**, in the US context, an analysis of the sectoral causal linkages between renewable and non-renewable energy usage and economic development was conducted. Their findings revealed no causal relationship between renewable energy consumption and real GDP in the commercial and industrial sectors. Conversely, a positive one-way causality was observed between residential renewable energy consumption and real GDP.

Then, **Apergis et Danuletiu, (2014)** examined the relationship between renewable energy and economic growth based on indicators from 80 countries. The result showed that there is a bidirectional relationship between the use of renewable energy and economic growth. In 2014, **(Leitão, 2014)** explored the correlation between globalization, renewable energy consumption, economic growth, and greenhouse gas emissions. The findings indicated a robust association between economic growth and renewable energy consumption. Similarly, **Soava et al., (2018)** demonstrated comparable outcomes in their analysis across 28 EU countries. Additionally, **Ntanos et al., (2018)** assessed the impact of effective communication in their study focusing on European countries.

A simultaneous equation model to examine the relationship between GDP and renewable energy consumption has been employed by **Darvishi and Varedi (2018)**. They utilize a dynamic panel dataset comprising 30 developed countries from 1990 to 2015. The findings indicate that both GDP and the real oil price significantly influence the sustainable utilization of energy in the countries under study. Likewise, over the same latest period **Zafar et al., (2020)** confirmed that economic growth has a positive impact on renewable energy consumption, in the case of the Organization for Economic Co-operation and Development countries (OECD). Also, the findings of **(Al-mulali et al., 2013)** showed that in 79% of the countries, there exists a positive two-way long-term relationship between renewable energy consumption and GDP growth.

Moreover, **Shahbaz et al., (2022)** validate the positive impact of economic growth on renewable energy consumption while introducing a nuanced aspect to this association. Their findings reveal a U-shaped pattern: during the initial stages of economic growth, there's a heightened demand for immediate energy solutions, often favoring non-renewable sources. However, as economies progress, environmental considerations gain prominence, leading to a phase where economic growth and renewable energy consumption advance together.

On the contrary, many studies treat the opposite case, as an illustration of the (Matei, 2017) research, in which higher GDP negatively and significantly impacts renewable energy consumption in the OECD sub-samples, utilizing panel data analysis across 34 OECD countries from 1990 to 2014. Comparatively, Tambari & Failler, (2020) indicated that investments in renewable energy instantly responded favorably to oil crises. However, investments in renewable energy continued negatively correlated with Africa's GDP by using unconstrained vector autoregressive model and an annual panel data approach spanning from 1990 to 2018.

As a matter of fact, Zhang et al., (2023), proved that GDP has a negative and considerable impact on the growth of renewable energy consumption both in the short and long term. Furthermore, Mai, (2023) investigated the influences of foreign direct investment (FDI), gross domestic product (GDP), and carbon dioxide (CO₂) emissions on renewable energy consumption in Southeast Asian nations. The findings propose that FDI inflows contribute positively to the region's renewable energy sector, whereas GDP and CO₂ emissions have adverse effects.

However, a significant number of researchers have examined how policy choices affect the development of renewable energy, and the majority of them contend that policies have a significant impact on the markets for renewable energy. As an illustration, Biresselioglu and Zengin Karabrahimoglu, (2012) demonstrated that there is a strong and favorable association between the use of renewable energy and the policy priorities of the nation. The study conducted by Uzar, (2020) thus leads to the conclusion that institutional quality has a long-term favorable impact on the use of renewable energy.

A combination of complementary policies and instruments is required because recent research shows that one policy is insufficient. For instance, del Río and Mir-Artigues (2014), Fagiani et al., (2014), and Yoon & Sim (2015) have all observed that the employment of a variety of policies is crucial to promoting the development of renewable energy sources.

Additionally, it has been asserted that government policies based on investment can be more successful than those based on production, but the two could complement one another to create a sustainable renewable energy microgrid market (Wang et al., 2020). Therefore, Yang et al., (2019) set 3 main suggestions: firstly, government subsidies have a positive threshold effect on renewable energy investment in China. When energy consumption intensity and bank credit are high, and the level of economic development is below the threshold, the impact of government subsidies on renewable energy investment is significantly increased. Secondly, both monetary subsidies and tax incentive policies can boost renewable energy investment, with tax incentives having a more

pronounced effect. Lastly, government subsidies are crucial in supporting the development of medium, small, and micro-sized renewable energy enterprises.

The comparative analysis of the European Union, Russia, and the United States, conducted by **(Karaeva, Magaril et Al-Kayiem, 2023)** reveals that creating and enforcing effective renewable energy policies are essential for driving the shift to clean energy and meeting global environmental objectives. At the same token, in the case of Asian countries **(Shokri et Heo, 2012)** find out that Feed-in tariff laws play the most crucial role in the success of the renewable energy sector in advanced countries, additionally, the renewable portfolio standard's impact is more noticeable in mature renewable energy markets.

Roslan, (2018) investigates the efficacy of policy tools in influencing the spread of solar photovoltaic (PV) capacity across six Asia Pacific countries from 2000 to 2015. The outcomes suggest that tax incentives enhance the shift to solar PV capacity and policy incentives can promote the widespread adoption of solar PV. For wind energy, **(Azhgaliyeva et al., 2018)** indicate that wind energy production is positively impacted by the two policy instruments: tax incentives and the strategic planning. **(Nasiri et al., 2022)** outline that policy gaps are presented in biomass and biofuels regulations in the case of European countries.

In addition, **Shen et al., (2016)** shed light on the evolution of building energy efficiency policies by examining practices across seven counties and regions. They argue that different countries have made significant progress in enhancing building energy efficiency through the adoption of various types of policy instruments, such as mandatory administration instruments, economic incentive instruments, and voluntary scheme instruments. Then, **Shen, (2017)** explores the dynamics within China's renewable energy policy community, highlighting the influential role of major companies, including wind turbine and solar panel manufacturers, as well as state-owned power entities. They underscore how industrial interest groups holding resources can constrain government autonomy in renewable energy policymaking.

The findings of **(Lee et Huh, 2017)** indicate that renewable portfolio standards have a greater impact on the proliferation of renewable energy in South Korea's electricity sector compared to feed-in tariffs. Additionally, **Li et al., (2022)** investigate the wind energy industry, focusing on technology incentive and demand attraction policies to foster innovation. Moreover, **Hua, Oliphant et Hu, (2016)** conduct a comparative analysis of renewable energy policies in Australia and China, finding commonalities such as the establishment of renewable energy targets and legislative support to propel development.

Furthermore, **Corcuera, (2017)** investigates the efficacy of feed-in tariffs in fostering renewable energy capacity, utilizing a dataset from 183 countries globally. The findings indicate that, overall, feed-in tariffs enhance the development of installed renewable energy capacity, both in terms of cumulative and incremental capacity. However, the extent of this impact varies across different types of renewable energy sources such as solar, wind, and geothermal.

As mentioned by **(Blazquez, Nezamuddin et Zamrik, 2018)**, various policy instruments can achieve the same level of renewable technology deployment, but they differ in terms of cost and speed, as investment subsidies are the most cost-effective policy for promoting renewables under favorable market conditions, also, Feed-in tariff yields the fastest promotion of renewables but is expensive.

According to the results of **(Smirnova et al., 2021)**, the main factors affecting the market for renewable energy include expanding access to finance for renewable energy sources, reducing the utilization rate of traditional energy sources, and providing public-private support for renewable energy projects. In a similar study conducted by **(Gallagher, 2013)**, the author explored four factors that may influence a government's decision to adopt pro-renewable energy policies: economic incentives; high endowment of renewable resources and/or low endowment of non-renewable sources; the political system; and cultural factors and attitudes. The following table offers a brief overview of each study examined in this chapter.

Table 3.1. Previous Studies

Authors and Year	Country/Area	Period	Research Methods	Key Findings
<u>Studies found a positive relationship between oil prices and renewable energy development</u>				
Dogan et al., (2021)	24 developed and 48 developing countries	1980 to 2016	Pooled ordinary least squares (POLS) Augmented mean group estimator	A 1% increase in energy prices results in a RE increase ranging from 0.07% to 0.99% across different indicators
Lee et Huh, (2017)	South Korea	1990-2015	Frank's Extended Logistic Growth Model	Elevated international oil prices correspond to increased rates of RE adoption
Zhao, Zhang et Wei, (2021)	China	42 sectors in 2015	Computable General Equilibrium (CGE) Model	A rise in international oil prices can stimulate both production and investment in renewable energy
Omri et al., (2015)	64 Worldwide countries	1990–2011	Panel Data Model	A 1% increase in real oil price leads to a rise of about 0.01% in the renewable energy consumption
Özdurak, (2021)	United States and China	2009 – 2021	DCC-GARCH models	When oil prices decrease, the volatility index tends to increase, indicating market fear of oil price surges, leading to a decrease in renewable investments.

Sahu et al., (2022)	United States	1970 to 2019	Nonlinear Autoregressive Distributed Lag (NARDL)	Higher crude oil prices, along with increases in GDP and population density, lead to augmented renewable energy consumption in both the short and long term
Apergis et Payne, (2014a)	Seven Central American countries	1980 to 2010	Panel Data Model	A long-term cointegrated relationship exists among per capita renewable energy consumption, real GDP, carbon emissions, coal prices, and oil prices, with all coefficients being positive and statistically significant.
Apergis et Payne, (2014b)	25 OECD countries	1980–2011	Panel Data Model	A positive long-run relationship exists between renewable energy consumption per capita, real GDP per capita, carbon dioxide emissions per capita and real oil prices.
Apergis et Payne, (2015)	11 South American	1980 to 2010	Panel Data Model	The long-run elasticity estimates for per capita real GDP, per capita carbon emissions, and real oil prices are positive and statistically significant.

Troster et al., (2018)	United States	1989 to 2016	Granger Causality Test	A positive dependence between oil price fluctuations and variations in renewable energy consumption
Brini, Amara et Jemmali, (2017)	Tunisia	1980 to 2011	Cointegration Bounds Test Approach Autoregressive Distributed Lag Model (ARDL)	A rise in oil prices might correspond to an increase in renewable energy consumption
Eder et al., (2018)	37 developed and developing countries	2006-2016	Panel Data Model	A 1% change in hydrocarbon prices results in a 1.05% change in renewable energy consumption
Tambari, Failler et Jaffry, (2023)	Africa	1990-2021	Panel Vector Error Correction Model (P-VECM)	Elevated oil prices have a positive influence on renewable energy development in oil-importing countries
Ayodele et Alege, (2021)	Nigeria	1986 to 2017.	Vector Error Correction Model (VECM)	A positive impact of oil price volatility on renewable energy consumption
Wang, Li et Pisarenko, (2020)	G-20 countries	1990-2017	Cointegration Bounds Test Approach	Oil price has a positive role in promoting renewable energy.
Cheng et al., (2021)	97 countries	1995-2015	Panel Data Model	Rising real oil prices result in higher renewable energy consumption (REC) in less

				democratic countries, whereas they have no significant impact in more democratic countries.
Murshed et Tanha, (2021)	4 Asia net oil-importing economies	1990–2018	Westerlund (2007) panel cointegration	Fluctuations in oil prices affect positively changes in renewable energy consumption, total final energy consumption, and overall production levels.
Rasheed et al., (2022)	30 European countries	1997–2017	FMOLS, Westerlund (2007) cointegration and the Driscoll–Kraay regression tests	A rise in oil prices increases the RE usage
Royal, Singh et Chander, (2022)	G7 nations	1971–2019.	FMOLS and Dynamic Ordinary Least Squares (DOLS)	In the long run, oil prices are a key factor influencing REC
Escoffier et al., (2021)	OECD and BRICS	1997–2016	Panel Smooth Transition Regression (PSTR)	Higher oil prices boost investment in renewable energy.
Husaini et Lean, (2022)	8 Asian countries	1980–2017	Panel Threshold Regression	A rise in oil prices increases public electricity production.

<u>Findings unaffected or negatively impacted by increasing oil prices</u>				
Payne (2012)	United States	1949 to 2009	Toda-Yamamoto long-causality test	Real oil prices had no causal impact on renewable energy penetration
Mukhtarov et al., (2020)	Azerbaijan	1992-2015	Structural Time Series Modeling (STSM)	long-term and statistically significant negative effect of oil prices on renewable energy consumption
Mukhtarov, Humbatova et Hajiyev, (2021)	Kazakhstan	1992–2015	Fully Modified Ordinary Least Squares Method (FMOLS) and Canonical Cointegrating Regression (CCR) techniques	Oil prices have negative effects on REC.
Guo et al., (2021)	G-7 Countries	1980-2018	Nonlinear Autoregressive Distributed Lag (NARDL)	In the case of England and Japan, the positive change in oil prices has a negative impact on REC
Sadorsky (2009a)	G-7 Countries	-	FMOLS and DOLS	An increase in oil prices have a smaller, although negative, impact on the consumption of renewable energy.

(Deka, Özdeşer et Seraj, 2023)	Emerging seven economies	-	Pedroni and Westerlund Panel cointegration	Oil prices, inflation rate and public sector credit show a negative effect on RE development
Karacan et al., (2021)	Russia	1990 to 2015	VECM and CCR	Oil prices have a negative impact on renewable energy consumption
<u>Studies found a positive relationship between economic growth and renewable energy development</u>				
Zeb et al., (2014)	South Asian Association for Regional Cooperation (SAARC) countries	1975–2010	FMOLS	GDP and poverty exert a favorable influence on renewable energy production
Chang et al., (2009)	Organization for Economic Cooperation and Development (OECD) countries	1997 to 2006	Panel Threshold Regression	High-economic growth nations can respond to high energy prices by using more renewable energy, whereas low-growth nations are often indifferent to changes in energy prices when it comes to their use of renewable energy.

Bamati and Raoofi, (2020)	25 countries	1990 to 2015	GLS (Generalized Least Square) Panel Data	GDP per capita has a positive impact on renewable energy production per capita for developed and developing countries
Apergis et Payne, (2010a)	OECD countries	1985-2005	Panel Data Model	<p>Sustained equilibrium relationship in the long term among real GDP, renewable energy consumption, real gross fixed capital formation, and labor, with all coefficients showing positive and statistically significant associations.</p> <p>Granger causality analysis reveals a bidirectional causal relationship between renewable energy consumption and economic growth, both in the short and long term</p>
Apergis et Payne, (2010b)	13 countries of Eurasia	1992-2007	Panel Cointegration Error Correction Model (ECM)	Granger causality analysis indicates a bidirectional causal relationship between renewable energy consumption and economic growth in both the short and long term.
Apergis et Payne, (2011a)	16 Emerging Market Economies	1990 to 2007	Panel Data Model	There is a unidirectional causality between economic growth and renewable electricity consumption in the short term, with

				<p>bidirectional causality observed in the long term.</p> <p>A bidirectional causality between non-renewable electricity consumption and economic growth, both in the short and long term.</p>
Apergis et Payne, (2011b)	Six Central American countries	1980-2006	Panel Data Model	<p>In the short term, economic growth unidirectionally causes renewable electricity consumption</p> <p>In the long term, there is a bidirectional causality between the two.</p>
Apergis et Payne, (2012)	80 countries	1990–2007	Panel Error Correction Model (ECM)	In both the short and long term, there is a bidirectional causality between renewable and non-renewable energy consumption and economic growth
Pao and Fu, (2013)	Brazil	1980 to 2010	VECM Model	Economic growth is essential to provide the resources for sustainable development
Ntanos et al., (2018)	25 European countries	2007 to 2016.	Autoregressive Distributed Lag (ARDL)	There is a stronger correlation between renewable energy consumption and

				economic growth in countries with higher GDP than in countries with lower GDP
Ohler and Fetters, (2014)	20 OECD countries	1990-2008	ECM	There is a bidirectional relationship between total renewable energy production and real GDP.
Tudor et Sova, (2021)	94 countries	1995 to 2019	Panel Data Model	GDP per capita contributes to the promotion of REC, particularly when it surpasses the threshold of USD 5,000
Sadorsky, (2009b)	18 Emerging economies	1993-2003	Panel Cointegration	In the long run, estimated that a 1% increase in real income per capita corresponded to an approximate 3.5% rise in renewable energy use per capita.
Bowden et Payne, (2010)	United States	1949 to 2006	Toda-Yamamoto long-run causality tests	Absence of relationship between renewable energy consumption and real GDP in the commercial and industrial sectors. There is a positive one-way causality was observed between residential renewable energy consumption and real GDP

Apergis et Danuletiu, (2014)	80 countries	1990-2012	Canning and Pedroni (2008) long-run causality test	There is a bidirectional relationship between the use of renewable energy and economic growth
Leitão, (2014)	Portugal	1970-2010	Ordinary Least Squares (OLS), Generalized Method of Moments (GMM), VEC model, and Granger causality	The Granger causality reports a unidirectional causality between renewable energy and economic growth. Both the OLS estimator and the GMM model show that carbon dioxide emissions and renewable energy are positively correlated with economic growth.
Soava et al., (2018)	28 countries of European Union	1995 to 2015	Panel Data Model	A positive impact of renewable energy consumption on economic growth
Darvishi and Varedi (2018)	30 developed countries	1990 to 2015	Dynamic Panel Data	Both GDP and the real oil price significantly influence the sustainable utilization of energy in the countries under study
Zafar et al., (2020)	OECD countries	1990-2015	Panel Cointegration Tests	Economic growth has a positive impact on renewable energy consumption
Al-mulali et al., (2013)	High income, upper middle income, lower	-	FMOLS	In 79% of the countries, there exists a positive bidirectional long-term relationship

	middle income, and high income countries			between renewable energy consumption and GDP growth 19% of the countries present absence of long run relationship between the variables. 2% of the countries present a unidirectional long run relationship from GDP growth to renewable energy consumption,
Shahbaz et al., (2022)	39 countries	2000-2019	Westerlund and Edgerton (2008) Panel Cointegration Test	Economic growth and fossil fuel consumption show a positive impact on renewable energy consumption
<u>Studies found a negative relationship between economic growth and renewable energy development</u>				
Matei, (2017)	34 OECD countries	1990 to 2014	Dynamic Panel Data	Higher GDP negatively and significantly impacts renewable energy consumption in the OECD sub-samples
Tambari & Failler, (2020)	African countries	1990-2018	Vector Auto Regression (VAR) model Panel Data Approach	Investments in renewable energy continued negatively correlated with Africa's GDP

Zhang et al., (2023)	Asian emerging economies	1975-2020	Panel Augmented Mean Group (AMG)	GDP has a negative and considerable impact on the growth of renewable energy consumption both in the short and long term.
Mai, (2023)	Southeast Asia countries	1990 to 2015	Ordinary least squares (OLS) regression model Panel Data Analysis	GDP and CO2 emissions contribute negatively to the region's renewable energy sector, whereas FDI inflows contribute positively.
<u>Policy Tools and Renewable Energy Development</u>				
Biresselioglu and Zengin Karaibrahimoglu, (2012)	Europe	1999 and 2009	Panel Data Analysis	There is a strong and favorable association between the use of renewable energy and the policy priorities of the nation
Uzar, (2020)	38 developed and developing countries	1990–2015	Panel Data Analysis	Institutional quality has a long-term favorable impact on the use of renewable energy.
del Río and Mir-Artigues (2014)	Europe	-	Analytical Approach by using RES-E support instruments	The most common combinations of instruments are between feed-in laws (including feed-in tariffs and the growing use of feed-in premiums) and financial supports such as investment subsidies, soft loans, and tax incentives.

Fagiani et al., (2014)	European Union	-	Dynamic Investment Model	Both, carbon reduction and renewable energy policies are necessary to achieve a sustainable power sector
Karaeva, Magaril et Al-Kayiem, (2023)	European Union, Russia and the United States	-	Comparative Analysis Approach	Creating and enforcing effective renewable energy policies are essential for driving the shift to clean energy and meeting global environmental objectives.
Yoon & Sim (2015)	South Korea	-	Qualitative Evaluation Methods, by interviewing 13 experts	The employment of a variety of policies is crucial to promoting the development of renewable energy sources.
(Wang et al., 2020)	24 RE microgrids worldwide	-	Analytical Approach	Government policies based on investment can be more successful than those based on production, but the two could complement one another to create a sustainable renewable energy microgrid market
Yang et al., (2019)	92 RE enterprises in China	2006 and 2007	Panel Threshold Regression Model	Government subsidies have a positive threshold effect on renewable energy investment in China. Both monetary subsidies and tax incentive policies can boost renewable energy

				<p>investment, with tax incentives having a more pronounced effect.</p> <p>Government subsidies are crucial in supporting the development of medium, small, and micro-sized renewable energy enterprises.</p>
Shen et al., (2016)	Seven countries including the United States, the European Union, Australia, China, Japan, Singapore, and India	-	Analytical Approach	Several countries have made significant progress in encouraging building energy-efficiency through the deployment of various types of policy instruments.
(Shokri et Heo, 2012)	Asian Countries	-	Comparative Analysis Approach	<p>Feed-in tariff laws play the most crucial role in the success of the renewable energy sector in advanced countries.</p> <p>The renewable portfolio standard's impact is more noticeable in mature renewable energy markets.</p>
Shen, (2017)	China	2005-2016	Qualitative Analysis through intensive field investigations,	That influential corporations, including leading wind turbine and solar panel manufacturers, have significantly influenced China's renewable energy policy process by

			stakeholder interviews, and document analysis.	framing strategic preferences, negotiating with state actors, and coordinating at both central and local levels
Li et al., (2022)	29 Chinese province	2007-2018	Panel Data Model	Local government technology incentive policy has a clear inductive effect on wind energy innovation in the region.
Hua, Oliphant et Hu, (2016)	China and Australia	-	Comparative Analysis Approach	<p>Australia's legislation and regulations are enforced more effectively compared to China's.</p> <p>China demonstrates a greater dedication to renewable energy than Australia.</p> <p>Both nations have very low levels of non-hydro renewable energy in their primary energy mix.</p>
Corcuera, (2017)	183 countries worldwide	1996-2016	Panel Data Model	FiT and RPS contribute to the growth of renewable installed capacities, both cumulative and additional, with varying impacts across different renewable energy sources such as solar, wind, and geothermal.

