ENERGY AND POWER IN INTERNATIONAL POLITICAL ECONOMY

Editor
Prof. Dr. Arzu AL

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PREFACE

Energy is not merely a resource; it is a foundational axis upon which the architecture of the global political economy rests. It underpins state power, influences military strategy, drives technological innovation, and shapes the contours of development and inequality. As climate change intensifies, strategic rivalries deepen, and the energy transition accelerates, the governance of energy becomes inseparable from the quest for security, justice, and sustainability. This edited volume, Energy and Power in International Political Economy, brings together leading scholars to examine energy as a multidimensional and contested field—located at the intersection of geopolitics, ethics, economic transformation, and global governance.

Throughout history, the control and securitization of energy resources have played a decisive role in shaping military doctrines, defense expenditures, and international alignments. At the same time, the global shift from fossil fuels to renewable sources has introduced new sources of competition—over critical minerals, technological leadership, and green market dominance. Energy has thus evolved from a purely technical domain into a strategic terrain of struggle, adaptation, and opportunity.

This book opens with **Chapter 1**, authored by *Prof. Dr. Arzu AL* and *Elife Beyza KAPLAN*, which explores the relationship between energy and militarism through the lens of International Political Economy. It reveals how national energy infrastructures are militarized, securitized, and embedded within geopolitical rivalries.

In **Chapter 2,** *Asst. Prof. Dr. Li ZENG* and *Prof. Dr. Wee-Yeap LAU* offer a comparative analysis of how the United States, China, and the European Union strategically navigate the global energy transition. Their work highlights competing visions of low-carbon leadership, revealing both cooperation and rivalry in shaping the next energy order.

Chapter 3, by *Asst. Prof. Dr. Khalid Muhammad MUNIB*, focuses on oil geopolitics in the Persian Gulf, particularly the Saudi-Iranian rivalry. It examines how energy corridors become contested geopolitical assets, with implications for regional and global stability.

Chapter 4, contributed by *Prof. Dr. John N. HATZOPOULOS*, takes a normative turn, proposing a science-based ethical framework for global energy management. It challenges conventional market-centered logics and argues for a value-driven, inclusive approach to energy governance.

In **Chapter 5,** *Prof. Dr. Andrii GRYTSENKO* and *Prof. Dr. Volodymyr LYPOV* explore the complementarities between state authority and market dynamics in ensuring energy security. Their institutional analysis sheds light on the hybrid governance structures needed for resilience.

Chapter 6, by *Prof. Dr. Cristina Raluca Gh. POPESCU*, situates Türkiye within the global conversation on energy, development, and inequality. Highlighting Türkiye's demographic, technological, and geographic advantages, the chapter envisions the country's potential role in the green and digital future.

Chapter 7, brings together *Prof. Dr. Afaq AHMAD, Asst. Prof. Dr. Basant KUMAR, Lect. Rajeev RAJENDRAN, Lect. Maha Al BALUSHİ, and Asst. Prof. Dr. Mohamed Sirajudeen YOOSUF,* who analyze energy security in the era of decarbonization. They explore the vulnerabilities and policy dilemmas that arise as states attempt to balance climate commitments with national interests.

In **Chapter 8,** *Ionela Luminita CANUTA BUCUROIU, Prof. Dr. Adrian IOANA, Asst. Prof. Dr. Ileana Mariana MATES, Prof. Dr. Augustin SEMENESCU,* and *Prof. Dr. Massimo POLLIFRONI* focus on Romania's green energy policies, with a special emphasis on ecological education as a transformative force for long-term sustainability.

Finally, **Chapter 9,** by *Prof. Dr. Khursheed ALAM*, investigates the political economy of energy in the Middle East, addressing contemporary challenges and offering policy responses to issues such as rentierism, reform, and external dependency.

Together, the chapters present a holistic, interdisciplinary, and globally informed exploration of energy as a pivotal driver of political and economic change. They reveal how energy debates intersect with broader questions of justice, sovereignty, transition, and structural inequality. In doing so, this book aims not only to advance scholarly understanding but also to inform policy debates and inspire more equitable and sustainable approaches to energy governance.

We extend our deepest gratitude to the contributors for their intellectual rigor and dedication. It is our hope that this volume will serve as a valuable resource for scholars, policymakers, and students alike—one that contributes meaningfully to ongoing efforts toward building a more resilient, just, and inclusive global energy future.

Prof. Dr. Arzu AL
July 12, 2025 – Türkiye

CHAPTER 1

THE RELATIONSHIP BETWEEN ENERGY AND MILITARISM IN THE CONTEXT OF INTERNATIONAL POLITICAL ECONOMY

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INTRODUCTION

International Political Economy (IPE) emerged in the 1970s as a distinct scholarly domain, rapidly asserting itself as a cornerstone of interdisciplinary inquiry within the social sciences. Rejecting the reductionist assumption that state behavior and international interactions can be adequately understood through a purely political lens, IPE offers a synthetic framework that integrates perspectives from economics, political science, sociology, and related disciplines. Conceived as "the reciprocal and dynamic interaction between the pursuit of power and the quest for wealth" (Gilpin 1975, 43), IPE is premised on the ontological inseparability of politics and economics, often likened to "two sides of the same coin" (Öniş & Kutlay 2014, 307). This paradigm engages with phenomena across multiple levels of analysis, elucidating complex interdependencies that conventional disciplinary silos frequently overlook. Consequently, IPE has become indispensable for interpreting contemporary global transformations, from geopolitical realignments to shifts in economic governance. Within this analytical purview, themes such as energy and militarism—which have long been focal points in their respective disciplines—can be recontextualised as interrelated constructs. Given IPE's foundational emphasis on power accumulation and resource distribution, an integrated analysis of how energy and militarism independently and jointly contribute to these dynamics is both intellectually and policy-relevant.

Historically, energy has constituted a sine qua non for societal continuity and state survival, serving not only as a physical necessity but also as a strategic asset. Unsurprisingly, the concept has generated a robust and multidisciplinary literature, spanning themes such as the geopolitics of energy resources, critical infrastructure, conflict over supply chains, sustainability transitions, and the securitisation of energy policy. Despite this thematic diversity, a converging analytic thread emerges: energy functions as a foundational mechanism in the pursuit of power and the orchestration of wealth accumulation.

Conversely, militarism—rooted in the institutionalisation of force and the strategic prioritisation of military means in the conduct of state affairs—has long been a hallmark of interstate rivalry and domestic governance. It enters the academic discourse not merely as a military doctrine but as a sociopolitical orientation that manifests in budgetary allocations, foreign policy postures, and security paradigms aimed at sustaining or expanding state power.

Contemporary scholarship has increasingly scrutinised how militaristic logics permeate ostensibly civilian domains, often under the guise of safeguarding national interests.

The potential confluence of energy and militarism, both analytically central and empirically significant, forms the core problematic of this study. Anchored in the theoretical scaffolding of International Political Economy, the article seeks to delineate the interdependencies between these two domains. It advances the proposition that only through an interdisciplinary and multi-scalar lens can the full complexity of the energy–militarism nexus be discerned. Accordingly, the first section outlines the IPE framework as the conceptual foundation for subsequent empirical and interpretive analyses.

The article's second section seeks to clarify the concept of energy. By reviewing the existing scholarship, it examines how deeply energy shapes countries' policy choices and their interactions with one another. To that end, the analysis draws extensively on international reports.

The third section turns to militarism. Relying on global indices and reports, it defines the concept, traces its historical evolution, and offers a broad assessment of states' militarist postures. This discussion is intended to provide the analytical foundation for exploring the relationship between energy and militarism.

After unpacking both concepts and analysing the relevant global data, the fourth section synthesises the preceding findings. Through integrated graphs and tables, it investigates the article's core research question—the energy–militarism nexus—and maps the connections that may link the two. By appraising these concepts in tandem, the section aims to contribute fresh insights to the literature.