Smirnova et al., (2021)	China, India, and Russia	03 January 3, 2020 to 03 April 2020	Qualitative Analysis through a survey of 57 experts Correlation-Regression model (CRM)	The key factors for the RE market are increased financing, reduced reliance on traditional energy, and strong public-private support. Favorable conditions in the studied countries, effective implementation requires coordinated efforts from both government and businesses.
Lee et Huh, (2017)	South Korea	1990-2015	Frank's Extended Logistic Growth Model	That the renewable portfolio standards more significantly influence the diffusion of renewable energy than the feed-in tariff in South Korea's electric power sector
Gallagher, (2013)	Germany, China, Danmark and US	-	Analytical Approach	Explored four factors that may influence a government's decision to adopt pro-renewable energy policies: economic incentives; high endowment of renewable resources and/or low endowment of non-renewable sources; the political system; and cultural factors and attitudes.
Nasiri et al., (2022)	European Countries	2004-2018	Comparative Analysis Approach	European Directives are not as effective in promoting renewable energy

				<p>Legal framework implementation impacts energy efficiency levels in countries.</p> <p>Policy gaps are presented in biomass and biofuels regulations.</p>
Azhgaliyeva et al., (2018)	106 countries	1997-2014	<p>Annual Data</p> <p>Comparative Analysis Approach</p>	<p>Wind energy production is positively impacted by the two policy instruments: tax incentives and the strategic planning</p>
Roslan, (2018)	6 Asia Pacific countries	2000 to 2015	pooled OLS model	<p>Tax incentives enhance the shift to solar PV capacity.</p> <p>Policy incentives can promote the widespread adoption of solar PV.</p>
Blazquez, Nezamuddin et Zamrik, (2018)	-	2006-2013	<p>Generator of potential renewable projects using Spanish Onshore Wind Data</p>	<p>Investment subsidies are the most cost-effective policy for promoting renewables under favorable market conditions.</p> <p>While cheap loans boost expected profits for private investors, they also slow down the pace of adoption.</p> <p>Feed-in tariff yields the fastest promotion of renewables but is expensive.</p>

Source: Realized by the researcher using different databases: Scopus, CAIRN, Science Direct, and Google Scholar

3.7 Study Impact

As a result, existing research indicates that there are regional and temporal variations in the relationship between economic conditions and the deployment of renewable energy (short and long term). Additionally, it emphasizes that institutional quality is a crucial strategic decision in the promotion of the use of renewable energy sources and the resolution of environmental issues.

While this paper shares numerous elements with previous research and has significantly profited from it in both conceptual and empirical frameworks, it also reveals several unique challenges that require further investigation in the field of research. The present research is different from the others in the following points:

- This study is the only one to bring together the effect of both economic conditions and policy tools in Algeria from 1980 to 2021, which has not been taken into account in previous empirical work.
- This thesis is one of the first studies in Algeria to examine the quantitative effect of the renewable energy and energy efficiency program (NREP) by considering it as a dummy variable in the ARDL model.

3.8 Conclusion

This chapter outlines the various studies that empirically address either, the relationship between economic conditions and REG, or policy instruments and REG in Algeria since.

In this chapter, a table has been created, summarizing *74 previous studies* that are directly relevant to our empirical analysis, detailing the *Authors and Year, Country/Area, Period, Research Methods, and Key Findings*. The literature review has been divided into several main sections. The first section presents studies that used time series data and found a positive/negative/none relationship between OILP and REG. The second section provides an overview of studies that have used time series data with a positive/negative/no relationship between GDP and REG. The third section presents previous studies that have used the impact of government decisions on REG. All studies are summarized in (Table. 3.1) to provide a foundation for addressing the research question, developing the research method, and formulating hypotheses.

Consequently, existing research demonstrates that the relationship between economic conditions and renewable energy deployment varies across regions and timeframes. It also underscores the strategic importance of institutional quality in advancing renewable energy adoption and tackling environmental challenges. Notably, it is *the first to simultaneously examine the impact of economic factors and policy tools on Algeria's renewable energy sector from 1980 to 2021*. Additionally, it is among the *first to quantitatively assess the effect of the National Renewable Energy and Energy Efficiency Program (NREP) by integrating it as a dummy variable in an ARDL model*. The data and methodology will be covered in the next chapter.

Chapter Four

Data and Methodology

4.1 Introduction

4.2 Research Approach

4.3 Study's Data

4.3.1 Source of Data

4.3.2 Variables of the Study.

4.3.2.1 The Dependent Variable

4.3.2.2 The Independent Variables

4.4 Principal Component Analysis (PCA)

4.4.1 Performing Sphericity Tests for PCA

4.4.2 Studying the Correlation between the Study Variables

4.4.3 Graphical Representation of the Study Variables

4.5 Study's Methodology

4.5.1 Model Specification

4.6 Conclusion

4.1 Introduction

Every scientific inquiry necessitates the implementation of diverse methodologies, also referred to as strategies or approaches, along with specific procedures to construct scientific knowledge, as articulated by **Rossouw (2000)**. This chapter primarily seeks to outline the progression of the study and elaborate on the methodologies employed, specifically focusing on investigating the influence of economic conditions and political decisions on RE production. It is divided into two parts: the initial segment offers a comprehensive elucidation of the data origins and variables employed, while the subsequent part delineates the methodology chosen to effectively test the hypotheses.

4.2 Research Approach

Research approaches comprise methods and procedures for conducting studies that span from general hypotheses to systematic techniques for collecting, analyzing, and interpreting data. These approaches involve numerous decisions that need not necessarily follow a linear sequence. Ultimately, the choice of methodology depends on various factors, including the philosophical underpinnings of the researcher, the research design, and the methods employed for data collection, analysis, and interpretation. The selection of a research approach is typically influenced by the nature of the research problem or question, the researcher's personal perspectives, and the intended audience of the study. Generally, there are three primary research approaches: quantitative, qualitative, and mixed-method research (**Creswell et Creswell, 2017**).

To achieve the study's objectives, a quantitative research approach is deemed suitable. Unlike qualitative research, which deals with non-numerical data, quantitative research focuses on numerical data or data that can be quantified. This approach is particularly pertinent when addressing challenges such as climate change, energy security, and sustainable development. The provided overview offers valuable insights into various energy sources, emerging technologies, geopolitical dynamics, and environmental impacts that influence the global energy landscape. By examining current trends and advancements, stakeholders can develop well-informed strategies to navigate the complexities of the energy transition and promote a more sustainable and resilient energy future.

The fundamental techniques utilized to explore numerical data are referred to as "statistics." Statistical methods encompass the organization, analysis, interpretation, and presentation of numerical data, as stated by **Sheard (2018)**. Quantitative research, as defined by **Creswell et Creswell (2017)**, involves testing objective theories by investigating the relationships between

variables. These variables are measurable, typically through instruments, enabling the analysis of numerical data using statistical procedures.

In contrast, **(King, Keohane et Verba, 1994)** assert that quantitative and qualitative analyses exhibit distinct characteristics. Quantitative analysis centers on numerical data and mathematical approaches. It involves observing numerical aspects of phenomena, abstracting from specific instances to seek general descriptions or assess explanatory hypotheses, and identifying measurements and analyses that can be replicated easily by other researchers.

Conversely, a wide range of techniques are included in qualitative analysis, although by definition, none of these methods rely on numerical measurements. Typically, qualitative research tends to focus on one or a limited number of cases, utilizing intensive interviews or in-depth examination of historical content. It is often characterized by its methodological approach, aiming to provide a comprehensive and nuanced understanding of specific events or units.

4.3 Study's Data

This section addresses the data sources, population, and variables utilized in the study.

4.3.1 Source of Data

According to **(Polit et Beck, 2004)**, the data collection process involves gathering the necessary information to address a research problem. Quantitative research typically employs structured data collection, which entails asking a predetermined set of questions in a specific order. In this current research study, data is sourced from various outlets, primarily from secondary sources such as statistical databases published by international institutions. The study relies on databases from the Ministry of Energy and Mines (MEM), World Bank Indicators (WBI), and Worldwide Governance Indicators (WGI).

4.3.2 Variables of the Study

The objective of this study is to examine the impact of economic conditions and policy decisions on renewable electricity generation in the case of Algeria, for the period 1980-2021.

To achieve this objective, the study attempts to identify the factors that significantly influence renewable electricity generation. Three macroeconomic factors, six governance indicators and a dummy variable were intuitively chosen as regressors to explain the variation in the dependent variable annually from the period 1980-2021.

4.3.2.1 The Dependent Variable

Our dependent variable is the Renewable Electricity Generation (REG) measured in GWh. This variable includes the production of hydropower, solar, and wind energy in Algeria. The REG is collected from the Ministry of Energy and Mines (MEM) and covers the period 1980-2021.

4.3.2.2 The Independent Variables

The explanatory variables used in this study include Oil Price (OILP, measured in US dollars per barrel), Gross Domestic Product Per Capita (GDPc, expressed in constant 2010 US dollars). These variables (OILP, GDPc) are collected from World Bank indicators over the period 1980-2021 and represent our economic variables.

The political variables in our study are the Governance Indicator which consists of six sub-indicators, these indicators have been released annually since 2002. Before this year, the indicators were published every two years starting from 1996, and their data were obtained from the World Governance Indicators website. The indicators are as follows: Voting and Accountability (VR), Political Stability and Absence of Violence (SP), Government Efficiency (GE), Regulation Quality (RQ), Quality of Laws (QL), and Corruption Control (CC). All indicators range from (-2.5), reflecting poor performance, to (+2.5), reflecting strong performance in the governance indicator

Furthermore, our study contains a dummy variable that represents the National Renewable Energy Program in Algeria (NREP), which was implemented in 2011, a value of one is assigned from the period 2011 to 2021, while zero is attributed in the other case. The following table summarizes the definitions and sources of variables

Table 4.1. The Definitions and Sources of Variables

Variables	Definitions	Source
REG	Renewable electricity generation in Algeria, measured in GWh, involves generating electrical power using sustainable energy sources within the nation's borders. These renewable sources commonly encompass solar, wind, and hydropower.	Ministry Of Energy and Mines

GDPc	Gross Domestic Product per capita is a measure of the average economic output per person in a country. GDP per capita is typically calculated by converting the GDP from the national currency to U.S. dollars and then dividing it by the total population. In this study, GDP per capita is represented in constant 2015 U.S. dollars and is indicated by the logarithms of GDPc.	World Bank Indicators
OILP	The oil price refers to the current market value of a barrel of crude oil, it reflects the price that purchasers are ready to offer for a quantity of oil at any moment and is influenced by a range of factors such as global supply and demand patterns, geopolitical events, economic circumstances, and governmental regulations. Typically designated in a specific currency such as US dollars per barrel (USD/bbl) and denoted by the logarithms of OILP.	World Bank Indicators
VA	Voting and Accountability expresses the level of freedom accessible to the population in a country and is derived from multiple sources. It ranges from (-2.5), reflecting poor performance, to (+2.5), reflecting strong performance in the governance indicator	Worldwide Governance indicators
SP	Political Stability and Absence of Violence it is an indicator that measures the potential for political instability or violence politically motivated. It spans from (-2.5), indicating weak performance, to (+2.5), indicating strong performance in the governance indicator.	Worldwide Governance indicators
GE	Government Effectiveness reflects perceptions of the quality of public services, the quality of civil services and their degree of independence from political pressures, the quality of policy development and implementation, and the credibility of the government's commitment to these policies. It varies between (-2.5), showing poor governance performance, and (+2.5), showing excellent governance performance.	Governance indicators

RQ	Quality of Regulation represents perceptions of the government's ability to formulate and implement policies and regulations that allow for the development and encouragement of the private sector. The scale goes from (-2.5), signifying poor results, to (+2.5), signifying strong results in the governance indicator.	Worldwide Governance indicators
QL	Quality of Laws is an indicator that reflects the extent to which agents or partners trust and adhere to the rules of society, particularly the quality of contract execution, property rights, courts, police, and the risk of crime and violence. It spans from (-2.5), indicating weak performance, to (+2.5), indicating strong performance in the governance indicator.	Worldwide Governance indicators
CC	Control of Corruption expresses the extent of private gains that can be obtained by those exercising power or responsibility, including small and large forms of corruption, the appropriation of public state property by elites or their private interests. It ranges from (-2.5), reflecting poor performance, to (+2.5), reflecting strong performance in the governance indicator.	Worldwide Governance indicators
NREP	National Renewable Energy and Energy Efficiency Program, which was adopted by the Algerian government in February 2011 and revised in May 2015, and placed as a national priority in February 2016. It represents our Dummy variable a value of one is assigned, while the zero is attributed in the other case.	-

Source: Realized by the researcher using data from Ministry of Energy and Mines (MEM), World Bank Indicators (WBI), and Worldwide Governance Indicators (WGI).

4.4 Principal Component Analysis (PCA)

In order to analyze the correlation between the study variables, i.e. between the dependent variable, which is the production of renewable electricity, and the other explanatory variables, and as a preliminary step before applying the PCA method, the KMO test and the Bartlett test must be carried out as sphericity tests.

4.4.1 Performing Sphericity Tests for PCA

The KMO test is used to judge the adequacy of the sample size used in the study, and the statistical value of this test lies between 0 and 1. The closer the value of this test is to 1, the greater the reliability of the factors obtained from the analysis, and vice versa (Table 4.2). The author of this test (Kaiser, 1974) points out that the minimum acceptable threshold for this statistic is 0.50 in order to judge the adequacy of the sample size.

As for Bartlett's test, its main objective is to determine whether the correlation matrix is a unit matrix. It's worth mentioning here that a unitary matrix is one whose elements are all equal to zero, with the exception of the elements on the diagonal of the matrix, which are equal to one, meaning that the correlation coefficients between all the variables are zero, which means that there are no correlations between the variables (Table 4.3).

The hypotheses of this test are formulated as follows:

Ho: There is no significant correlation between the variables studied.

H1: There is a significant correlation between the variables studied.

Table 4.2. Sphericity Test (KMO Test)

KMO Sphericity Test	
Precision measurement of Kaiser-Meyer-Olkin sampling.	0.806

Source: SPSS 21 output

The previous table shows that the conditions for using the PCA method are met since the results of the KMO test show that the value of this test (0.806) is greater than the threshold (0.50), and that the sample size is sufficient for this study.

Table 4.3. Sphericity tests (Bartlett's test)

Bartlett Sphericity Test	
Chi² (Observed value)	198.886
Chi² (Critical value)	50.998

DDL	36
P-value	< 0.0001
Alpha	0.5

Source: SPSS 21 output

Table (4.3) demonstrates that the results of Bartlett's test indicate rejection of the null hypothesis (Ho) and acceptance of the alternative hypothesis (H1), as we find that the probability value of this test (0.0001=P-value) is less than 5%, and the calculated Chi-square value (198.886) is greater than the critical value (50.998).

The correlation matrix can therefore be considered not to be a unit matrix. Thus, the conditions for principal components are fulfilled.

4.4.2 Study of Correlation between Study Variables

The aim of the correlation analysis between the variables studied is to reveal the nature of the relationship between the dependent variable (REG) and the independent variables (GDPc, OILP, GE, RQ, QL, CC, VA, and PS). The table below shows the matrix of Pearson correlation coefficients between the study variables over the period (1980-2021).

Table 4.4. Matrix of Correlation

	REG	GDPc	OILP	VA	PS	GE	RQ	QL	CC
REG	1.000								
GDPc	0.708	1.000							
OILP	0.488	0.741	1.000						
VA	0.343	0.705	0.527	1.000					
PS	0.753	0.842	0.548	0.632	1.000				
GE	0.568	0.863	0.628	0.737	0.711	1.000			
RQ	-0.561	-0.617	-0.523	-0.076	-0.445	-0.294	1.000		
QL	0.429	0.652	0.515	0.640	0.498	0.862	-0.32	1.000	
CC	0.479	0.645	0.730	0.558	0.530	0.580	-0.356	0.487	1.000

Source: SPSS 21 output

The correlation results reveal that there is a positive correlation between renewable electricity generation (REG) and the majority of the variables in the study. The highest correlation is observed with the Political Stability (PS) variable, which has a coefficient of 0.753 (Bougueroua et Cherifi, 2024).

As for the other variables, the results of the correlation coefficient matrix are as follows:

There is a strong positive relationship between Gross Domestic Product per capita (GDPc) and REG with a value of 0.708.

There is an average positive correlation between Government Effectiveness (GE), Corruption Control (CC), Quality of Laws (QL), Oil Price (OILP), and REG with respectively, 0.568, 0.429, 0.479, and 0.488.

Thus, there is an average negative correlation between Regulatory Quality (RQ) and Renewable Electricity Generation (REG) of -0.561.

4.4.3 Graphical Representation of Variables

The Principal Component Analysis (PCA) method is primarily based on the interpretation and analysis of all the variations and differences between the data through a small set of linear combinations in the basic variables, and so the main objective of this analytical method is to interpret the data and find out the extent of their differences and the reasons for this difference, as well as to process the data in a reduced way (Data Reduction) through the smallest possible number of linear relationships that explain as much as possible of the differences between them. The following table shows the coordinates of the variables on the main axes:

Table 4.5. Component Matrix

	F1	F2
REG	0.748	-0.365
GDPc	0.961	-0.098
OILP	0.803	-0.129
VA	0.755	0.450
PS	0.850	-0.109
GE	0.898	0.285

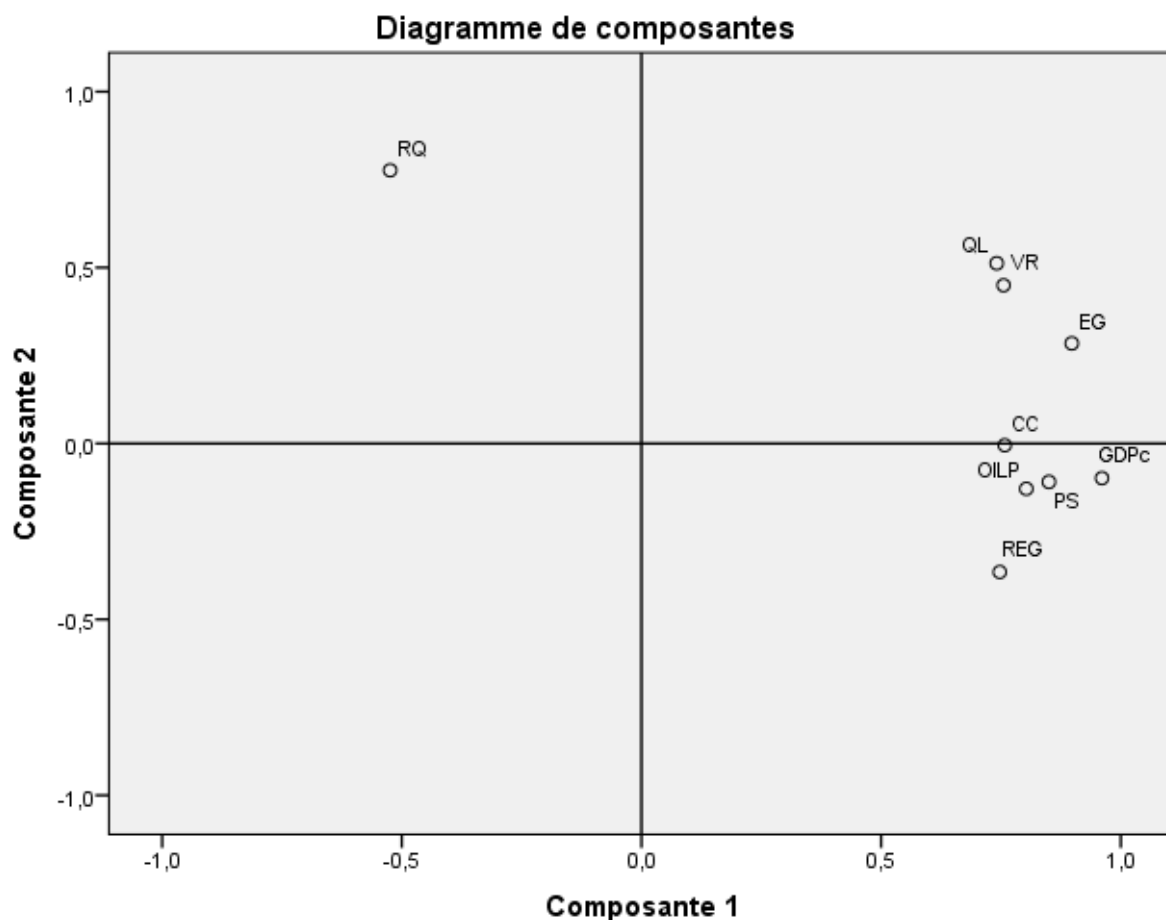
RQ	-0.524	0.777
QL	0.741	0.512
CC	0.758	-0.05

Source: SPSS 21 output

Based on the results in appendix (4.3), the percentage representation of the variables in the level is 77.166%, which is a good percentage and sufficient to give a clear picture of the cloud of variables in the teacher, and it is distributed on two axes, the vertical axis F2 by 14.671% and the horizontal axis F1 by 62.494%.

The following figure shows the projection of the variables used in this study onto the factorial axes:

Figure 4.1. Graphical Representation of Study Variables



Source: SPSS 21 output

In table (4.5) and figure (4.1), which present the two-dimensional graph of the study variables, we observe that the horizontal axis is positively and strongly correlated with all variables except RQ. The highest positive correlation was found with GDPc (0.961), followed by EG (0.898), PS (0.850), OILP (0.803), CC (0.758), VA (0.757), QL (0.741), and finally the dependent variable REG with a value of 0.744.

Regarding the vertical axis, which accounts for 14.671% of the total inertia or explained variance, it reflects a relatively small degree of importance in representing the variables, making it less significant compared to the first axis. A negative correlation was observed with RQ (-0.524).

From the results obtained from the PCA principal component analysis (**Bougueroua et Cherifi, 2024**), we can deduce that:

- Higher levels of GDPc are associated with increased production of renewable electricity. With a stronger economy, Algeria can allocate more public and private funds to the development of renewable energy projects, such as solar and wind farms. These investments require substantial up-front capital, and better economic performance facilitates their financing.
- A moderate positive correlation between the oil price (OILP) and the production of renewable electricity (REG) suggests that, when oil prices rise, so do the costs of energy from fossil fuels. This in turn encourages government and business to turn to renewable energies, which become a more competitive and economically viable alternative.
- Stable political environments support the development of renewable energies. Political stability (PS) creates a climate of confidence for investors, both domestic and international. Investors are more inclined to commit capital to long-term projects, such as renewable energies, when they perceive a low risk of political disruption.
- An average negative correlation between Regulatory Quality (RQ) and REG could suggest that better regulatory quality can mean stricter standards and more complex regulations. This can make market entry more difficult for new players and slow the development of renewable energy projects, leading to a reduction in RE production.
- Effective governments (EG) are able to formulate and implement clear policies and strategies for the development of renewable energies. This includes long-term plans, precise targets and appropriate support measures.
- The high correlation between voting and accountability (VA) indicates that governance practices, especially related to democratic processes and accountability, may play a significant role in fostering renewable energy development.

- Rigorous control of corruption (CC) ensures that funds earmarked for renewable energy projects are used transparently and responsibly. This reduces the risk of embezzlement and mismanagement.
- Well-designed and consistently applied laws (QL) create a favorable regulatory framework for renewable energies. This includes tax incentives, subsidies, and feed-in tariffs for renewable electricity.

In conclusion, we applied the PCA method to detect the variables that have a relationship with our dependent variable the production of renewable electricity (REG). We found a high correlation between (GDPc, OILP, VA, GE, CC, QL, PS) and REG and a low correlation between RQ and REG.

In our model, there are many political variables. To mitigate the issue of multicollinearity among these variables, we considered conducting a separate principal component analysis (PCA) focused only on the political variables, this approach aims to reduce the number of variables in a data set while preserving as much as possible of the original information by providing less correlated and more significant main variables.

Following the second PCA, we found that the political variables were grouped into two factors (see Appendix (4.5) and (4.6)). The first factor, called the Political Factor (PF), includes VA, CC, QL, PS, and GE, while the second factor, named the Regulation Quality Factor (RQF), consists only of RQ.

4.5 Methodology of the Study

Previously, we applied the PCA method to detect variables that have a relationship with our dependent variable, renewable electricity generation (REG).

Basing on the previous results of the PCA method, the main objective of this research is to determine the impact of economic conditions (economic growth, and oil prices) as well as policy decisions, namely the Political factor, Regulatory Quality Factor, and the national renewable energy program, on the deployment of renewable electricity in Algeria for the period 1980-2021. The study uses annual data for each variable: REG, GDPc, OILP, PF, RQF, and NREP. The ARDL model is used to achieve this objective.

The ARDL model is employed to investigate if there exists both short- and long-term relationships between the dependent variable and the independent variables. A unit root test, utilizing four different methods such as the Dickey-Fuller test (**Dickey and Fuller, 1979**), the Augmented Dickey-Fuller test (**Augmented Dickey and Fuller, 1979**), the Phillips and Perron test (**Phillips and Perron, 1988**),

and the Zivot and Andrews test (Zivot and Andrews, 2002) to assess the stationarity of each variable. Furthermore, the ARDL bounds test is constructed to explore the co-movement of variables. To validate the outcomes of this test, various specification tests are applied, including the Durbin-Watson, Breusch-Godfrey LM, and Jaque Bera and Ramsey RESET tests.

4.5.1 Econometric Model of the Study

We perform the autoregressive distributed lag (ARDL) model to study the renewable energy deployment, in the electric power sector in Algeria, related to both economic conditions and policy decisions.

The mentioned approach above, by using the single equation model of (Pesaran and al, 2001), has several benefits including the ability to estimate both short- and long-term effects simultaneously. It can also solve the endogeneity problem for the variables.

Although it doesn't need all the variables under consideration to be integrated in the same order, it does allow for robust estimations when the sample size is small.

Our ARDL model is:

$$\Delta REG_t = \beta_0 + \sum_{j=1}^{l_1} \beta_{1j} \Delta REG_{t-j} + \sum_{j=0}^{l_2} \beta_{2j} \Delta OILP_{t-j} + \sum_{j=0}^{l_3} \beta_{3j} \Delta GDPc_{t-j} + \sum_{j=0}^{l_4} \beta_{4j} \Delta PF_{t-j} + \sum_{j=0}^{l_5} \beta_{5j} \Delta RQF_{t-j} + \sum_{j=0}^{l_6} \beta_{6j} \Delta NREP_{t-j} + \eta_1 REG_{t-1} + \eta_2 OILP_{t-1} + \eta_3 GDPc_{t-1} + \eta_4 PF_{t-1} + \eta_5 RQF_{t-1} + \eta_6 NREP_{t-1} + \eta_7 break_t + \varepsilon_t (*)$$

Where $l_1 - l_6$ are the lag length of each variable respectively, $break$ is the break years, β_0 is the constant parameter, and Δ is the first difference.

We considered a no cointegration hypothesis ($H_0: \eta_1 = \eta_2 = \eta_3 = \eta_4 = \eta_5 = \eta_6 = \eta_7 = 0$) against a cointegration one ($H_1: \eta_1 \neq \eta_2 \neq \eta_3 \neq \eta_4 \neq \eta_5 \neq \eta_6 \neq \eta_7 \neq 0$).

The previous hypothesis is examined by contrasting the estimated F-statistic with the two crucial values, as proposed by (Pesaran et al., 2001). The alternative hypothesis is accepted if this value has a greater significance than the upper bound value. The null hypothesis is accepted if the specified value is less than the lower bound value. We cannot support any hypothesis if the estimated F-statistic lies between the two crucial levels.

4.6 Conclusion

This chapter outlined the research approach and the approved methodology used to provide a well-supported answer to the study's questions. To identify the variables related to the dependent variable -renewable electricity generation (REG)- we applied Principal Components Analysis (PCA). This method led to handle the issue of multicollinearity among the political variables we categorized them into two factors: the Political Factor (PF), comprising VA, CC, QL, PS, and GE, and the Regulation Quality Factor (RQF), which includes only the RQ variable.

Therefore, the main objective of this research is to determine the impact of economic conditions (economic growth, and oil prices) as well as policy decisions, namely the Political factor, Regulatory Quality, and the national renewable energy program, on the deployment of renewable electricity in Algeria for the period 1980-2021. The study uses annual data for each variable: REG, GDPc, OILP, PF, RQF, and NREP. The ARDL model is used to achieve this objective. The following chapter presents the results of the estimations and analysis.

Chapter five

Result and discussion

5.1 Introduction

5.2 Statistical Analysis

5.2.1 Descriptive Statistics

5.2.2 The Optimal Lag

5.2.3 Stationarity Tests

5.2.4 Cointegration Examination Using ARDL Bounds Test

5.3 Diagnostic Tests

5.3.1 Parameter Stability Test

5.3.2 Diagnostic tests for the model's validity

5.4 Conclusion

5.1 Introduction

In this chapter, we undertake the following steps. First, we analyze the statistical data that describes the relevant variables. Next, we look at the variable's stationarity. Thirdly, we investigate whether there is a long-term relationship between the factors. Fourth, we estimate the long- and short-term coefficients and test the model's stability using the ARDL approach. To examine the causation between all variables. And finally, we Conduct diagnostic tests to assess the adequacy of the model, which include tests for serial correlation, heteroskedasticity, normality of residuals, and structural stability.

5.2 Statistical Analysis

Through this section, we aim to offer comprehensive insights into the dynamics of the variables being investigated, facilitating a deeper understanding of the factors influencing renewable energy deployment in the Algerian electric power sector.

5.2.1 Descriptive statistics

As an initial step, a series of statistical tests should be carried out on the study variables, the most important of which are the maximum, minimum values, mean, median and standard deviations, and the results are presented in the table below:

Table 5.1. Summary Statistics

Statistics \ variables	REG	OILP	GDPc	PF	RQF
Maximum	845	111.669	4224.037	1.840	1.343
Minimum	21.000	12.715	2884.120	-1.930	-1.835
Mean	329.115	56.882	3698.648	0.126	8.54E-17
Median	259.500	3842.826	54.355	0.308	0.402
Standard deviation	254.125	31.039	441.089	1.114	1.000

Source: Realized by the researcher using EViews 10

The results presented in (Table. 5.1) show a deviation in GDPc observations which has the highest Max value with 4224.037 USD, the highest Min value with 2884.120 USD, the highest Mean value with 3698.648 USD, and the highest value of standard deviation with 441.089 USD. Additionally, the policy instruments (PF) and (RQF) respectively predict the lowest variation with minimum values of -1.930 and -1.835, maximum values of 1.840 and 1.343, means of 0.126 and 8.54E-17, medians of 0.308 and 0.402, and standard deviations of 1.114 and 1.000. This is due to the fact that these policy variables represent governance indicators, which are confined to the range of (-2.5) to (+2.5).

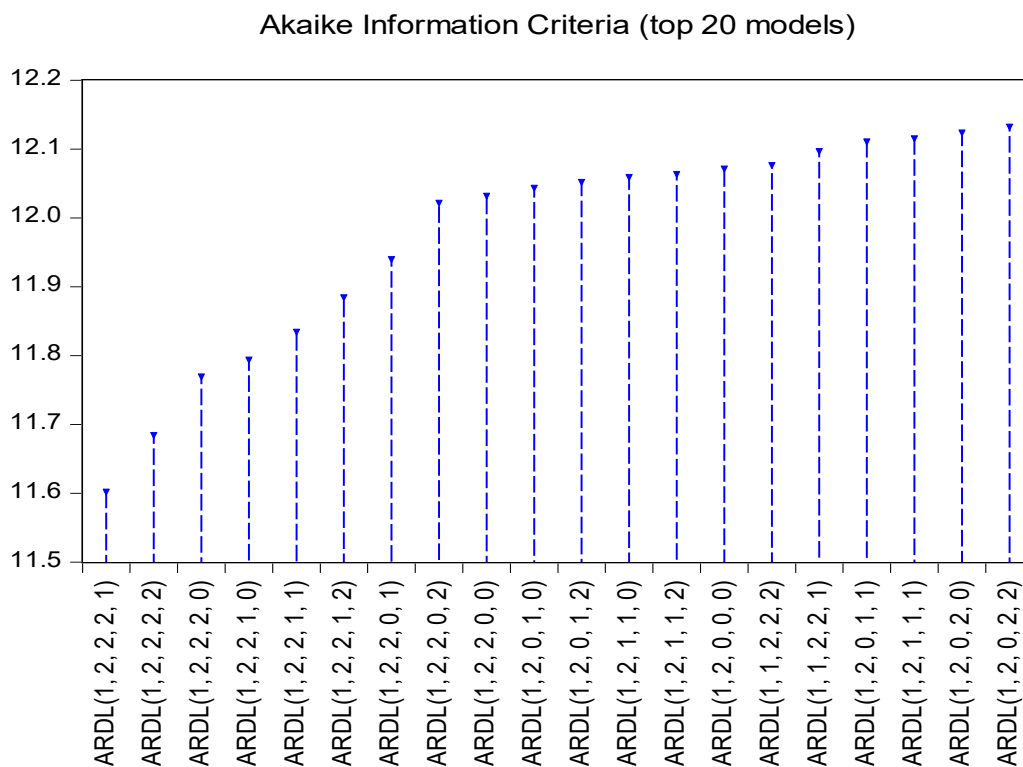
5.2.2 The Optimal Lag

The question at hand is: what is the appropriate number of lags to incorporate into the model? There isn't a definitive rule for selecting the lag length. Moreover, it's an empirical matter, without a predetermined guideline for the maximum lag length (**Gujarati, 2004**).

With annual data, it's common to use a limited number of lags, usually one or two, to avoid sacrificing degrees of freedom. For quarterly data, a range of one to eight lags is suitable. Monthly data allows for the utilization of six, twelve, or twenty-four lags, provided there are enough data points available (**Lefief, 2021**).

In order to test the existence of a long-term equilibrium relationship between the study variable (Cointegration Test), it is essential to conduct Auto Regressive Distributed Lag (ARDL) estimation. Determining the most suitable lag length involves relying on the Akaike Information Criterion (AIC). Consequently, the model that obtained the lowest AIC value is selected to fulfill this criterion. The following figure reveals that the model with the lowest AIC is **ARDL (1, 2, 2, 2, 1)**

Figure 5.1. The Optimal Lag for the Model



Source: EViews 10 Output

5.2.3 Stationary Tests

The notion that macroeconomic data often contains stochastic trends and is defined by unit root was initially proposed by researchers (**Granger et Newbold, 1974**). They also highlighted the risk of spurious regression when utilizing these variables in econometric models. Therefore, verifying stationarity becomes crucial to prevent potential fabrication of regression outcomes.

We conduct several tests, such as those introduced by (**Dickey and Fuller, 1979**), (**Augmented Dickey and Fuller, 1979**), and (**Phillips and Perron, 1988**) to confirm the stationarity of the variables. In models with intercept and models with intercept and trend, the unit root test is applied. The findings, presented in (Tables 5.2-5.4), indicate that all variables are I(1) at level. The variables at the first difference, however, are stationary.

Traditional unit root tests as discussed earlier, are unsuitable for time series data that feature structural breaks. Several researchers **Jiménez-Rodríguez and Sánchez, (2005)**, **Narayan and Smyth, (2005)**, **Apergis and Tsoumas, (2011)** have employed the unit root test developed by (**Zivot and Andrews, 2002**), which allows for the inclusion of one break point in the data, This helps mitigate potential biases in the findings. **Zivot and Andrews, (2002)** conducted tests for non-stationarity (presence of unit root) versus stationarity (absence of unit root) in specifications with

intercept, trend, and both intercept and trend, considering the structural break. The last test's outcomes as indicated in (Table. 5.5) supported those of the previously, more established tests. In fact, the stationary hypothesis is approved for all variables at first difference whereas the non-stationary one is accepted for all variables at level, This confirms that the series are integrated of order one, $I(1)$, justifying the use of techniques such as the ARDL model to analyze their long-term relationships.

According to the four types of unit root tests indicated in the following tables, REG, OILP, GDPc, PF, and RQF are all expected to have $I(1)$ in level and $I(0)$ in first difference. Additionally, there is no variable that $I(2)$. These findings give us the green light to examine the long-term correlation between the variables we studied. For more details see Appendices (from 5.2 to 5.73).

Table 5.2. Augmented Dickey–Fuller Test

Variables	Augmented Dickey–Fuller test statistic	
	Intercept	Intercept and trend
<i>REG</i>	-1.4883(0)	-2.9721(0)
<i>OILP</i>	-1.2411(0)	-2.3607(0)
<i>GDPc</i>	-1.4055(3)	-2.2807(2)
<i>PF</i>	-2.3255(0)	-1.9962(0)
<i>RQF</i>	-1.3649(1)	-2.0395(5)
Δ <i>REG</i>	-7.3847(0)***	-6.0657(4)***
Δ <i>OILP</i>	-5.8628(0)***	-5.7861(0)***
Δ <i>GDPc</i>	-4.0540(0)***	-4.0094(0)**
Δ <i>PF</i>	-5.9483(0)***	-6.2676(0)***
Δ <i>RQF</i>	-2.9517(0)*	-4.6594(0)**

The values between () denotes the Lag length

***refers to the significance at 1% level; **refers to the significance at 5%; * refers to the significance at 10%

Source: Realized by the researcher using EViews 10

Table 5.3. Dickey-Fuller GLS Test

Variables	Dickey-Fuller GLS test statistic	
	Intercept	Intercept and trend
<i>REG</i>	-1.4137(0)	-3.0025(0)
<i>OILP</i>	-1.4248(0)	-2.2143(0)
<i>GDPc</i>	-1.4130(3)	-2.4830(3)
<i>PF</i>	-1.7907(0)	-2.1009(0)
<i>RQF</i>	-1.4606(1)	-2.1074(1)
Δ <i>REG</i>	-7.3756 (0)***	-7.5320(0)***
Δ <i>OILP</i>	-5.8995(1)***	-5.8025(0)***
Δ <i>GDPc</i>	-4.0955(0)***	-4.1109(0)***
Δ <i>PF</i>	-6.0807(0)***	-6.5163(0)***
Δ <i>RQF</i>	-2.5313(0)**	-2.9378(0)*

The values between () denotes the Lag length

***refers to the significance at 1% level; **refers to the significance at 5%; * refers to the significance at 10%

Source: Realized by the researcher using EViews 10

Table 5.4. Phillips-Perron Test

Variables	Phillips-Perron test statistic	
	Intercept	Intercept and trend
<i>REG</i>	-1.1038(5)	-2.9019(3)
<i>OILP</i>	-1.4114(0)	-2.3607(0)
<i>GDPc</i>	-0.8275(4)	-1.5750(4)
<i>PF</i>	-2.3255(0)	-1.9962(0)
<i>RQF</i>	-0.9323(2)	-2.6240(1)
Δ <i>REG</i>	-10.0114(27)***	-20.4728(39)***

$\Delta OILP$	-5.7983(4)***	-5.7107(4)***
$\Delta GDPc$	-4.1587(3)***	-4.1092(3)**
ΔPF	-5.9483(0)***	-6.2864(1)***
ΔRQF	2.8767(3)*	-3.5437(3)*

The values between () denotes the Lag length

***refers to the significance at 1% level; **refers to the significance at 5%; * refers to the significance at 10%

Source: Realized by the researcher using EViews 10

Table 5.5. Nonlinear Unit Root Test (Zivot-Andrews)

Variables	Zivot-Andrews unit root test			
	Intercept	Break year	Intercept and trend	Brek year
<i>REG</i>	-3.8998(0)	1988	-4.4422(0)	2003
<i>OILP</i>	-3.5482(0)	2004	-3.5783(0)	2005
<i>GDPc</i>	-3.5281(3)	2002	- 2.8526(3)	1991
<i>PF</i>	-3.8945(0)	2011	-3.8769(0)	2011
<i>RQF</i>	-3.5482(0)	2005	-2.6240(1)	2005
ΔREG	-6.5118(4)**	2009	-7.1161(4)**	2013
$\Delta OILP$	-6.6500(0)***	2013	- 6.9420(0)***	2014
$\Delta GDPc$	-5.5727(0)***	1995	-5.8581(0)***	1995
ΔPF	-5.9483(0)***	1996	-6.2864(1)***	1998
ΔRQF	3.8767(3)*	2005	-3.4537(3)*	2002

The values between () denotes the Lag length

***refers to the significance at 1% level; **refers to the significance at 5%; * refers to the significance at 10%

Source: Realized by the researcher using EViews 10

5.2.4 Cointegration Examination Using ARDL Bounds Test

Economic analysis suggests a long-term relationship exists among the variables, as posited by theory, implying perfect properties of this relationship. Specifically, it suggests that means and variations remain constant and independent of time. However, empirical research indicates that the constancy of means and variances is often not met when analyzing time series variables. To address this issue, various cointegration techniques, such as the Autoregressive Distributed Lag (ARDL)

Cointegration or bound Cointegration technique, are commonly applied, estimated, and interpreted (Pesaran and al., 2001).

The autoregressive distributed lag (ARDL) model stands out from others due to its focus on measuring long-run relationships and cointegration, relying on vector autoregressive models (VAR). This test was developed by Pesaran and al., (2001). It has gained widespread use in experimental models due to its characteristics. Notably, it can be applied to analyze non-cointegrated time series of similar orders. Following a stationarity test, some variables are found to be stationary at their original level, while others exhibit stationarity in their first differences. Consequently, the study explores whether cointegration exists among the variables.

The null hypothesis of the cointegration test suggests no cointegration among the variables, while the alternative hypothesis proposes the presence of cointegration. This test is conducted on the original levels of the variables, not on their first differences, and the data is transformed into logarithmic form as mentioned earlier.

If the computed F-statistic exceeds the critical value for the upper bound I(1), the null hypothesis is rejected, indicating cointegration and hence a long-run relationship. Conversely, if the calculated F-statistic falls below the critical value for the lower bound I(0), the null hypothesis is retained, indicating no cointegration and thus no long-run relationship. Consequently, the short-run model, the autoregressive distributed lag (ARDL), is estimated (Pesaran and al., 2001).

As illustrated in (Table. 5.6), the results of the ARDL cointegration test suggest the presence of a cointegration relationship among GDP per capita, OILP, NREP, PF, RQF and REG. Specifically, the calculated F-statistic (14.54854) exceeds the upper critical bound value at 1% (4.37).

Table 5.6. Bound Test Cointegration Results

$REG_t = f(OILP_t, GDPc_t, NREP_t, PF_t, RQF_t)$	
Bound test F-statistic	14.54854***
Significance	1%
Lower I(0) Bound	3.29
Upper I(1) Bound	4.37

*** indicates the significance at 1%level

Source: Realized by the researcher using EViews 10

The next table outlines the short- and long-term ARDL estimations regarding the impact of the Oil Price, Gross Domestic Product per capita, Political Factor, Regulatory Quality Factor, and National Renewable Energy Program on the Renewable Electricity Generation.