1. INTERNATIONAL POLITICAL ECONOMY AND ENERGY

International Political Economy (IPE) rests on an effort to elucidate the nexus between politics and economics (Al 2015, 143); the literature routinely depicts the two realms as "two sides of the same coin" (Öniş & Kutlay 2014, 307) and defines the field itself as an inquiry into the interplay of power and wealth in international affairs (Gilpin 1975, 43). Even this brief set of descriptions reveals IPE's essentially interdisciplinary habitat and underscores its capacity to analyse disparate concepts within a single analytical frame.

Since its emergence in the 1970s, IPE has functioned as a bridge discipline between economics and politics (Al 2015, 145). Scholars commonly portray it as a "set of questions" that embraces multiple approaches, assumptions, terms, and methods (Şen 1998, 393). Accordingly, it would be mistaken to treat IPE as the preserve of anyone theory or paradigm; on the contrary, the field is explicitly designed to probe the complex patterns of mutual dependence that bind politics and economics. Within such a framework, every concept can be examined on its own terms, yet potential linkages among concepts—especially those rooted in the pursuit of power and prosperity—can likewise be explored under the broad canopy of IPE.

The term *energy*—from the Greek *energeia* and first rendered by Aristotle in the sixth century BCE as "the realisation of a potential"—has since migrated into numerous academic disciplines (Oxford Reference, n.d.). Dictionaries routinely define energy as "the capacity to do work" (Britannica, n.d.), and historians of technology widely agree that mastery over energy lies at the heart of humanity's transition to modernity (EIA 2022). By its very nature, energy can be neither destroyed nor created from nothing (Leipzig University, n.d.). Precisely because of its indispensability, the struggle to control energy resources and transit routes has fuelled conflicts throughout the ages. That historical record alone attests to the vital importance of securing—and efficiently utilising—energy.

Energy, pivotal to human existence, can be extracted from a variety of sources and converted from one form to another, a quality that vastly broadens its practical utility. In the literature, energy sources are commonly classified into five overarching categories—according to their sustainability, convertibility, organic or inorganic composition, physical state, and whether they are located above or below ground. Within these five categories lie eight recognised forms of energy: kinetic, electrical, nuclear, chemical, potential, thermal, light, and sound (Al & Kaya 2022, 72–73).

Because each form can be transformed into another, energy's convertibility represents a major advantage for human society. Yet the physical law that energy can neither be created ex nihilo nor annihilated imposes an intrinsic limit on supply. That scarcity generates competition for access and has historically fuelled conflict—whether over resource deposits themselves or over the transit routes that carry those resources to market. Such struggles underscore energy's strategic value, and numerous studies have demonstrated correlations between a state's level of development and its access to, or control over, energy resources.

Empirical research on energy overwhelmingly relies on data produced by international bodies. Among the most frequently cited primary sources are reports from the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), the World Energy Council (WEC), the International Renewable Energy Agency (IRENA), and British Petroleum (BP). These publications furnish detailed statistics on national energy consumption patterns, resource endowments, and broader trends in the global energy landscape, supplying the evidentiary backbone for much of the scholarly work in the field.

The literature generally treats the history of energy in four successive phases. The first, extending from the appearance of the earliest humans to the eleventh century, coincides with a nomadic way of life in which energy was obtained through a rudimentary "cut-and-burn" method: wood supplied heat for shelter, warmth, and cooking, while also furnishing light after dark. The second phase, running from the eleventh to the fifteenth century, saw communities harness water and wind power for milling grain and processing hides—developments that ushered in the first tentative "energy policies" aimed at expanding and stabilising supply. The third phase, spanning the sixteenth to eighteenth centuries, began with coal's adoption in England; coal soon supplanted wood, energised both homes and early factories, and underwrote the emergence of urban life. The fourth and still-unfolding phase, which starts in the nineteenth century, is characterised by the rise of petroleum and a host of additional energy sources that have driven industrialisation, technological innovation, and notable gains in human welfare (Demir & Yakışık 2024, 1336–1341).

International datasets compiled by bodies such as the IEA, EIA, WEC, IRENA, and BP underscore energy's global significance, and—as the graphs below drawn from Ritchie, Rosado, and Roser (2020) show—both production and consumption accelerate sharply after the 1800s, revealing humanity's steadily intensifying dependence on energy in all its forms.