Table 5.7. Long and Short-Run ARDL Estimations

$REG_t = \beta_0 + \beta_1 OILP_t + \beta_2 GDPc_t + \beta_3 PF_t + \beta_4 RQF_t + \beta_5 NREP_t + \varepsilon_t$				
Variables	Coefficient	Standard Error	T-Statistic	p-Values
<i>Long-Run Analysis</i>				
Constant	220.156	818.527	0.268	0.7934
OILP (-2)	-4.610**	1.647	-2.798	0.0181
GDPc (-2)	1.392**	0.446	3.116	0.0109
PF	119.113**	44.931	2.650	0.0243
RQF	263.718***	77.346	3.409	0.0067
NREP	275.980**	96.969	2.846	0.0174
<i>Short-Run Analysis</i>				
Δ (OILP)	0.706	0.673	1.048	0.3190
Δ (OILP (-1))	4.610***	0.856	5.385	0.0003
Δ (GDPc)	-0.164	0.177	-0.927	0.357
Δ (GDPc (-1))	-0.139***	0.229	-6.075	0.0001
Δ (PF)	119.113***	19.753	6.029	0.0001
Δ (PF(-1))	74.440***	22.478	3.311	0.0079
Δ (RQF)	263.718***	45.304	5.821	0.0002
NREP	275.980***	26.324	10.483	0.0000
ECT (-1)	-1.152***	0.100	-11.442	0.0000
R2	0.922			
Adjusted R2	0.880			
F-statistic	22.057***			0.0000

***refers to the significance at 1% level;

**refers to the significance at 5%;

*refers to the significance at 10%

Source: Realized by the researcher using EViews 10

A negative value of ECT indicates how quickly RE production adjusts back to its long-term equilibrium after a shock or change. A value of -1.15 suggests that any deviation in RE production from its equilibrium level is corrected by 115% in the next period.

The long-term findings presented in (Table. 5.7), reveal that OILP in the second lags exerts a negative and significant influence on the REG. Conversely, there is a positive and statistically significant relationship between REG and the rest of variables.

In the short term, the results reveal a negative and statistically significant relationship between GDPc in the first lags and REG. However, the rest of variables have positive and statistically significant impacts. Notably, the effect of NREP on REG is notably stronger compared to the influence of the other policy tools such as PF and RQF.

As evident from the data, there is a positive correlation between OILP and REG in the short term. A 1% rise in OILP corresponds to a 4.610% increase in REG. The Algerian economy heavily relies on the oil and gas sector, which holds significant prominence. In 2021, the nation exported crude oil and petroleum products amounting to more than 23 billion U.S. dollars. Additionally, approximately 10 percent of the GDP was attributed to oil rents (**Statista, 2024**). This underscores the significant dependence of the Algerian economy on hydrocarbon revenues. When oil prices are high, there's a potential incentive for the Algerian government to diversify its economy by investing in alternative sectors like renewable energy. Such diversification efforts could yield short-term benefits by reducing reliance on oil revenues and fostering the adoption of renewable energy. Furthermore, the substantial budget surplus generated by the government during periods of high oil prices offers additional motivation to diversify the economy, providing ample funding for research and development (R&D) initiatives and renewable energy projects. These findings align with several studies (**Tambari, Failler et Jaffry, 2023**), (**Husaini et Lean, 2022**), (**Sahu et al., 2022**), (**Rasheed et al., 2022**), (**Royal, Singh et Chander, 2022**), (**Escoffier et al., 2021**), (**Dogan et al., 2021**), (**Zhao et al., 2021**), (**Lee and Huh, 2017**), (**Özdemir, 2021**), (**Cheng et al., 2021**), (**Wang, Li et Pisarenko, 2020**) (**Apergis et Payne, 2014a**) (**Apergis et Payne, 2014b**), (**Apergis et Payne, 2015**), (**Troster, Shahbaz et Uddin, 2018**) which support the notion of economic diversification in response to high oil prices. Conversely, our results contradict those of (**Deka, Özdeşer et Seraj, 2023**), (**Guo et al., 2021**), (**Karacan et al., 2021**) (**Payne, 2012**), (**Sadorsky (2009a)**), (**Mukhtarov et al., 2020**), (**Mukhtarov, Humbaeva et Hajiyeu, 2021**).

In the long run, a 1% increase in OILP adversely affects the REG (-4.610%). When oil prices increase for a prolonged period, there's a tendency for the government to prioritize the exploitation and maximization of revenues from oil resources instead of actively promoting renewable energy (**Karacan et al., 2021**).

In the long term, there is a positive correlation between REG and GDP per capita. A 1% increase in GDPc corresponds to a 1.392% rise in renewable energy generation. Essentially, sustained increases in GDP per capita may signify ongoing economic growth and an expansion in the country's fiscal capabilities. This can incentivize policymakers to diversify the economy and invest in sectors like renewable energy, aiming to decrease reliance on fossil fuels and promote long-term sustainable development. As indicated by the Embassy of the People's Democratic Republic of Algeria in Brussels, Algeria, as a participant in the Paris Climate Agreement, might be obligated to adhere to international commitments aimed at reducing greenhouse gas emissions and transitioning to a low-carbon economy. Achieving this transition may necessitate an uptick in renewable energy deployment over the long term, with GDP per capita serving as an indicator of the country's financial capacity to facilitate this transition. This finding is consistent with various studies (**Shahbaz et al., 2022**), (**Zafar et al., 2020**), (**Tudor et Sova, 2021**), (**Dogan et al., 2021**), (**Bamati and Raoofi, 2020**), (**Apergis et Payne, 2010a**), (**Apergis et Payne, 2010b**), (**Al-mulali et al., 2013**), (**Darvishi et Varedi, 2018**), (**Ntanos et al., 2018**). and differs from that of (**Mai, 2023**), (**Zhang et al., 2023**), (**Tambari and Failler, 2020**), (**Matei, 2017**).

Otherwise, in the short term, GDP per capita exerts a negative impact, specifically, a 1% increase in GDP per capita corresponds to a decrease in renewable energy investment by -0.139%. While an uptick in GDP per capita may signify additional financial resources for the government, these funds could be directed towards other pressing priorities like infrastructure, education, social services, and healthcare. Despite the long-term cost-saving potential of renewable energy compared to fossil fuels, the initial implementation costs can be substantial. This is particularly relevant for Algeria, a nation with an established energy infrastructure heavily reliant on fossil fuels. Consequently, there might be a preference for quicker and more economical energy solutions in the short term, such as expanding existing oil or gas infrastructure. This finding aligns with the research of (**Tambari and Failler, 2020**).

In both, the short and long term, there exists a positive correlation between PF, RQF, NREP and the REG. A 1% increase in renewable energy programs leads respectively to a substantial 119.113%, 263.718%, 275.980% increase in renewable energy generation. This high coefficient suggests that Algeria prioritizes political decisions over economic conditions such as oil prices and GDP per capita regarding renewable energy deployment.

Political factors play a crucial role in the production of renewable electricity in Algeria. Factors such as voice and accountability, control of corruption, effectiveness of governance, quality of laws, and political stability directly influence the country's ability to attract investment and implement

renewable energy projects. For example, a stable political framework and transparent governance improve investor confidence and facilitate the realization of long-term projects. Controlling corruption is also essential, as it ensures that resources allocated to projects are used efficiently and in the public interest.

At the same time, the quality of regulation plays a key role in the implementation of sustainable policies. Clear, well-defined regulations encourage the adoption of renewable technologies and help overcome bureaucratic obstacles.

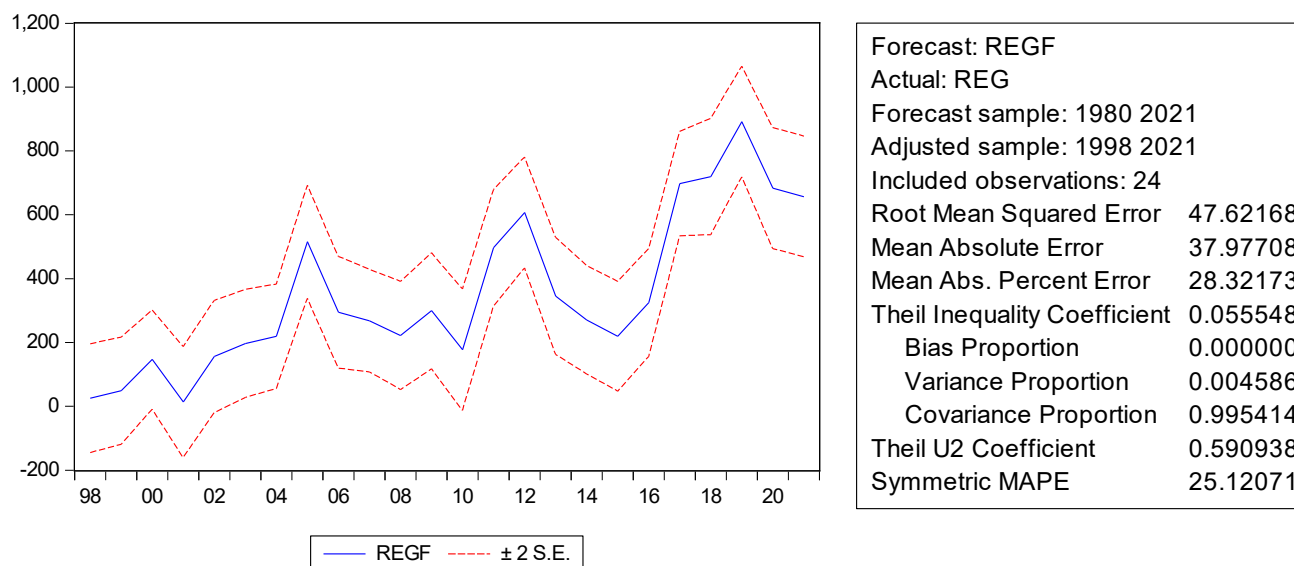
Algeria has made commitments to renewable energies as part of its efforts to address environmental challenges and preserve fossil energy resources. The updated NREP aims to achieve a clean energy capacity of 22,000 MW by 2030, constituting 27% of the total installed electrical capacity and 37% of electricity production (MEM, n. d.). This program not only seeks to increase the share of renewable energies in the national energy mix but also aims to reduce dependence on fossil fuels for power generation. Numerous studies have explored how policy decisions impact renewable energy development, with many indicating that policies play a significant role in shaping renewable energy markets. For instance, (Biresselioglu and Zengin Karaimrahimoglu, 2012), (Uzar, 2020), (Smirnova et al., 2021), (Gallagher, 2013), (del Río and Mir- Artigues, 2014), (Fagiani et al. 2014) (Yoon and Sim, 2015).

5.2.5 Testing Forecast Performance in Unrestricted Error Correction Models

Predictive performance testing of an Unrestricted Error Correction Model (UECM) involves evaluating how well the model forecasts future values of the dependent variable (renewable energy production -REG-). This testing helps determine the model's accuracy and robustness.

After estimating the ARDL model, the Osum procedure, which is based on the Theil index, is employed to evaluate the model's predictive power. The findings are depicted in the following figure.

Figure 5.2. Forecast Performance Test.



Source: EViews 10 Output

The graph shows how well the forecasted values align with the actual data over time. The blue line represents the forecasted values of REGF. The dashed red lines indicate the confidence interval (± 2 standard errors) around the forecast.

- Theil Inequality Coefficient (T= 0.055548): A value near 0 suggests an almost perfect prediction, whereas a value approaching 1 indicates poor forecasting performance. In this case, the low value suggests that the forecast is highly accurate.
- Bias Proportion (BP= 0): Indicates that there is no systematic bias between forecast and actual data.
- Variance Proportion (VP=0.004586): Shows that most of the forecast errors are not due to variance.
- Covariance Proportion (CP= 0.995414): Indicates that the model captures the co-movement between forecasted and actual values well.

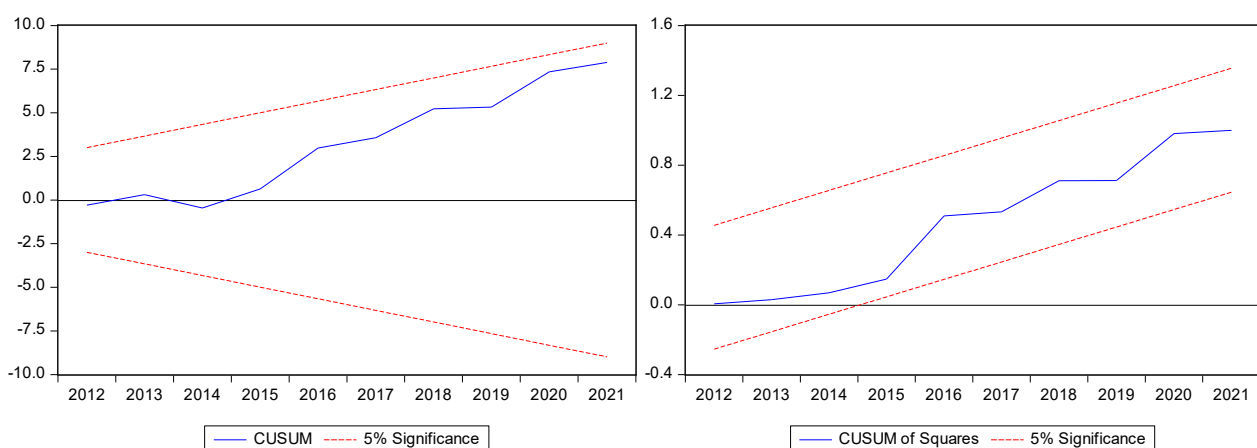
5.3 Diagnostics tests

Diagnostic tests are an essential component of statistical analysis, allowing researchers to assess the validity and reliability of their models. Parameter stability tests, on the other hand, evaluate the consistency and reliability of the estimated parameters over time or across different datasets. These tests assess whether the relationships between variables remain stable and unchanged, providing insights into the robustness of the model estimates.

5.3.1 Parameter Stability

The stability of model outcomes can be compromised by unstable parameters. Hence, our objective is to examine the estimated long-term parameters to understand their variation over time. To assess the stability of these long-term parameters in the cointegrating equation, with renewable energy generation as the dependent variable, we utilize the (Pesaran and Pesaran, 1997) test. This test involves estimating the error-correction model specified by Eq. (1) using ordinary least squares and analyzing the residuals using the cumulative sum of the recursive residuals (COSUM) and COSUM squared (COSUMsq) tests. The results of these COSUM and COSUMsq stability tests are presented in (Figure. 5.5). In this figure, the vertical axis represents the year, the horizontal axis displays COSUM statistics, and the dotted red lines represent the 5% critical limits for the statistics. The results of both COSUM and COSUMsq tests indicate the stability of the ARDL parameters, as both diagrams fall within the critical limits.

Figure 5.3. CUSUM and CUSUM of Squares Plot of Recursive Residual.



Source: EViews 10 Output

5.3.2 Diagnostic tests for the model's validity

To validate the findings of this study, it is imperative to conduct various specification tests that serve to identify any potential issues or anomalies in the data that may affect the accuracy of the results. Typical diagnostic examinations encompass evaluations for autocorrelation, heteroskedasticity, normality of residuals, and the model specification test. The table below presents a summary of the results obtained from diagnostic tests:

Table 5.8. Diagnostic Tests Outcomes

Diagnostic Tests	Value	P-Value	Decision
Breusch-Godfrey (LM test)	2.371	0.158	Accept H_0 : Absence of autocorrelation
Durbin Watson Test	2.685	-	Accept H_0 : Absence of autocorrelation
Normality (Jarque-Bera)	2.334	0.311	Accept H_0 : Normality distribution of residuals
Breusch-Pagan-Godfrey	0.726	0.710	Accept H_0 : Absence of heteroskedasticity
Ramsey RESET Test	0.175	0.864	Accept H_0 : Model has no omitted variables

Source: Realized by the researcher using EViews 10

There are numerous sources of autocorrelation in time series regression analysis, with several possible causes. In many instances, it occurs because the analyst fails to incorporate one or more essential predictor variables into the model. The Breusch-Godfrey LM Test evaluates the null hypothesis that the residuals from a regression are not auto-correlated against the alternative one that the residuals are auto-correlated. $H_0 : P = 0$; $H_1 : P \neq 0$. The null hypothesis of $P = 0$ implies that the error term in one period is not correlated with the error term in the previous period. $P \neq 0$ means the error term in one period is either positively or negatively correlated with the error term in the previous period (**Hock Ann et Midi, 2011**).

The Durbin-Watson Test is also employed to check serial correlation problems. The null hypothesis posits no autocorrelation, while the alternative hypothesis suggests the existence of serial correlation. The Durbin-Watson statistic falls within the range of 0 to 4. A value close to 2 suggests the absence of autocorrelation, while a value closer to 0 indicates positive autocorrelation and a value nearing 4 suggests negative autocorrelation (**White, 1992**).

Therefore, the Breusch-Pagan-Godfrey test is utilized to examine the presence of heteroskedasticity. The null hypothesis assumes that the residuals' variance is homoskedastic, while the alternative hypothesis suggests the opposite, indicating heteroskedastic variance (**Godfrey, 1978**). Furthermore, the Jarque-Bera test is applied to assess the normality of residuals. In this test, the null hypothesis states that the residuals follow a normal distribution, whereas the alternative hypothesis proposes otherwise, indicating the non-normal distribution of residuals (**Thadewald et Buning, 2007**).

The Ramsey RESET (Regression Specification Error Test) is a diagnostic tool utilized in regression analysis to examine whether the model's functional form is correctly specified. It aims to detect omitted variables or potential misspecifications within the model. The null hypothesis of the RESET test posits that the model is correctly specified, while the alternative hypothesis implies misspecification. Rejection of the null hypothesis suggests the presence of omitted variables or other specification errors in the model (**Bronk Ramsey et al., 2015**).

According to the findings in (Table. 5.13) the value of Breusch Godfrey LM Test is 2.371 with a probability of 0.158 which is more than the critical value 5% therefore, there is no serial correlation. Moreover, the value of Durbin-Watson is (2.685) near to 2, Consequently, we accept the null hypothesis. As a result, there is an absence of autocorrelation. Likewise, the value of the Breusch-Pagan-Godfrey test is 0.726 with a prob-value of 0.710, in that case, we accept the null hypothesis, then we conclude that there is no heteroskedasticity issue present. The prob-value of the Jarque-Bera test for normality is 0.311, as this value is significantly higher than 0.05, we do not reject the null hypothesis that the residuals are normally distributed. Moreover, the Ramsey RESET test indicates that the model is correctly specified because the obtained p-value of 0.864 exceeds the 5% critical value.

5.4 Conclusion

In this chapter, we began with a statistical analysis of the variables, including descriptive statistics and the determination of the optimal lag for the model. Next, we performed stationarity tests to assess the time-series properties of the variables. Then we examined cointegration using the ARDL bounds test to determine the existence of a long-term relationship between the variables. Following this, we estimated both short- and long-term coefficients using the ARDL approach. Finally, we conducted diagnostic tests to evaluate the model's validity, including parameter stability tests, as well as checks for serial correlation, heteroskedasticity, normality of residuals, and structural stability

The chapter has arrived at the following conclusions:

- The descriptive statistics provided an overview of the data distribution, while the optimal lag selected with the lowest AIC value ensured the robustness of the model.
- The stationarity test results indicate that all variables are non-stationary at their levels but become stationary after first differencing, justifying the use of the ARDL model.
- The long-term ARDL estimates indicate that oil price (OILP) negatively impacts renewable electricity generation (REG), whereas the gross domestic product per capita (GDPC) has a positive effect on REG. However, in the short term, the ARDL estimates show that oil price (OILP) positively influences renewable electricity generation (REG), while gross domestic product per capita (GDPC) has a negative impact on REG (**Cherifi et al., 2024**). In both, the short and long term, there exists a positive correlation between policy tools (National Renewable Energy Program and Governance Indicators) and the REG.
- Parameter stability tests of both COSUM and COSUMsq indicate the stability of the ARDL parameters, as both diagrams fall within the critical limits.
- The diagnostic tests validated the model's reliability, with no evidence of serial correlation or heteroskedasticity, and the residuals followed a normal distribution.

Chapter Six

Conclusion

6.1 Introduction

6.2 Key Findings of the study

6.3 Testing Hypothesis

6.4 Implications and Recommendations

6.5 Limits and Perspectives

6.1 Introduction

The main objective of our study is to find out the role of economic conditions, mainly the variation of oil prices (OILP) and economic growth (GDPc), as well as political decisions [(Political Factor (PF), which includes 5 sub-factors: -1. Political Stability (PS) -2. Voting and accountability (VA), -3. Control of corruption (CC), -4. Governance effectiveness (GE), -5. Quality of Laws (QL), Regulation Quality Factor (RQF), and Renewable Energy and Energy Efficiency Program (NREP)] in the production of renewable electricity in Algeria over the period 1980-2021. By giving an increased understanding of all aspects of the causal relationship between OILP, GDPc, PF, RQF, NREP, and REG, this paper attempts to strengthen the knowledge gained from previous studies in the field. The main reason is the lack of research regarding this relationship in Algeria.

In view of this objective, we examined an econometric model based on both linear unit root tests (Dickey-Fuller, Augmented Dickey-Fuller, Phillips and Perron) and non-linear unit root tests (Zivot and Andrews), as well as the cointegration approach ARDL bounds testing. To validate the outcomes of this dissertation, various specification tests are applied, including the Durbin-Watson, Breusch-Godfrey LM, and Jaque Bera and Ramsey RESET tests.

6.1 Key Findings of the Study

Our findings highlight that Algeria's transition to renewable energy is influenced by a combination of political and economic factors. The empirical results derived from the Autoregressive Distributed Lag (ARDL) model provide valuable insights into the short- and long-term determinants of renewable electricity generation in the country.

In the short run, our estimates suggest that rising oil prices have a positive and significant effect on renewable electricity generation. This could be attributed to the increased revenues from oil exports, which may provide financial resources for investment in renewable energy infrastructure. Furthermore, policy instruments, including government incentives, regulatory frameworks, and financial support mechanisms, also demonstrate a positive and significant impact on renewable electricity generation. These findings underscore the crucial role of policy-driven initiatives in fostering the development of Algeria's renewable energy sector. Conversely, gross domestic product (GDP) per capita negatively influences renewable electricity generation in the short term, possibly indicating that economic growth is still primarily linked to fossil fuel consumption, which may delay the shift toward renewables.

In the long run, the relationship between these variables exhibits notable differences. Contrary to the short-term effects, oil prices exert a negative impact on renewable energy adoption over time. This suggests that prolonged periods of high oil prices may reduce the urgency of investing in alternative energy sources, as reliance on fossil fuel revenues continues. However, GDP per capita has a positive effect on renewable electricity generation in the long term, implying that as economic prosperity increases, the country may allocate more resources toward clean energy development. Additionally, policy instruments remain a crucial driver of long-term renewable energy expansion, reinforcing the importance of sustained governmental support and strategic planning to ensure a successful energy transition.

Overall, our findings emphasize the dual role of economic and political factors in shaping Algeria's renewable energy trajectory. While oil prices present both opportunities and challenges, the implementation of robust policy frameworks and the promotion of economic growth can significantly enhance the country's renewable energy potential. These insights provide a foundation for policymakers to design targeted strategies that balance Algeria's dependence on fossil fuels with the need for sustainable energy development.

6.2 Testing Hypothesis

As discussed, this research has three hypotheses: one theoretical hypothesis and two empirical hypotheses. The theoretical one examines whether **Algeria's investment in renewable energy is primarily driven by the need to diversify its energy mix and economy to reduce dependence on fossil fuels**. The second explores the extent to which **renewable electricity generation in Algeria is significantly influenced by both oil prices and Gross Domestic Product**. The final hypothesis assesses **the positive significant contribution of the National Renewable Energy and Energy Efficiency Program, along with governance indicators, to the advancement of renewable electricity in Algeria**.

Several studies confirm that the primary driver of Algeria's investments in renewable energy is the need to diversify its energy mix and economy to reduce dependence on fossil fuels. For example, **(Bouznit, Pablo-Romero et Sánchez-Braza, 2020), (Bouraiou et al., 2020), (Stambouli et al., 2012), (Stambouli, 2011)** highlight the Algerian government's commitment to shifting away from fossil fuels in favor of renewable energy sources, both to preserve depleting fossil fuel reserves and to achieve long-term environmental goals. Similarly, other studies indicate that despite its vast fossil fuel reserves, Algeria faces a major challenge due to the rapidly increasing domestic energy demand and lack of economic diversification, pushing the country to adopt renewable energy. For

instance, (Bouznit, Pablo-Romero et Sánchez-Braza, 2020) (Haddoum, Bennour et Ahmed Zaïd, 2018), (Makhloufi et al., 2022), (Abada et Bouharkat, 2018), (Bélaïd et Youssef, 2017). Furthermore, (Bouزيد, Ghellai et Mezghiche, 2015), note that Algeria must diversify its energy mix by incorporating renewable sources, particularly solar energy, to reduce its reliance on fossil fuels. As a result, the theoretical hypothesis indicating that **the primary driver for Algeria's investment in renewable energy is the need to diversify its energy mix and economy to reduce dependence on fossil fuels is confirmed.**

In the light of the results of the ARDL estimation, the separated t-calculated of both GDPc and OILP is greater than the t-student tabulated at the 5% level in both the short and long term. Thus, we **accept** hypothesis 2 indicating that **Renewable electricity generation in Algeria is significantly influenced by both oil prices and Gross Domestic Product.**

It is also shown that there exists a positive correlation between PF, RQF, NREP, and REG. Political factors (PF) are vital to the development of renewable electricity production in Algeria. Aspects such as voice and accountability, corruption control, effective governance, rule of law, and political stability have a direct impact on the country's capacity to attract investment and implement renewable energy initiatives. A stable political environment and transparent governance, for example, boost investor confidence and make it easier to carry out long-term projects. Additionally, combating corruption is critical as it ensures that resources for these projects are utilized effectively and for the public good.

Furthermore, the Regulatory Quality (RQF) framework plays a crucial role in shaping sustainable policies. Well-structured and clear regulations support the adoption of renewable energy technologies and help navigate bureaucratic challenges.

The National Program for the Development of Renewable Energies and Energy Efficiency (PNEREE) is a key element in this dynamic. The program aims to diversify the country's energy sources and increase the share of renewable energies in the energy mix. Numerous studies have explored how policy decisions impact renewable energy development, with many indicating that policies play a significant role in shaping renewable energy markets. For instance, (Lee et Huh, 2017), (Karaeva, Magaril et Al-Kayiem, 2023), (Nasiri et al., 2022), (Wang, Li et Pisarenko, 2020), (Yang et al., 2019), (Li et al., 2022), (Biresselioglu and Zengin Karaibrahimoglu, 2012), (Uzar, 2020), (Smirnova et al., 2021), (Gallagher, 2013), (del Río and Mir- Artigues, 2014), (Fagiani et al. 2014) (Yoon and Sim, 2015). Therefore, we **accept** hypothesis 3, indicating that **the**

National Renewable Energy and Energy Efficiency Program, along with governance indicators, plays a significant and positive role in advancing renewable electricity in Algeria.

6.3 Implications and Recommendations

This paper has several policy implications:

- **Economic Diversification:** The findings highlight the dual role of oil prices in shaping renewable energy development. While high oil prices can provide short-term incentives for diversification, long-term dependence on fossil fuel revenues can slow renewable energy investments. This underscores the need for a structured transition strategy.
- **Policy Commitment:** The significant long-term impact of GDP per capita on renewable energy generation suggests that economic growth can facilitate energy transitions. However, short-term economic pressures may divert resources from renewable initiatives, emphasizing the importance of strong policy commitments.
- **Financial Allocation:** Budget surpluses from high oil revenues should be strategically allocated to renewable energy projects to ensure continuous development, rather than being redirected toward immediate economic or social priorities.
- **Governance and Institutional Support:** The role of governance indicators suggests that regulatory frameworks and institutional stability are crucial for renewable energy advancement. Strengthening governance structures can enhance investor confidence and policy effectiveness.

Recommendations

- **Create a Sovereign Green Investment Fund:** Establishing a dedicated fund from hydrocarbon revenues to finance renewable energy projects can ensure long-term sustainability and reduce reliance on fossil fuels.
- **Strengthen Regulatory Frameworks:** Implementing clear, stable, and transparent policies will encourage private sector participation and foreign investment in renewable energy.
- **Promote Research and Development (R&D):** Increased investment in R&D can improve technology adoption, efficiency, and innovation in the renewable energy sector.

- **Diversify Energy Subsidies:** Redirecting subsidies from fossil fuels toward renewables can enhance the competitiveness of clean energy sources and accelerate their adoption.
- **Encourage Public-Private Partnerships (PPPs):** Facilitating collaboration between the government and private sector through incentives, tax benefits, and risk-sharing mechanisms can drive large-scale renewable energy projects.
- **Regional Benchmarking:** Conducting comparative studies with other MENA countries can help identify best practices and tailor policies to Algeria's specific economic and institutional landscape.

6.4 Limits and Perspectives

6.4.1 Limits

- **Data Availability and Quality:** Despite relying on official sources, inconsistencies and gaps in the data, particularly for certain policy variables in Algeria, may affect the reliability of the results.
- **Difficulty in Quantifying Political Variables:** Most political variables are qualitative or represented as dummy variables, limiting their precision in econometric modeling and reducing the accuracy of their estimated impact.

6.4.2 Perspectives

- **Expanding the Scope:** Future studies could incorporate a broader range of macroeconomic and institutional variables, such as Transparency and security Situation, to provide a more comprehensive analysis of the factors influencing renewable energy deployment. Integrating these variables would allow for a deeper understanding of how economic and political environments shape renewable energy investment decisions.
- **Regional Comparisons:** A comparative study with other MENA countries could help identify common trends and region-specific factors that influence renewable energy adoption. Given the region's shared challenges—such as fossil fuel dependency, energy subsidies, and climate change—analyzing cross-country variations could reveal best practices and policy lessons applicable to Algeria and beyond.
- **Dynamic Modeling Approaches:** Future research could explore advanced econometric techniques, such as machine learning models, nonlinear time series analysis, or panel data approaches, to enhance forecasting accuracy and policy evaluation. These methods could help capture complex interactions between economic, policy, and environmental factors, leading to more robust predictions of renewable energy trends.

- **Policy Simulation:** Future studies could integrate policy simulation models to evaluate the potential impact of different regulatory frameworks, subsidy structures, and incentive programs on renewable energy growth. Simulating scenarios under various policy conditions would offer valuable guidance to policymakers and industry stakeholders in designing more effective strategies for accelerating the energy transition.

References

References

- Abada, Z., & Bouharkat, M. (2018).** Study of management strategy of energy resources in Algeria. *Energy Reports*, 4, 1–7. <https://doi.org/10.1016/j.egy.2017.09.004>
- Ahmedbelbachir, M. (2023).** International Conference on Management Economics and Business Renewable Energies, Transition and Prospects: The Case of Algeria. *The Eurasia Proceedings of Educational & Social Sciences (EPESS)*, 32, 62–70. University of Tlemcen.
- Ahmedbelbachir, M. (2023).** Renewable Energies, Transition, and Prospects: The Case of Algeria. *The Eurasia Proceedings of Educational and Social Sciences*, 32, 62–70. <https://doi.org/10.55549/epess.1412817>
- Al-mulali, U., Fereidouni, H. G., Lee, J. Y., & Sab, C. N. B. C. (2013).** Examining the bi-directional long run relationship between renewable energy consumption and GDP growth. *Renewable and Sustainable Energy Reviews*, 22, 209–222. <https://doi.org/10.1016/j.rser.2013.02.005>
- Apergis, N., & Danuletiu, D. C. (2014).** Renewable Energy and Economic Growth: Evidence from the Sign of Panel Long-Run Causality. *International Journal of Energy Economics and Policy*, 4(4), Article 4.
- Apergis, N., & Payne, J. (2010a).** Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, 38(1), 656–660.
- Apergis, N., & Payne, J. E. (2010b).** Renewable energy consumption and growth in Eurasia. *Energy Economics*, 32(6), 1392–1397.
- Apergis, N., & Payne, J. E. (2011a).** Renewable and non-renewable electricity consumption–growth nexus: Evidence from emerging market economies. *Applied Energy*, 88(12), 5226–5230. <https://doi.org/10.1016/j.apenergy.2011.06.041>
- Apergis, N., & Payne, J. E. (2011b).** The renewable energy consumption–growth nexus in Central America. *Applied Energy*, 88(1), 343–347. <https://doi.org/10.1016/j.apenergy.2010.07.013>
- Apergis, N., & Payne, J. E. (2012).** Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. *Energy Economics*, 34(3), 733–738. <https://doi.org/10.1016/j.eneco.2011.04.007>
- Apergis, N., & Payne, J. E. (2014a).** Renewable energy, output, CO2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy Economics*, 42, 226–232. <https://doi.org/10.1016/j.eneco.2014.01.003>
- Apergis, N., & Payne, J. E. (2014b).** The causal dynamics between renewable energy, real GDP, emissions and oil prices: Evidence from OECD countries. *Applied Economics*, 46(36), 4519–4525. <https://doi.org/10.1080/00036846.2014.964834>

References

- Apergis, N., & Payne, J. E. (2015a).** Renewable Energy, Output, Carbon Dioxide Emissions, and Oil Prices: Evidence from South America. *Energy Sources, Part B: Economics, Planning, and Policy*, 10(3), 281–287. <https://doi.org/10.1080/15567249.2013.853713>
- Apergis, N., & Payne, J. E. (2015b).** Renewable Energy, Output, Carbon Dioxide Emissions, and Oil Prices: Evidence from South America. *Energy Sources, Part B: Economics, Planning, and Policy*, 10(3), 281–287. <https://doi.org/10.1080/15567249.2013.853713>
- Apergis, N., & Tsoumas, C. (2011).** Integration properties of disaggregated solar, geothermal and biomass energy consumption in the U.S. *Energy Policy*, 39(9), 5474–5479. <https://doi.org/10.1016/j.enpol.2011.05.015>
- Ashton, T. S. (1997).** *The Industrial Revolution 1760-1830*. Oxford University Press. <https://doi.org/10.1093/oso/9780192892898.001.0001>
- Ayodele, M. T., & Alege, P. O. (2021).** Oil Price Volatility and Renewable Energy Consumption in Nigeria. *International Journal of Energy Economics and Policy*, 11(4), Article 4.
- Azhgaliyeva, D., Belitski, M., Kalyuzhnova, Y., & Romanov, M. (2018).** Policy instruments for renewable energy: An empirical evaluation of effectiveness. *International Journal of Technology Intelligence and Planning*, 12(1), 24–48. <https://doi.org/10.1504/IJTIP.2018.094409>
- Bamati, N., & Raofi, A. (2020).** Development level and the impact of technological factor on renewable energy production. *Renewable Energy*, 151, 946–955. <https://doi.org/10.1016/j.renene.2019.11.098>
- Bangura, Y., Mustapha, R., & Adamu, S. (1983).** The Deepening Economic Crisis and Its Political Implications. *Africa Development / Afrique et Développement*, 8(3), 97–119.
- Bélaïd, F., & Abderrahmani, F. (2013).** Electricity consumption and economic growth in Algeria: A multivariate causality analysis in the presence of structural change. *Energy Policy*, 55, 286–295. <https://doi.org/10.1016/j.enpol.2012.12.004>
- Bélaïd, F., & Youssef, M. (2017).** Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria. *Energy Policy*, 102, 277–287. <https://doi.org/10.1016/j.enpol.2016.12.012>
- Bernardi, L., Morales, L., Lühiste, M., & Bischof, D. (2018).** The effects of the Fukushima disaster on nuclear energy debates and policies: A two-step comparative examination. *Environmental Politics*, 27(1), 42–68. <https://doi.org/10.1080/09644016.2017.1383007>
- Biresselioglu, M. E., & Zengin Karaibrahimoglu, Y. (2012).** The government orientation and use of renewable energy: Case of Europe. *Renewable Energy*, 47, 29–37. <https://doi.org/10.1016/j.renene.2012.04.006>
- Blazquez, J., Nezamuddin, N., & Zamrik, T. (2018).** Economic policy instruments and market uncertainty: Exploring the impact on renewables adoption. *Renewable and Sustainable Energy Reviews*, 94, 224–233. <https://doi.org/10.1016/j.rser.2018.05.050>

References

- Boudghene Stambouli, A. (2011).** Algerian renewable energy assessment: The challenge of sustainability. *Energy Policy*, 39(8), 4507–4519. <https://doi.org/10.1016/j.enpol.2010.10.005>
- Boudia, S. M., & Santos, J. A. (2019).** Assessment of large-scale wind resource features in Algeria. *Energy*, 189, 116299. <https://doi.org/10.1016/j.energy.2019.116299>
- Bougueroua, M., & Cherifi, A. (2024).** Economic and Political Factors: How Do They Relate to Algeria's Energy Transition? *The POIDEX Review*, 13(2), 230-250. <https://asjp.cerist.dz/en/article/259978>
- Boukhatem, I., & Oei, P.-Y. (2024).** Fossil gas lock-in risks: Analysis of Algeria's electricity sector and implications for a renewable energy transition. *Sustainability Nexus Forum*. <https://doi.org/10.1007/s00550-024-00532-2>
- Boukli Hacène, F., Kasbadji Merzouk, N., Abdelbaki, C., Sheu, E., & Bouhadda, Y. (2016).** Assessment of using wind energy for pumping water: A case study from Ténès (Algeria). *Desalination and Water Treatment*, 57(21), 9718–9727. <https://doi.org/10.1080/19443994.2015.1031705>
- Bouraiou, A., Necaibia, A., Boutassetta, N., Mekhilef, S., Dabou, R., Ziane, A., Sahouane, N., Attoui, I., Mostefaoui, M., & Touaba, O. (2020b).** Status of renewable energy potential and utilization in Algeria. *Journal of Cleaner Production*, 246, 119011. <https://doi.org/10.1016/j.jclepro.2019.119011>
- Bouزيد, Z., Ghellai, N., & Mezghiche, T. (2015).** Overview of Solar Potential, State of the Art and Future of Photovoltaic Installations in Algeria. *International Journal Of Renewable Energy Research*, 5(2), Article 2.
- Bouznit, M., Pablo-Romero, M. del P., & Sánchez-Braza, A. (2020).** Measures to Promote Renewable Energy for Electricity Generation in Algeria. *Sustainability*, 12(4), Article 4. <https://doi.org/10.3390/su12041468>
- Bowden, N., & Payne, J. E. (2010).** Sectoral Analysis of the Causal Relationship Between Renewable and Non-Renewable Energy Consumption and Real Output in the US. *Energy Sources, Part B: Economics, Planning, and Policy*, 5(4), 400–408. <https://doi.org/10.1080/15567240802534250>
- Brini, R., Amara, M., & Jemmali, H. (2017).** Renewable energy consumption, International trade, oil price and economic growth inter-linkages: The case of Tunisia. *Renewable and Sustainable Energy Reviews*, 76, 620–627. <https://doi.org/10.1016/j.rser.2017.03.067>
- Bronk Ramsey, C., Housley, R. A., Lane, C. S., Smith, V. C., & Pollard, A. M. (2015).** The RESET tephra database and associated analytical tools. *Quaternary Science Reviews*, 118, 33–47. <https://doi.org/10.1016/j.quascirev.2014.11.008>
- Brunk, I. (Wuerth), & Hakimi, M. (2022).** Russia, Ukraine, and the Future World Order. *American Journal of International Law*, 116(4), 687–697. <https://doi.org/10.1017/ajil.2022.69>

References

- Chang, T.-H., Huang, C.-M., & Lee, M.-C. (2009).** Threshold effect of the economic growth rate on the renewable energy development from a change in energy price: Evidence from OECD countries. *Energy Policy*, 37(12), 5796–5802. <https://doi.org/10.1016/j.enpol.2009.08.049>
- Cherifi, A., Bougueroua, M. Amri, F. (2024).** The Impact of economic conditions and policy decisions on renewable electricity deployment in Algeria (1980-2021). *Management and Economic Research Journal*, 6(2), 419-446. <https://asjp.cerist.dz/en/article/247051>
- Cheng, Y., Awan, U., papoer, S., & Tan, Z. (2021).** How do technological innovation and fiscal decentralization affect the environment? A story of the fourth industrial revolution and sustainable growth. *Technological Forecasting and Social Change*, 162, 120398. <https://doi.org/10.1016/j.techfore.2020.120398>
- Clemente-Suárez, V. J., Navarro-Jiménez, E., Moreno-Luna, L., Saavedra-Serrano, M. C., Jimenez, M., Simón, J. A., & Tornero-Aguilera, J. F. (2021).** The Impact of the COVID-19 Pandemic on Social, Health, and Economy. *Sustainability*, 13(11), Article 11. <https://doi.org/10.3390/su13116314>
- Corcuera, U. U. T. (2017).** *Effectiveness of Renewable Energy Policies in Promoting Renewable Energy Development: The case of Feed-in-Tariff (FiT) and Renewable Portfolio Standard (RPS)*. <https://thesis.eur.nl/pub/41605>
- Creswell, J. W., & Creswell, J. D. (2017).** *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications. <https://scholar.google.com/scholar?cluster=5941254364905912610&hl=en&oi=scholar>
- Darvishi, H., & Varedi, S. (2018).** Assessment of the contemporaneous impacts of GDP and renewable energy consumption, applying the Dynamic Panel Data: Evidence from developed countries. *International Journal of Energy Economics and Policy*, 8(1), Article 1.
- Deka, A., Özdeşer, H., & Seraj, M. (2023).** The impact of oil prices, financial development and economic growth on renewable energy use. *International Journal of Energy Sector Management*, 18(2), 351–368. <https://doi.org/10.1108/IJESM-09-2022-0008>
- del Río, P., & Mir-Artigues, P. (2014).** Combinations of support instruments for renewable electricity in Europe: A review. *Renewable and Sustainable Energy Reviews*, 40, 287–295. <https://doi.org/10.1016/j.rser.2014.07.039>
- Dickey, D. A., & Fuller, W. A. (1979).** Distribution of the Estimators for Autoregressive Time Series with a Unit Root. *Journal of the American Statistical Association*, 74(366a), 427–431. <https://doi.org/10.1080/01621459.1979.10482531>
- Dogan, E., Inglesi-Lotz, R., & Altinoz, B. (2021).** Examining the determinants of renewable energy deployment: Does the choice of indicator matter? *International Journal of Energy Research*, 45(6), 8780–8793. <https://doi.org/10.1002/er.6413>

References

- Eder, L. V., Provornaya, I. V., Filimonova, I. V., Kozhevnikov, V. D., & Komarova, A. V. (2018).** World energy market in the conditions of low oil prices, the role of renewable energy sources. *Energy Procedia*, 153, 112–117. <https://doi.org/10.1016/j.egypro.2018.10.068>
- Ekins, P. (2004).** Step changes for decarbonising the energy system: Research needs for renewables, energy efficiency and nuclear power. *Energy Policy*, 32(17), 1891–1904. <https://doi.org/10.1016/j.enpol.2004.03.009>
- Ellabban, O., H. Abu-Rub, and F. Blaabjerg (2014).** Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*. (39), 748–764.
- Escoffier, M., Hache, E., Mignon, V., & Paris, A. (2021).** Determinants of solar photovoltaic deployment in the electricity mix: Do oil prices really matter? *Energy Economics*, 97, 105024. <https://doi.org/10.1016/j.eneco.2020.105024>
- Fagiani, R., Richstein, J. C., Hakvoort, R., & De Vries, L. (2014).** The dynamic impact of carbon reduction and renewable support policies on the electricity sector. *Utilities Policy*, 28, 28–41. <https://doi.org/10.1016/j.jup.2013.11.004>
- Gallagher, K. S. (2013).** Why & How Governments Support Renewable Energy. *Daedalus*, 142(1), 59–77. https://doi.org/10.1162/DAED_a_00185
- Ghezloun, A., Chergui, S., & Oucher, N. (2011).** Algerian energy strategy in the context of sustainable development (Legal framework). *Energy Procedia*, 6, 319–324. <https://doi.org/10.1016/j.egypro.2011.05.036>
- Guo, Y., Yu, C., Zhang, H., & Cheng, H. (2021).** Asymmetric between oil prices and renewable energy consumption in the G7 countries. *Energy*, 226, 120319. <https://doi.org/10.1016/j.energy.2021.120319>
- Hamiche, A. M., Stambouli, A. B., & Flazi, S. (2015).** Apergis. *Renewable and Sustainable Energy Reviews*, 41, 261–276. <https://doi.org/10.1016/j.rser.2014.08.024>
- Hebri, A. (2018).** Les transitions énergétiques des pays méditerranéens d'ici 2040. Etude des scénarios proposés par l'Observatoire Méditerranéen de l'énergie OME . , (2)3, 369–350. *الأفاق للدراسات الاقتصادية*
- Himri, Y., Belkacem, D., & Himri, S. (2008).** Wind power potential assessment for three location in Algeria. 12, 2495–2504.
- Himri, Y., Malik, A. S., Boudghene Stambouli, A., Himri, S., & Draoui, B. (2009).** Review and use of the Algerian renewable energy for sustainable development. *Renewable and Sustainable Energy Reviews*, 13(6), 1584–1591. <https://doi.org/10.1016/j.rser.2008.09.007>
- Hock Ann, L., & Midi, H. (2011).** *The effect of high leverage points on the robust autocorrelation test in multiple linear regression* (p. 188).

References

- Hua, Y., Oliphant, M., & Hu, E. J. (2016).** Development of renewable energy in Australia and China: A comparison of policies and status. *Renewable Energy*, 85, 1044–1051. <https://doi.org/10.1016/j.renene.2015.07.060>
- Husaini, D. H., & Lean, H. H. (2022).** Renewable and non-renewable electricity-growth nexus in Asia: The role of private power plants and oil price threshold effect. *Resources Policy*, 78, 102850. <https://doi.org/10.1016/j.resourpol.2022.102850>
- Inglesi-Lotz, R. (2016).** The impact of renewable energy consumption to economic growth: A panel data application. *Energy Economics*, 53, 58–63. <https://doi.org/10.1016/j.eneco.2015.01.003>
- Issawi, C. (1978).** The 1973 Oil Crisis and After. *Journal of Post Keynesian Economics*. <https://www.tandfonline.com/doi/abs/10.1080/01603477.1978.11489099>
- Jiménez-Rodríguez, R., & Sánchez, M. (2005).** Oil price shocks and real GDP growth: Empirical evidence for some OECD countries. *Applied Economics*, 37(2), 201–228. <https://doi.org/10.1080/0003684042000281561>
- Karacan, R., Mukhtarov, S., Barış, İ., İşleyen, A., & Yardımcı, M. (2021).** The Impact of Oil Price on Transition toward Renewable Energy Consumption? Evidence from Russia. *Energies*, 14, 2947. <https://doi.org/10.3390/en14102947>
- Karaeva, A., Magaril, E., & Al-Kayiem, H. H. (2023).** Review and Comparative Analysis of Renewable Energy Policies in the European Union, Russia and the United States. *International Journal of Energy Production and Management*. 2023. Vol. 8. Iss. 1, 8(1), 11–19. <https://doi.org/10.18280/ijepm.080102>
- King, G., Keohane, R. O., & Verba, S. (1994).** Designing Social Inquiry: Scientific Inference in Qualitative Research. In *Designing Social Inquiry*. Princeton University Press. <https://doi.org/10.1515/9781400821211>
- Kuik, F., Adolfsen, J. F., Meyler, A., & Lis, E. (2022).** *Energy price developments in and out of the COVID-19 pandemic – from commodity prices to consumer prices*. https://www.ecb.europa.eu/press/economic-bulletin/articles/2022/html/ecb.ebart202204_01~7b32d31b29.en.html
- Lee, C.-Y., & Huh, S.-Y. (2017).** Forecasting the diffusion of renewable electricity considering the impact of policy and oil prices: The case of South Korea. *Applied Energy*, 197, 29–39. <https://doi.org/10.1016/j.apenergy.2017.03.124>
- Lefilef, A. (2021).** *The Role of Foreign Direct Investment in Achieving Economic Growth, Surveying a Group of International Experiences with Emphasis on the Case of Algeria. Empirical Study for the Period 1990-2018* [Thesis, Kasdi Merbah University - Ouargla]. <http://dspace.univ-ouargla.dz/jspui/handle/123456789/26333>
- Leitão, N. C. (2014).** Economic Growth, Carbon Dioxide Emissions, Renewable Energy and Globalization. *International Journal of Energy Economics and Policy*, 4(3), Article 3.

References

- Li, C., Shi, H., Zeng, L., & Dong, X. (2022).** How Strategic Interaction of Innovation Policies between China's Regional Governments Affects Wind Energy Innovation. *Sustainability*, *14*(5), Article 5. <https://doi.org/10.3390/su14052543>
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009).** The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *BMJ (Clinical Research Ed.)*, *339*, b2700. <https://doi.org/10.1136/bmj.b2700>
- Lipp, J. (2007).** Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. *Energy Policy*, *35*(11), 5481–5495. <https://doi.org/10.1016/j.enpol.2007.05.015>
- Liu, J. (2019).** China's renewable energy law and policy: A critical review. *Renewable and Sustainable Energy Reviews*, *99*, 212–219. <https://doi.org/10.1016/j.rser.2018.10.007>
- Maammeur, H., Hamidat, A., Loukarfi, L., Missoum, M., Abdeladim, K., & Nacer, T. (2017).** Performance investigation of grid-connected PV systems for family farms: Case study of North-West of Algeria. *Renewable and Sustainable Energy Reviews*, *78*, 1208–1220. <https://doi.org/10.1016/j.rser.2017.05.004>
- Maeda, M., & Oe, M. (2017).** Mental Health Consequences and Social Issues After the Fukushima Disaster. *Asia Pacific Journal of Public Health*, *29*(2_suppl), 36S-46S. <https://doi.org/10.1177/1010539516689695>
- Mai, T. N. (2023).** Renewable Energy, GDP (Gross Domestic Product), FDI (Foreign Direct Investment) and CO2 Emissions in Southeast Asia Countries. *International Journal of Energy Economics and Policy*, *13*(2), 284–289.
- Matei, I. (2017a).** Is there a Link between Renewable Energy Consumption and Economic Growth? A Dynamic Panel Investigation for the OECD Countries. *Revue d'économie politique*, *127*(6), 985–1012. <https://doi.org/10.3917/redp.276.0985>
- Matei, I. (2017b).** Is there a Link between Renewable Energy Consumption and Economic Growth? A Dynamic Panel Investigation for the OECD Countries. *Revue d'économie politique*, *127*(6), 985–1012. <https://doi.org/10.3917/redp.276.0985>
- Mitchell, T. (2014).** The Resources of Economics: Making the 1973 Oil Crisis. In *The Limits of Performativity*. Routledge.
- Mukhtarov, S., Humbatova, S., & Hajiyev, N. G.-O. (2021).** Is the Transition to Renewable Energy Consumption Hampered by High Oil Prices? *International Journal of Energy Economics and Policy*, *11*(5), Article 5.
- Mukhtarov, S., Mikayilov, J. I., Humbatova, S., & Muradov, V. (2020).** Do High Oil Prices Obstruct the Transition to Renewable Energy Consumption? *Sustainability*, *12*(11), Article 11. <https://doi.org/10.3390/su12114689>

References

- Murshed, M., & Tanha, M. M. (2021a).** Oil price shocks and renewable energy transition: Empirical evidence from net oil-importing South Asian economies. *Energy, Ecology and Environment*, 6(3), 183–203. <https://doi.org/10.1007/s40974-020-00168-0>
- Murshed, M., & Tanha, M. M. (2021b).** Oil price shocks and renewable energy transition: Empirical evidence from net oil-importing South Asian economies. *Energy, Ecology and Environment*, 6(3), 183–203. <https://doi.org/10.1007/s40974-020-00168-0>
- Narayan, P. K., & Smyth, R. (2005).** Electricity consumption, employment and real income in Australia evidence from multivariate Granger causality tests. *Energy Policy*, 33(9), 1109–1116. <https://doi.org/10.1016/j.enpol.2003.11.010>
- Nasiri, E., Rocha-Meneses, L., Inayat, A., & Kikas, T. (2022).** Impact of Policy Instruments in the Implementation of Renewable Sources of Energy in Selected European Countries. *Sustainability*, 14(10), Article 10. <https://doi.org/10.3390/su14106314>
- Newell, R. G., Pizer, W. A., & Raimi, D. (2019).** U.S. federal government subsidies for clean energy: Design choices and implications. *Energy Economics*, 80, 831–841. <https://doi.org/10.1016/j.eneco.2019.02.018>
- Ntanos, S., Skordoulis, M., Kyriakopoulos, G., Arabatzis, G., Chalikias, M., Galatsidas, S., Batzios, A., & Katsarou, A. (2018a).** Renewable Energy and Economic Growth: Evidence from European Countries. *Sustainability*, 10(8), Article 8. <https://doi.org/10.3390/su10082626>
- Ohler, A., & Fetters, I. (2014).** The causal relationship between renewable electricity generation and GDP growth: A study of energy sources. *Energy Economics*, 43, 125–139. <https://doi.org/10.1016/j.eneco.2014.02.009>
- Omri, A. (2013).** CO2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. *Energy Economics*, 40, 657–664. <https://doi.org/10.1016/j.eneco.2013.09.003>
- Omri, A., Daly, S., & Nguyen, D. K. (2015).** A robust analysis of the relationship between renewable energy consumption and its main drivers. *Applied Economics*, 47(28), 2913–2923. <https://doi.org/10.1080/00036846.2015.1011312>
- Özdurak, C. (2021).** Nexus between crude oil prices, clean energy investments, technology companies and energy democracy. *Green Finance*, 3(3), Article GF-03-03-017. <https://doi.org/10.3934/GF.2021017>
- Panwar, N. L., Kaushik, S. C., & Kothari, S. (2011).** Role of renewable energy sources in environmental protection: A review. *Renewable and Sustainable Energy Reviews*, 15(3), 1513–1524. <https://doi.org/10.1016/j.rser.2010.11.037>
- Pao, H.-T., & Fu, H.-C. (2013).** Renewable energy, non-renewable energy and economic growth in Brazil. *Renewable and Sustainable Energy Reviews*, 25, 381–392. <https://doi.org/10.1016/j.rser.2013.05.004>

References

- Payne, J. E. (2012).** The Causal Dynamics Between US Renewable Energy Consumption, Output, Emissions, and Oil Prices. *Energy Sources, Part B: Economics, Planning, and Policy*, 7(4), 323–330. <https://doi.org/10.1080/15567249.2011.595248>
- Augmented**
- Phillips, P. C. B., & Perron, P. (1988).** Testing for a unit root in time series regression. *Biometrika*, 75(2), 335–346. <https://doi.org/10.1093/biomet/75.2.335>
- Polit, D. F., & Beck, C. T. (2004).** *Nursing Research: Principles and Methods*. Lippincott Williams & Wilkins.
- Pollack, G. A. (1974).** The Economic Consequences of the Energy Crisis. *Foreign Affairs*, 52(3), 452–471. <https://doi.org/10.2307/20038064>
- Rasheed, M. Q., Haseeb, A., Adebayo, T. S., Ahmed, Z., & Ahmad, M. (2022).** The long-run relationship between energy consumption, oil prices, and carbon dioxide emissions in European countries. *Environmental Science and Pollution Research*, 29(16), 24234–24247. <https://doi.org/10.1007/s11356-021-17601-4>
- Ritchie, H., Roser, M., & Rosado, P. (2020).** CO₂ and Greenhouse Gas Emissions. *Our World in Data*. <https://ourworldindata.org/co2/country/algeria>
- Roslan, F. (2018).** The Role of Policy Instruments on the Pattern of Diffusion: The Case of Solar Photovoltaic in Asia Pacific. *European Journal of Economics and Business Studies Articles*, 4. <https://ideas.repec.org//a/eur/ejesjr/231.html>
- Rossouw, S. (2000).** Research Methodology for the Business and Administrative Sciences. *South African Journal of Industrial Psychology*, 26. <https://doi.org/10.4102/sajip.v26i1.690>
- Royal, S., Singh, K., & Chander, R. (2022).** A nexus between renewable energy, FDI, oil prices, oil rent and CO₂ emission: Panel data evidence from G7 economies. *OPEC Energy Review*, 46(2), 208–227. <https://doi.org/10.1111/opec.12228>
- Sadorsky, P. (2009a).** Renewable energy consumption and income in emerging economies. *Energy Policy*, 37(10), 4021–4028. <https://doi.org/10.1016/j.enpol.2009.05.003>
- Sadorsky, P. (2009b).** Renewable energy consumption, CO₂ emissions and oil prices in the G7 countries. *Energy Economics*, 31(3), 456–462. <https://doi.org/10.1016/j.eneco.2008.12.010>
- Sahu, P. K., Solarin, S. A., Al-mulali, U., & Ozturk, I. (2022).** Investigating the asymmetry effects of crude oil price on renewable energy consumption in the United States. *Environmental Science and Pollution Research*, 29(1), 817–827. <https://doi.org/10.1007/s11356-021-15577-9>
- Schumacher, K. (2017).** Large-scale renewable energy project barriers: Environmental impact assessment streamlining efforts in Japan and the EU. *Environmental Impact Assessment Review*, 65, 100–110. <https://doi.org/10.1016/j.eiar.2017.05.001>

References

- Shah, I. H., Hiles, C., & Morley, B. (2018).** How do oil prices, macroeconomic factors and policies affect the market for renewable energy? *Applied Energy*, 215, 87–97. <https://doi.org/10.1016/j.apenergy.2018.01.084>
- Shahbaz, M., Sinha, A., Raghutla, C., & Vo, X. V. (2022).** Decomposing scale and technique effects of financial development and foreign direct investment on renewable energy consumption. *Energy*, 238, 121758. <https://doi.org/10.1016/j.energy.2021.121758>
- Sharpton, T., Lawrence, T., & Hall, M. (2020).** Drivers and barriers to public acceptance of future energy sources and grid expansion in the United States. *Renewable and Sustainable Energy Reviews*, 126, 109826. <https://doi.org/10.1016/j.rser.2020.109826>
- Sheard, J. (2018).** Quantitative data analysis. In *Research Methods: Information, Systems, and Contexts, Second Edition* (pp. 429–452). Elsevier. <https://doi.org/10.1016/B978-0-08-102220-7.00018-2>
- Shen, C., Alberini, A., & Timilsina, G. (2022).** *The Impact of COVID-19 on Electricity Generation: An Empirical Investigation*. The World Bank. <https://doi.org/10.1596/1813-9450-10116>
- Shen, L., He, B., Jiao, L., Song, X., & Zhang, X. (2016).** Research on the development of main policy instruments for improving building energy-efficiency. *Journal of Cleaner Production*, 112, 1789–1803. <https://doi.org/10.1016/j.jclepro.2015.06.108>
- Shen, W. (2017).** Who drives China’s renewable energy policies? Understanding the role of industrial corporations. *Environmental Development*, 21, 87–97. <https://doi.org/10.1016/j.envdev.2016.10.006>
- Smirnova, E., Kot, S., Kolpak, E., & Shestak, V. (2021).** Governmental support and renewable energy production: A cross-country review. *Energy*, 230, 120903. <https://doi.org/10.1016/j.energy.2021.120903>
- Soava, G., Mehedintu, A., Sterpu, M., & Raduteanu, M. (2018).** Impact of renewable energy consumption on economic growth: Evidence from European Union countries. *Technological and Economic Development of Economy*, 24(3), Article 3. <https://doi.org/10.3846/tede.2018.1426>
- Stambouli, A. B. (2011a).** Promotion of renewable energies in Algeria: Strategies and perspectives. *Renewable and Sustainable Energy Reviews*, 15(2), 1169–1181. <https://doi.org/10.1016/j.rser.2010.11.017>
- Stambouli, A. B. (2011b).** Promotion of renewable energies in Algeria: Strategies and perspectives. *Renewable and Sustainable Energy Reviews*, 15(2), 1169–1181. <https://doi.org/10.1016/j.rser.2010.11.017>
- Strielkowski, W., Civin, L., Tarkhanova, E., Tvaronavičienė, M., & Petrenko, Y. (2021).** Renewable Energy in the Sustainable Development of Electrical Power Sector: A Review. *Energies*, 14(24), Article 24. <https://doi.org/10.3390/en14248240>

References

- Susskind, L., Chun, J., Gant, A., Hodgkins, C., Cohen, J., & Lohmar, S. (2022).** Sources of opposition to renewable energy projects in the United States. *Energy Policy*, *165*, 112922. <https://doi.org/10.1016/j.enpol.2022.112922>
- Tahchi, B. (2024).** Algerian gas to strengthen energy security of the European Union: Policy, capacity and strategy. *Energy Reports*, *11*, 3600–3613. <https://doi.org/10.1016/j.egy.2024.03.022>
- Tambari, I., & Failler, P. (2020).** Determining If Oil Prices Significantly Affect Renewable Energy Investment in African Countries with Energy Security Concerns. *Energies*, *13*(24), 6740. <https://doi.org/10.3390/en13246740>
- Tambari, I. J. T., Failler, P., & Jaffry, S. (2023).** The Differential Effects of Oil Prices on the Development of Renewable Energy in Oil-Importing and Oil-Exporting Countries in Africa. *Energies*, *16*(9), Article 9. <https://doi.org/10.3390/en16093803>
- Thadewald, T., & Buning, H. (2007).** Jarque-Bera Test and its Competitors for Testing Normality—A Power Comparison. *Journal of Applied Statistics*, *34*, 87–105. <https://doi.org/10.1080/02664760600994539>
- Troster, V., Shahbaz, M., & Uddin, G. S. (2018).** Renewable energy, oil prices, and economic activity: A Granger-causality in quantiles analysis. *Energy Economics*, *70*, 440–452. <https://doi.org/10.1016/j.eneco.2018.01.029>
- Tudor, C., & Sova, R. (2021).** On the Impact of GDP per Capita, Carbon Intensity and Innovation for Renewable Energy Consumption: Worldwide Evidence. *Energies*, *14*(19), Article 19. <https://doi.org/10.3390/en14196254>
- Uzar, U. (2020).** Political economy of renewable energy: Does institutional quality make a difference in renewable energy consumption? *Renewable Energy*, *155*, 591–603. <https://doi.org/10.1016/j.renene.2020.03.172>
- Wang, N., Tang, L., & Pan, H. (2017).** Effectiveness of policy incentives on electric vehicle acceptance in China: A discrete choice analysis. *Transportation Research Part A: Policy and Practice*, *105*, 210–218. <https://doi.org/10.1016/j.tra.2017.08.009>
- Wang, Q., Li, S., & Pisarenko, Z. (2020).** Heterogeneous effects of energy efficiency, oil price, environmental pressure, R&D investment, and policy on renewable energy—Evidence from the G20 countries. *Energy*, *209*, 118322. <https://doi.org/10.1016/j.energy.2020.118322>
- Wang, R., Hsu, S.-C., Zheng, S., Chen, J.-H., & Li, X. I. (2020).** Renewable energy microgrids: Economic evaluation and decision making for government policies to contribute to affordable and clean energy. *Applied Energy*, *274*, 115287. <https://doi.org/10.1016/j.apenergy.2020.115287>
- White, K. J. (1992).** The Durbin-Watson Test for Autocorrelation in Nonlinear Models. *The Review of Economics and Statistics*, *74*(2), 370–373. <https://doi.org/10.2307/2109675>
- Wrigley, E. A. (1972).** The Process of Modernization and the Industrial Revolution in England. *The Journal of Interdisciplinary History*, *3*(2), 225–259. <https://doi.org/10.2307/202329>

References

- Wrigley, E. A., & Wrigley, E. A. (1990).** *Continuity, Chance and Change: The Character of the Industrial Revolution in England*. Cambridge University Press.
- Yang, X., He, L., Xia, Y., & Chen, Y. (2019).** Effect of government subsidies on renewable energy investments: The threshold effect. *Energy Policy*, *132*, 156–166. <https://doi.org/10.1016/j.enpol.2019.05.039>
- Yoon, J.-H., & Sim, K. (2015).** Why is South Korea's renewable energy policy failing? A qualitative evaluation. *Energy Policy*, *86*, 369–379. <https://doi.org/10.1016/j.enpol.2015.07.020>
- Zafar, M. W., Shahbaz, M., Sinha, A., Sengupta, T., & Qin, Q. (2020).** How renewable energy consumption contribute to environmental quality? The role of education in OECD countries. *Journal of Cleaner Production*, *268*, 122149. <https://doi.org/10.1016/j.jclepro.2020.122149>
- Zahraoui, Y., Khan, M. R. B., AlHamrouni, I., Mekhilef, S., & Ahmed, M. (2021).** Current Status, Scenario, and Prospective of Renewable Energy in Algeria: A Review. *Energies*, *14*(9), Article 9. <https://doi.org/10.3390/en14092354>
- Zeb, R., Salar, L., Awan, U., Zaman, K., & Shahbaz, M. (2014).** Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: Progress towards green economy. *Renewable Energy*, *71*, 123–132. <https://doi.org/10.1016/j.renene.2014.05.012>
- Zhang, T., Yin, J., Li, Z., Jin, Y., Ali, A., & Jiang, B. (2023).** RETRACTED: A dynamic relationship between renewable energy consumption, non-renewable energy consumption, economic growth and CO2 emissions: Evidence from Asian emerging economies. *Frontiers in Environmental Science*, *10*. <https://doi.org/10.3389/fenvs.2022.1092196>
- Zhao, J., Dong, K., Dong, X., & Shahbaz, M. (2022).** How renewable energy alleviate energy poverty? A global analysis. *Renewable Energy*, *186*, 299–311. <https://doi.org/10.1016/j.renene.2022.01.005>
- Zhao, Y., Zhang, Y., & Wei, W. (2021).** Quantifying international oil price shocks on renewable energy development in China. *Applied Economics*, *53*(3), 329–344. <https://doi.org/10.1080/00036846.2020.1808173>
- Zivot, E., & Andrews, D. W. K. (2002).** Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. *Journal of Business & Economic Statistics*, *20*(1), 25–44. <https://doi.org/10.1198/073500102753410372>
- Z. Jacobson, M. (2009).** Review of solutions to global warming, air pollution, and energy security. *Energy & Environmental Science*, *2*(2), 148–173. <https://doi.org/10.1039/B809990C>
- Zulkifli, N., & Haqem, D. (2022).** The Opec Oil Shock Crisis (1973): An Analysis. *Asian Journal of Research in Business Economics and Management*, *4*, 136–148. <https://doi.org/10.55057/ajrbm.2022.4.1.12>

References

in French

Baudhuin, F. (1968). Dictionary of Contemporary Economics, Edition Gérard, Belgium, [in French].

George P. (1950). Geography of energy. Paris, [in French].

Gergaud, O. (2002). Energy modeling and economic optimization of a grid-coupled wind and photovoltaic generation system. Doctoral thesis, Paris Saclay. France.[in French].

Harribey, J-M. (1998). Sustainable development, Economica, Paris. [in French].

Hermans J., (2014). Energy in all its forms. How does it change? Paris, EDP Sciences. [in French].

Marlot, L. (1979). Energy Dictionary, Centre Buref, Paris, [in French].

Merenne-Schoumaker B., (2007). Geography of energy. Actors. Places and issues. Berlin [in French].

Mirecki, A. (2005). Comparative study of energy conversion chains dedicated to a small wind turbine. Doctoral thesis, Institut National Polytechnique de Toulouse, France. [in French].

in Arabic

Al-Zawka, M-K, (2001). Geography of Energy, University Knowledge House, Alexandria, Egypte, [in Arabic].

Ammar, M. (1989). Energy, its sources and economics, The Egyptian Renaissance Bookshop, [in Arabic].

Chitour, C. (1996). Energy - Challenges for the year 2000, OPU. [in Arabic]

Nikolai O-V. (1997). Energy and environmental security. Translated by Bassam Hammoud, Arab Center for Training and Translation and Authorship, Damascus 2000. [in Arabic].

Thesis

Abdelhamid, L. (2012). Contribution to the Improvement of the Performance of Wind Generators - Evaluation of the Impact of Renewable Energies on the Environment. PhD thesis in electronics. Université Hadj Lakhdar de Batna. Algeria. p. 08

Bornan, I. (2007). Natural gas and its role in securing future energy demand - the case of Algeria, PhD thesis, Faculty of Economics and Management, University of Algiers, [in French].

Reports

Balian, R. *The long development of the concept of energy.* The evolution of disciplines and the history of discoveries. Institute of France Science Academy. *March 2013* [in French].

Bp Statistical Review of World Energy 2022 | 71st edition

References

- Climate And Health Country Profile – 2015 Algeria*. WHO (World Health Organization).
- Directive (EU) 2018/ 2001 Of The European Parliament And Of The Council. 11 December 2018*.
- DN, G., Porter, D., & Gunasekar, S. 2013. *Basic Econometrics* Fifth Edition.
- Emissions due to agriculture. Global, regional, and country trends 1990–2018*. FAO (Food and Agriculture Organization) of the United Nations.
- Energy Transition in Algeria - Lessons, Current Status and Perspectives for Accelerated Development of Renewable Energy*, CEREFÉ (Renewable Energy and Energy Efficiency Commission), Algiers, Edition 2020.
- Guerri, D. O. 2011. *Wind energy in Algeria: A brief overview*. CDER.
- Hadji, L. *How is 100% Renewable Energy Possible for Algeria by 2030?* GENI (Global Energy Network Institute) May, 2016.
- Legislative and Regulatory Texts Relating to Renewable Energy and Energy Efficiency*. CEREFÉ (Renewable Energy and Energy Efficiency Commission) May 3, 2024
- Monthly Gas Market Report*. Gas Exporting Countries Forum- GECF-. May 13, 2024.
- National energy balance 2022*, Ministry of Energy and Mines, 2023 Edition.
- Oil Market Report*. 2023, January 18. International Energy Agency -IEA.
- Sonatrach Annual Report, 2022.
- Tracking SDG7 The Energy Progress Report, 2022*.
- Algeria MPO Report*, World Bank, 2024

Websites

- <https://www.worldbank.org/>
- <https://www.irena.org/>
- <https://www.iea.org/>
- <https://www.bp.com/>
- <https://www.statista.com/>
- <https://www.imf.org/>
- <https://ourworldindata.org/>
- <https://www.connaissancedesenergies.org/>
- <https://www.forbes.com/>
- <https://world-nuclear.org/>

References

<https://www.govindicators.org>

<https://www.enerdata.net/>

https://commission.europa.eu/index_en

Appendices

Appendices

Appendix (4.1): KMO and Bartlett Test for Sphericity

Indice KMO et test de Bartlett		
Mesure de précision de l'échantillonnage de Kaiser-Meyer-Olkin.		,806
	Khi-deux approximé	198,886
Test de sphéricité de Bartlett	Ddl	36
	Signification de Bartlett	,000

Appendix (4.2): Matrix of Correlation of the Study

Matrice de corrélation										
	REG	GDPc	OILP	VR	PS	GE	RQ	QL	CC	
Corrélation	REG	1,000	,708	,488	,343	,753	,568	-,561	,429	,479
	GDPc	,708	1,000	,741	,705	,842	,863	-,617	,652	,645
	OILP	,488	,741	1,000	,527	,548	,628	-,523	,515	,730
	VR	,343	,705	,527	1,000	,632	,737	-,076	,640	,558
	PS	,753	,842	,548	,632	1,000	,711	-,445	,498	,530
	GE	,568	,863	,628	,737	,711	1,000	-,294	,862	,580
	RQ	-,561	-,617	-,523	-,076	-,445	-,294	1,000	-,032	-,356
	QL	,429	,652	,515	,640	,498	,862	-,032	1,000	,487
	CC	,479	,645	,730	,558	,530	,580	-,356	,487	1,000

Appendix (4.3): Total Explained Variance of the Model

Composante	Variance totale expliquée					
	Valeurs propres initiales			Extraction Sommes des carrés des facteurs retenus		
	Total	% de la variance	% cumulés	Total	% de la variance	% cumulés
1	5,625	62,494	62,494	5,625	62,494	62,494
2	1,320	14,671	77,166	1,320	14,671	77,166
3	,724	8,049	85,215			
4	,453	5,032	90,247			
5	,404	4,484	94,731			
6	,210	2,338	97,069			
7	,156	1,734	98,803			
8	,072	,801	99,603			
9	,036	,397	100,000			

Méthode d'extraction : Analyse en composantes principales.

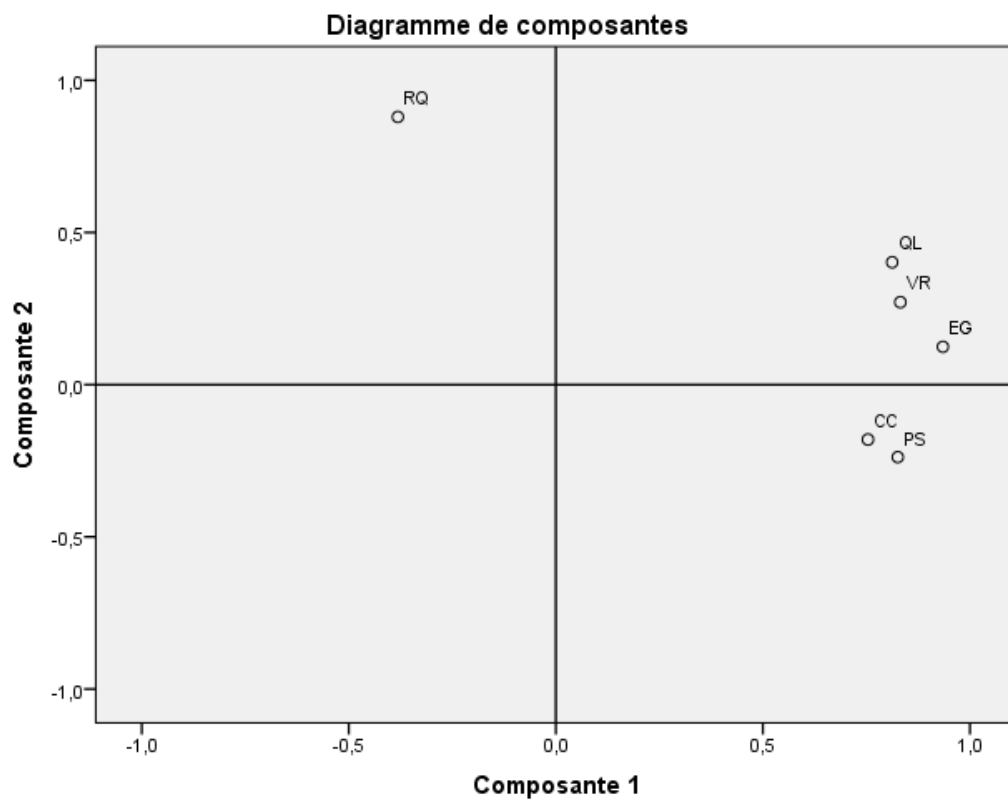
Appendix (4.4): Matrix of Components Regarding all Independent Variables and REG

Matrice des composantes^a

	Composante	
	1	2
REG	,748	-,365
GDPc	,961	-,098
OILP	,803	-,129
VR	,755	,450
PS	,850	-,109
GE	,898	,285
RQ	-,524	,777
QL	,741	,512
CC	,758	-,005

Méthode d'extraction : Analyse en composantes principales.
a. 2 composantes extraites.

Appendix (4.5): Graphical Representation of Political Variables



Appendix (4.6): Matrix of Components regarding Political variables and REG

Matrice des composantes^a

	Composante	
	1	2
VR	,832	,271
PS	,826	-,238
EG	,935	,124
RQ	-,382	,880
QL	,812	,402
CC	,754	-,180

Méthode d'extraction : Analyse en composantes principales.
a. 2 composantes extraites.

Appendix (4.7). Output Without PCA Method

Presence of autocorrelation / Presence of Multicollinearity / Invalid ARDL model

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	8.680673	Prob. F(2,4)	0.0351
Obs*R-squared	20.31865	Prob. Chi-Square(2)	0.0000

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	3.904252	Prob. F(18,6)	0.0497
Obs*R-squared	23.03347	Prob. Chi-Square(18)	0.1893
Scaled explained SS	1.524879	Prob. Chi-Square(18)	1.0000

Dependent Variable: REG

Method: ARDL

Date: 08/14/24 Time: 20:44

Sample (adjusted): 1997 2021

Included observations: 25 after adjustments

Dependent lags: 1 (Fixed)

Dynamic regressors (1 lag, fixed): OILP GDPC CC PS GE QL RQ VA

Fixed regressors: NREP C

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
REG(-1)	-0.027059	0.077112	-0.350910	0.7376
OILP	-2.722377	1.165163	-2.336477	0.0581
OILP(-1)	-0.323166	0.669209	-0.482908	0.6463
GDPC	1.314596	0.274391	4.790952	0.0030
GDPC(-1)	-1.018004	0.334177	-3.046304	0.0226
CC	2082.423	237.7186	8.760034	0.0001

Appendices

CC(-1)	-549.0352	134.6304	-4.078093	0.0065
PS	952.8648	159.5995	5.970351	0.0010
PS(-1)	-201.7186	82.82729	-2.435413	0.0508
GE	1319.875	191.8034	6.881398	0.0005
GE(-1)	-1485.592	189.5115	-7.839058	0.0002
QL	-321.5592	178.7843	-1.798588	0.1222
QL(-1)	90.76114	218.5277	0.415330	0.6923
RQ	-195.3489	200.0472	-0.976514	0.3665
RQ(-1)	1473.454	184.1812	8.000027	0.0002
VA	-1693.098	196.4800	-8.617152	0.0001
VA(-1)	-1448.967	236.9449	-6.115206	0.0009
NREP	1036.202	81.62866	12.69409	0.0000
C	-1387.167	851.4089	-1.629260	0.1544
<hr/>				
R-squared	0.995635	Mean dependent var	340.7600	
Adjusted R-squared	0.982538	S.D. dependent var	252.1863	
S.E. of regression	33.32465	Akaike info criterion	9.943355	
Sum squared resid	6663.193	Schwarz criterion	10.86970	
Log likelihood	-105.2919	Hannan-Quinn criter.	10.20028	
F-statistic	76.02398	Durbin-Watson stat	3.805651	
Prob(F-statistic)	0.000013			

Appendix (5.1): Descriptive Statistics of the Variables

	REG	GDPG	OILP	PF	RQF
Mean	329.1154	3698.648	56.88269	0.126454	8.54E-17
Median	259.5000	3842.826	54.35500	0.308060	0.402035
Maximum	845.0000	4224.037	111.6700	1.840280	1.343940
Minimum	21.00000	2884.120	12.72000	-1.930570	-1.825750
Std. Dev.	254.1251	441.0897	31.03933	1.114540	1.000000
Skewness	0.596940	-0.664280	0.353259	-0.525821	-0.439708
Kurtosis	2.118505	2.034604	2.001281	2.543491	1.840574
Jarque-Bera	2.385912	2.921814	1.621322	1.423883	2.294109
Probability	0.303323	0.232026	0.444564	0.490691	0.317571
Sum	8557.000	96164.85	1478.950	3.287800	1.11E-15
Sum Sq. Dev.	1614489.	4864003.	24086.00	31.05498	25.00000
Observations	26	26	26	26	26

Appendix (5.2): The Output of the Augmented Dickey-Fuller Test for Stationarity (REG at Level Only Cons)

Null Hypothesis: REG has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.488315	0.5295
Test critical values:		
1% level	-3.600987	
5% level	-2.935001	
10% level	-2.605836	

Appendices

Appendix (5.3): The Output of the Augmented Dickey-Fuller Test for Stationarity (REG at Level Cons and Trend)

Null Hypothesis: REG has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.972168	0.1521
Test critical values:		
1% level	-4.198503	
5% level	-3.523623	
10% level	-3.192902	

Appendix (5.4): The Output of the Augmented Dickey-Fuller Test for Stationarity (REG at 1st Difference Only Cons)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-7.384747	0.0000
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

Appendix (5.5): The Output of the Augmented Dickey-Fuller Test for Stationarity (REG at 1st Difference Cons and Trend)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 4 (Automatic - based on SIC, maxlag=9)

Appendices

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.065784	0.0001
Test critical values:		
1% level	-4.234972	
5% level	-3.540328	
10% level	-3.202445	

Appendix (5.6): The Output of the Dickey-Fuller Test for Stationarity (REG at Level Only Cons)

Null Hypothesis: REG has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-1.413798
Test critical values:	
1% level	-2.622585
5% level	-1.949097
10% level	-1.611824

Appendix (5.7): The Output of the Dickey-Fuller Test for Stationarity (REG at Level Cons and Trend)

Null Hypothesis: REG has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-3.002569
Test critical values:	
1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendices

Appendix (5.8): The Output of the Dickey-Fuller Test for Stationarity (REG at 1st Difference Only Cons)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-7.375645
Test critical values: 1% level	-2.624057
5% level	-1.949319
10% level	-1.611711

Appendix (5.9): The Output of the Dickey-Fuller Test for Stationarity (REG at 1st Difference Cons and Trend)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-7.532029
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendix (5.10): The Output of the Phillips and Perron Test for Stationarity (REG at Level Only Cons)

Null Hypothesis: REG has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
--	-------------	--------

Appendices

Phillips-Perron test statistic		-2.901987	0.1725
Test critical values:	1% level	-4.198503	
	5% level	-3.523623	
	10% level	-3.192902	

Appendix (5.11): The Output of the Phillips and Perron Test for Stationarity (REG at Level Cons and Trend)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant

Bandwidth: 27 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-10.01404	0.0000
Test critical values:	1% level	-3.605593	
	5% level	-2.936942	
	10% level	-2.606857	

Appendix (5.12): The Output of the Phillips and Perron Test for Stationarity (REG at 1st Difference Only Cons)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant

Bandwidth: 27 (Newey-West automatic) using Bartlett kernel

		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		-10.01404	0.0000
Test critical values:	1% level	-3.605593	
	5% level	-2.936942	
	10% level	-2.606857	

Appendices

Appendix (5.13): The Output of the Phillips and Perron Test for Stationarity (REG at 1st Difference Cons and Trend)

Null Hypothesis: D(REG) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 39 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-20.47287	0.0000
Test critical values:		
1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

Appendix (5.14): The Output of the Zivot and Andrew Test for Stationarity (REG at Level Only Cons)

Zivot-Andrews Unit Root Test

Date: 06/09/24 Time: 23:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: REG has a unit root with a structural
break in the intercept

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 1988

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-3.899826	0.255228
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

Appendix (5.15): The Output of the Zivot and Andrew Test for Stationarity (REG at Level Cons and Trend)

Zivot-Andrews Unit Root Test

ate: 06/09/24 Time: 23:06

Sample: 1980 2021

Appendices

Included observations: 42

Null Hypothesis: REG has a unit root with a structural
break in both the intercept and trend

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 2003

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-4.442284	0.211397
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Appendix (5.16): The Output of the Zivot and Andrew Test for Stationarity (REG at 1st Difference Only Cons)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: DREG has a unit root with a structural
break in the intercept

Chosen lag length: 4 (maximum lags: 4)

Chosen break point: 2009

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-6.511832	0.027435
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

Appendices

Appendix (5.17): The Output of the Zivot and Andrew Test for Stationarity (REG at 1st Difference Cons and Trend)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: DREG has a unit root with a structural
break in both the intercept and trend

Chosen lag length: 4 (maximum lags: 4)

Chosen break point: 2013

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-7.116189	0.010996
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Appendix (5.18): The Output of the Augmented Dickey-Fuller Test for Stationarity (OILP at Level Only Cons)

Null Hypothesis: OILP has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.411416	0.5674
Test critical values:		
1% level	-3.600987	
5% level	-2.935001	
10% level	-2.605836	

Appendices

Appendix (5.19): The Output of the Augmented Dickey-Fuller Test for Stationarity (OILP at Level Cons and Trend)

Null Hypothesis: OILP has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.360717	0.3936
Test critical values:		
1% level	-4.198503	
5% level	-3.523623	
10% level	-3.192902	

Appendix (5.20): The Output of the Augmented Dickey-Fuller Test for Stationarity (OILP at 1st Difference Only Cons)

Null Hypothesis: D(OILP) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.862890	0.0000
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

Appendix (5.21): The Output of the Augmented Dickey-Fuller Test for Stationarity (OILP at 1st Difference Cons and Trend)

Null Hypothesis: D(OILP) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
--	-------------	--------

Appendices

Augmented Dickey-Fuller test statistic		-5.786129	0.0001
Test critical values:	1% level	-4.205004	
	5% level	-3.526609	
	10% level	-3.194611	

Appendix (5.22): The Output of the Dickey-Fuller Test for Stationarity (OILP at Level Only Cons)

Null Hypothesis: OILP has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-1.424870
Test critical values:	1% level	-2.622585
	5% level	-1.949097
	10% level	-1.611824

Appendix (5.23): The Output of the Dickey-Fuller Test for Stationarity (OILP at Level Cons and Trend)

Null Hypothesis: OILP has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-2.214316
Test critical values:	1% level	-3.770000
	5% level	-3.190000
	10% level	-2.890000

Appendices

Appendix (5.24): The Output of the Dickey-Fuller Test for Stationarity (OILP at 1st Difference Only Cons)

Null Hypothesis: D(OILP) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-5.899556
Test critical values: 1% level	-2.624057
5% level	-1.949319
10% level	-1.611711

Appendix (5.25): The Output of the Dickey-Fuller Test for Stationarity (OILP at 1st Difference Cons and Trend)

Null Hypothesis: D(OILP) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-5.802521
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendix (5.26): The Output of the Zivot and Andrew Test for Stationarity (OILP at Level Only Cons)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: OILP has a unit root with a structural

Appendices

break in the intercept

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 2004

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-3.548266	0.029974
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

Appendix (5.27): The Output of the Zivot and Andrew Test for Stationarity (OILP at Level Cons and Trend)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: OILP has a unit root with a structural

break in both the intercept and trend

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 2005

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-3.578340	0.016897
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Appendix (5.28): The Output of the Zivot and Andrew Test for Stationarity (OILP at 1st Difference Only Cons)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Appendices

Null Hypothesis: DOILP has a unit root with a structural
break in the intercept

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 2013

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-6.650064	0.022273
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

Appendix (5.29): The Output of the Zivot and Andrew Test for Stationarity (OILP at 1st Difference Cons and Trend)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: DOILP has a unit root with a structural
break in both the intercept and trend

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 2014

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-6.942016	0.004211
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Appendix (5.30): The Output of the Phillips and Perron Test for Stationarity (OILP at Level Only Cons)

Null Hypothesis: OILP has a unit root

Exogenous: Constant

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

Appendices

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.411416	0.5674
Test critical values:		
1% level	-3.600987	
5% level	-2.935001	
10% level	-2.605836	

Appendix (5.31): The Output of the Phillips and Perron Test for Stationarity (OILP at Level Cons and Trend)

Null Hypothesis: OILP has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.360717	0.3936
Test critical values:		
1% level	-4.198503	
5% level	-3.523623	
10% level	-3.192902	

Appendix (5.32): The Output of the Phillips and Perron Test for Stationarity (OILP at 1st Difference Only Cons)

Null Hypothesis: D(OILP) has a unit root

Exogenous: Constant

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-5.798397	0.0000
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

Appendices

Appendix (5.33): The Output of the Phillips and Perron Test for Stationarity (OILP at 1st Difference Cons and Trend)

Null Hypothesis: D(OILP) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-5.710711	0.0002
Test critical values:		
1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

Appendix (5.34): The Output of the Augmented Dickey-Fuller Test for Stationarity (GDPC at at Level Only Cons)

Null Hypothesis: GDPC has a unit root

Exogenous: Constant

Lag Length: 3 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.405564	0.5694
Test critical values:		
1% level	-3.615588	
5% level	-2.941145	
10% level	-2.609066	

Appendix (5.35): The Output of the Augmented Dickey-Fuller Test for Stationarity (GDPC at Level Cons and Trend)

Null Hypothesis: GDPC has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 2 (Automatic - based on SIC, maxlag=9)

Appendices

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.280714	0.4340
Test critical values:		
1% level	-4.211868	
5% level	-3.529758	
10% level	-3.196411	

Appendix (5.36): The Output of the Augmented Dickey-Fuller Test for Stationarity (GDPc at 1st Difference Only Cons)

Null Hypothesis: D(GDPC) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.054012	0.0030
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

Appendix (5.37): The Output of the Augmented Dickey-Fuller Test for Stationarity (GDPc at 1st Difference Cons and Trend)

Null Hypothesis: D(GDPC) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.009480	0.0163
Test critical values:		
1% level	-4.205004	
5% level	-3.526609	
10% level	-3.194611	

Appendices

Appendix (5.38): The Output of the Dickey-Fuller Test for Stationarity (GDPc at Level Only Cons)

Null Hypothesis: GDPC has a unit root

Exogenous: Constant

Lag Length: 3 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-1.413085
Test critical values: 1% level	-2.627238
5% level	-1.949856
10% level	-1.611469

Appendix (5.39): The Output of the Dickey-Fuller Test for Stationarity (GDPc at Level Cons and Trend)

Null Hypothesis: GDPC has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 3 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-2.483037
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendix (5.40): The Output of the Dickey-Fuller Test for Stationarity (GDPc at 1st Difference Only Cons)

Null Hypothesis: D(GDPC) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
--	-------------

Appendices

Elliott-Rothenberg-Stock DF-GLS test statistic		-4.095580
Test critical values:	1% level	-2.624057
	5% level	-1.949319
	10% level	-1.611711

Appendix (5.41): The Output of the Dickey-Fuller Test for Stationarity (GDPc at 1st Difference Cons and Trend)

Null Hypothesis: D(GDPC) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-4.110951
Test critical values:	1% level
	5% level
	10% level

Appendix (5.42): The Output of the Phillips and Perron Test for Stationarity (GDPc at Level Only Cons)

Null Hypothesis: GDPC has a unit root

Exogenous: Constant

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-0.827567	0.8005
Test critical values:	1% level	-3.600987
	5% level	-2.935001
	10% level	-2.605836

Appendices

Appendix (5.43): The Output of the Phillips and Perron Test for Stationarity (GDPc at Level Cons and Trend)

Null Hypothesis: GDPC has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.575036	0.7856
Test critical values:		
1% level	-4.198503	
5% level	-3.523623	
10% level	-3.192902	

Appendix (5.44): The Output of the Phillips and Perron Test for Stationarity (GDPc at 1st Difference Only Cons)

Null Hypothesis: D(GDPC) has a unit root

Exogenous: Constant

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-4.158744	0.0023
Test critical values:		
1% level	-3.605593	
5% level	-2.936942	
10% level	-2.606857	

Appendix (5.45): The Output of the Phillips and Perron Test for Stationarity (GDPc at 1st Difference Cons and Trend)

Null Hypothesis: D(GDPC) has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
--	-------------	--------

Appendices

Phillips-Perron test statistic		-4.109276	0.0127
Test critical values:	1% level	-4.205004	
	5% level	-3.526609	
	10% level	-3.194611	

Appendix (5.46): The Output of the Zivot and Andrew Test for Stationarity (GDPc at Level Only Cons)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: GDPc has a unit root with a structural
break in the intercept

Chosen lag length: 3 (maximum lags: 4)

Chosen break point: 2002

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-3.528186	0.042982
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

Appendix (5.47): The Output of the Zivot and Andrew Test for Stationarity (GDPc at Level Cons and Trend)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: GDPc has a unit root with a structural
break in both the intercept and trend

Chosen lag length: 3 (maximum lags: 4)

Chosen break point: 1991

Appendices

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-2.852607	0.273234
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Appendix (5.48): The Output of the Zivot and Andrew Test for Stationarity (GDPc at 1st Difference Only Cons)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: DGDPC has a unit root with a structural
break in the intercept

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 1995

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-5.572712	0.000664
1% critical value:	-5.34	
5% critical value:	-4.93	
10% critical value:	-4.58	

Appendix (5.49): The Output of the Zivot and Andrew Test for Stationarity (GDPc at 1st Difference Cons and Trend)

Zivot-Andrews Unit Root Test

Date: 06/10/24 Time: 00:06

Sample: 1980 2021

Included observations: 42

Null Hypothesis: DGDPC has a unit root with a structural
break in both the intercept and trend

Appendices

Chosen lag length: 0 (maximum lags: 4)

Chosen break point: 1995

	t-Statistic	Prob. *
Zivot-Andrews test statistic	-5.858188	0.007788
1% critical value:	-5.57	
5% critical value:	-5.08	
10% critical value:	-4.82	

Appendix (5.50): The Output of the Augmented Dickey-Fuller Test for Stationarity (PF at Level Only Cons)

Null Hypothesis: PF has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.325552	0.1722
Test critical values:		
1% level	-3.724070	
5% level	-2.986225	
10% level	-2.632604	

Appendix (5.51): The Output of the Augmented Dickey-Fuller Test for Stationarity (PF at Level Cons and Trend)

Null Hypothesis: PF has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.996291	0.5750
Test critical values:		
1% level	-4.374307	
5% level	-3.603202	
10% level	-3.238054	

Appendices

Appendix (5.52): The Output of the Augmented Dickey-Fuller Test for Stationarity (PF at 1st Difference Only Cons)

Null Hypothesis: D(PF) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-5.948346	0.0001
Test critical values:		
1% level	-3.737853	
5% level	-2.991878	
10% level	-2.635542	

Appendix (5.53): The Output of the Augmented Dickey-Fuller Test for Stationarity (PF at 1st Difference Cons and Trend)

Null Hypothesis: D(PF) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.267621	0.0002
Test critical values:		
1% level	-4.394309	
5% level	-3.612199	
10% level	-3.243079	

Appendix (5.54): The Output of the Dickey-Fuller GLS Test for Stationarity (PF at Level Only Cons)

Null Hypothesis: PF has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-1.790732
Test critical values:	
1% level	-2.660720
5% level	-1.955020
10% level	-1.609070

Appendices

Appendix (5.55): The Output of the Dickey-Fuller GLS Test for Stationarity (PF at Level Cons and Trend)

Null Hypothesis: PF has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-2.100930
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendix (5.56): The Output of the Dickey-Fuller GLS Test for Stationarity (PF at 1st Difference Only Cons)

Null Hypothesis: D(PF) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-6.080765
Test critical values: 1% level	-2.664853
5% level	-1.955681
10% level	-1.608793

Appendix (5.57): The Output of the Dickey-Fuller GLS Test for Stationarity (PF at 1st Difference Cons and Trend)

Null Hypothesis: D(PF) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-6.516301
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendices

Appendix (5.58): The Output of the Phillips-Perron Test for Stationarity (PF at Level Only Cons)

Null Hypothesis: PF has a unit root

Exogenous: Constant

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.325552	0.1722
Test critical values: 1% level	-3.724070	
5% level	-2.986225	
10% level	-2.632604	

Appendix (5.59): The Output of the Phillips-Perron Test for Stationarity (PF at Level Cons and Trend)

Null Hypothesis: PF has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-1.996291	0.5750
Test critical values: 1% level	-4.374307	
5% level	-3.603202	
10% level	-3.238054	

Appendix (5.60): The Output of the Phillips-Perron Test for Stationarity (PF at 1st Difference Only Cons)

Null Hypothesis: D(PF) has a unit root

Exogenous: Constant

Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-5.948346	0.0001
Test critical values: 1% level	-3.737853	
5% level	-2.991878	
10% level	-2.635542	

Appendices

Appendix (5.61): The Output of the Phillips-Perron Test for Stationarity (PF at 1st Difference Cons and Trend)

Null Hypothesis: D(PF) has a unit root
Exogenous: Constant, Linear Trend
Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-6.286436	0.0002
Test critical values:		
1% level	-4.394309	
5% level	-3.612199	
10% level	-3.243079	

Appendix (5.62): The Output of the Augmented Dickey-Fuller Test for Stationarity (RQF at Level Only Cons)

Null Hypothesis: RQF has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.364927	0.5820
Test critical values:		
1% level	-3.737853	
5% level	-2.991878	
10% level	-2.635542	

Appendix (5.63): The Output of the Augmented Dickey-Fuller Test for Stationarity (RQF at Level Cons and Trend)

Null Hypothesis: RQF has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 5 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.039551	0.3454
Test critical values:		
1% level	-4.498307	
5% level	-3.658446	
10% level	-3.268973	

Appendices

Appendix (5.64): The Output of the Augmented Dickey-Fuller Test for Stationarity (RQF at 1st Difference Only Cons)

Null Hypothesis: D(RQF) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-2.951742	0.0542
Test critical values: 1% level	-3.737853	
5% level	-2.991878	
10% level	-2.635542	

Appendix (5.65): The Output of the Augmented Dickey-Fuller Test for Stationarity (RQF at 1st Difference Cons and Trend)

Null Hypothesis: D(RQF) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-4.659451	0.0401
Test critical values: 1% level	-4.394309	
5% level	-3.612199	
10% level	-3.243079	

Appendix (5.66): The Output of the Dickey-Fuller GLS Test for Stationarity (RQF at Level Only Cons)

Null Hypothesis: RQF has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-1.460684
Test critical values: 1% level	-2.664853
5% level	-1.955681
10% level	-1.608793

Appendices

Appendix (5.67): The Output of the Dickey-Fuller GLS Test for Stationarity (RQF at Level Cons and Trend)

Null Hypothesis: RQF has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-2.107444
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendix (5.68): The Output of the Dickey-Fuller GLS Test for Stationarity (RQF at 1st Difference Only Cons)

Null Hypothesis: D(RQF) has a unit root

Exogenous: Constant

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-2.531374
Test critical values: 1% level	-2.664853
5% level	-1.955681
10% level	-1.608793

Appendix (5.69): The Output of the Dickey-Fuller GLS Test for Stationarity (RQF at 1st Difference Cons and Trend)

Null Hypothesis: D(RQF) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=5)

	t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic	-2.937894
Test critical values: 1% level	-3.770000
5% level	-3.190000
10% level	-2.890000

Appendix (5.70): The Output of the Phillips-Perron Test for Stationarity (RQF at Level Only Cons)

Null Hypothesis: RQF has a unit root

Exogenous: Constant

Bandwidth: 2 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-0.932317	0.7606
Test critical values: 1% level	-3.724070	
5% level	-2.986225	
10% level	-2.632604	

Appendix (5.71): The Output of the Phillips-Perron Test for Stationarity (RQF at Level Cons and Trend)

Null Hypothesis: RQF has a unit root

Exogenous: Constant, Linear Trend

Bandwidth: 1 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.624054	0.2736
Test critical values: 1% level	-4.374307	
5% level	-3.603202	
10% level	-3.238054	

Appendix (5.72): The Output of the Phillips-Perron Test for Stationarity (RQF at 1st Difference Only Cons)

Null Hypothesis: D(RQF) has a unit root

Exogenous: Constant

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-2.876785	0.0630
Test critical values: 1% level	-3.737853	
5% level	-2.991878	
10% level	-2.635542	

Appendices

Appendix (5.73): The Output of the Phillips-Perron Test for Stationarity (RQF at 1st Difference Cons and Trend)

Null Hypothesis: D(RQF) has a unit root

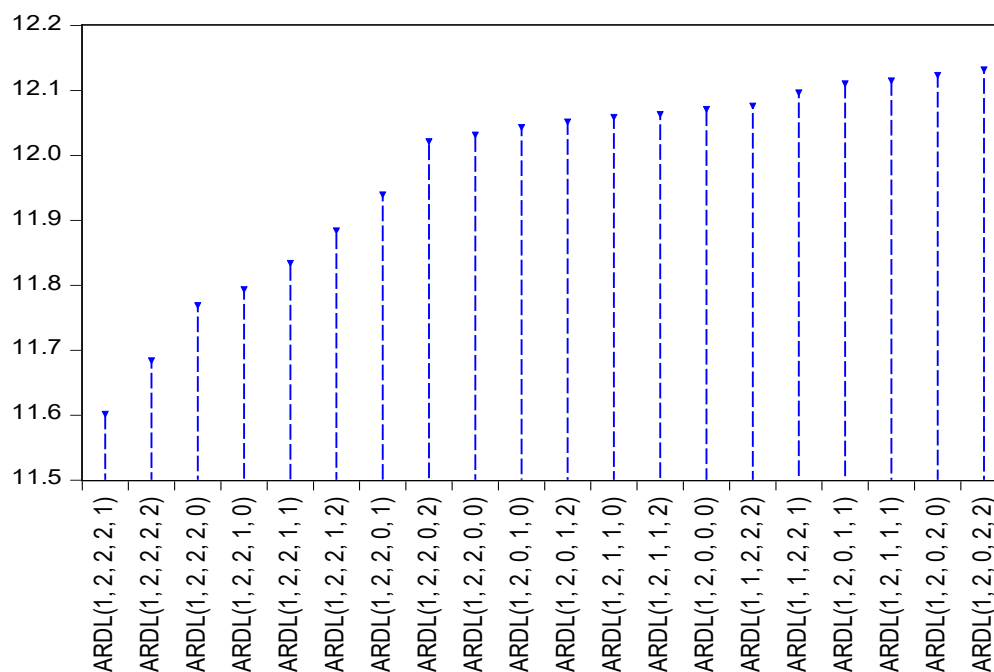
Exogenous: Constant, Linear Trend

Bandwidth: 3 (Newey-West automatic) using Bartlett kernel

	Adj. t-Stat	Prob.*
Phillips-Perron test statistic	-3.543757	0.0699
Test critical values: 1% level	-4.394309	
5% level	-3.612199	
10% level	-3.243079	

Appendix (5.74): Akaike Information Criteria

Akaike Information Criteria (top 20 models)



Appendix (5.75): The results of the ARDL estimation

Dependent Variable: REG

Method: ARDL

Date: 07/03/24 Time: 11:22

Sample (adjusted): 1998 2021

Appendices

Included observations: 24 after adjustments

Maximum dependent lags: 1 (Automatic selection)

Model selection method: Akaike info criterion (AIC)

Dynamic regressors (2 lags, automatic): OILP GDPC PF RQF

Fixed regressors: NREP C

Number of models evaluated: 81

Selected Model: ARDL(1, 2, 2, 2, 1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
REG(-1)	-0.152421	0.185874	-0.820023	0.4313
OILP	0.706437	1.128137	0.626198	0.5452
OILP(-1)	-1.108439	1.363064	-0.813196	0.4350
OILP(-2)	-4.610454	1.647721	-2.798080	0.0189
GDPC	-0.164406	0.424276	-0.387497	0.7065
GDPC(-1)	-1.133339	0.427363	-2.651939	0.0242
GDPC(-2)	1.392078	0.446621	3.116912	0.0109
PF	119.1134	44.93160	2.650995	0.0243
PF(-1)	74.47227	47.04234	1.583090	0.1445
PF(-2)	-74.44007	38.65468	-1.925771	0.0830
RQF	263.7188	77.34686	3.409560	0.0067
RQF(-1)	-208.5291	123.6033	-1.687083	0.1225
NREP	275.9806	96.96957	2.846053	0.0174
C	220.1561	818.5276	0.268966	0.7934
R-squared	0.966301	Mean dependent var		354.0833
Adjusted R-squared	0.922492	S.D. dependent var		248.4599
S.E. of regression	69.17186	Akaike info criterion		11.60226
Sum squared resid	47847.47	Schwarz criterion		12.28946
Log likelihood	-125.2272	Hannan-Quinn criter.		11.78458
F-statistic	22.05721	Durbin-Watson stat		2.685203
Prob(F-statistic)	0.000013			

*Note: p-values and any subsequent tests do not account for model

selection.

Appendix (5.76): the results of the Bounds Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	14.54854	10%	2.2	3.09
K	4	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37
			Finite Sample: n=35	
Actual Sample Size	24	10%	2.46	3.46
		5%	2.947	4.088
		1%	4.093	5.532
			Finite Sample: n=30	
		10%	2.525	3.56
		5%	3.058	4.223
		1%	4.28	5.84

Appendix (5.77): The Findings of the ARDL Error Correction Regression

ARDL Error Correction Regression

Dependent Variable: D(REG)

Selected Model: ARDL(1, 2, 2, 2, 1)

Case 2: Restricted Constant and No Trend

Appendices

Date: 07/20/24 Time: 13:13

Sample: 1980 2021

Included observations: 24

ECM Regression

Case 2: Restricted Constant and No Trend

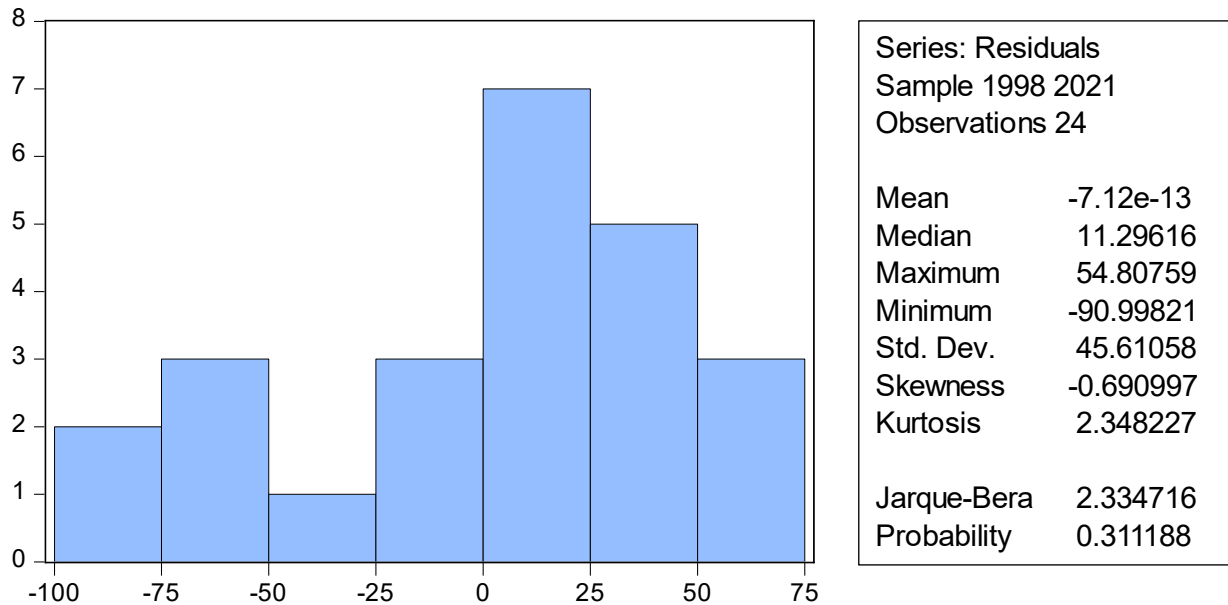
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(OILP)	0.706437	0.673600	1.048748	0.3190
D(OILP(-1))	4.610454	0.856161	5.385033	0.0003
D(GDPC)	-0.164406	0.177327	-0.927133	0.3757
D(GDPC(-1))	-1.392078	0.229142	-6.075189	0.0001
D(PF)	119.1134	19.75363	6.029953	0.0001
D(PF(-1))	74.44007	22.47804	3.311680	0.0079
D(RQF)	263.7188	45.30421	5.821065	0.0002
NREP	275.9806	26.32476	10.48369	0.0000
CointEq(-1)*	-1.152421	0.100712	-11.44276	0.0000

R-squared	0.922384	Mean dependent var	26.70833
Adjusted R-squared	0.880989	S.D. dependent var	163.7157
S.E. of regression	56.47859	Akaike info criterion	11.18560
Sum squared resid	47847.47	Schwarz criterion	11.62737
Log likelihood	-125.2272	Hannan-Quinn criter.	11.30280
Durbin-Watson stat	2.685203		

* p-value incompatible with t-Bounds distribution.

Appendices

Appendix (5.78): The Findings of the Jaque Bera Normality Test



Appendix (5.79): The Findings of the Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.371482	Prob. F(1,9)	0.1580
Obs*R-squared	5.005115	Prob. Chi-Square(1)	0.0253

Appendix (5.80): The Findings of the Heteroskedasticity Test: Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.726332	Prob. F(13,10)	0.7104
Obs*R-squared	11.65579	Prob. Chi-Square(13)	0.5561
Scaled explained SS	1.364119	Prob. Chi-Square(13)	1.0000

Appendix (5.81): The Findings of the Ramsey RESET Test

Ramsey RESET Test

Equation: ARDL

Specification: REG REG(-1) OILP OILP(-1) OILP(-2) GDPC GDPC(-1)

GDPC(-2) PF PF(-1) PF(-2) RQF RQF(-1) NREP C

Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.175474	9	0.8646
F-statistic	0.030791	(1, 9)	0.8646

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	163.1396	1	163.1396
Restricted SSR	47847.47	10	4784.747
Unrestricted SSR	47684.33	9	5298.259