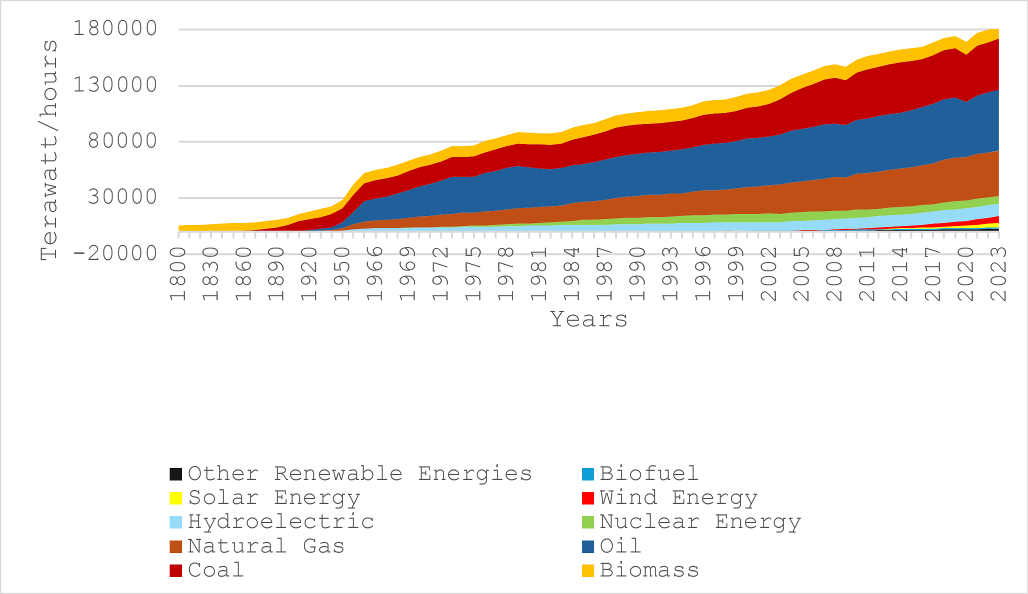

Figure 1. Global Primary Energy Consumption by Source[3]

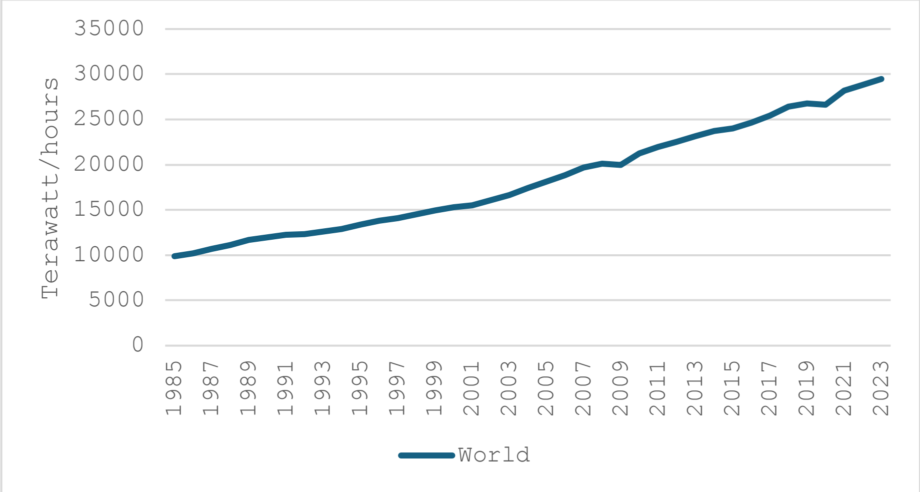

Figure 2. World Electricity Generation[4]

[3] Author's calculations based on *Our World in Data* figures. For more information, see: https://ourworldindata.org/energy-production-consumption
[4] Author's calculations based on Our World in Data figures. For more information, see: https://ourworldindata.org/energy-production-consumption

As the preceding graphs make clear, global energy consumption and production have risen steadily over time, a trend that cannot be attributed solely to technological progress or population growth. States also engage with energy directly in order to raise citizens' welfare and to enhance their own power. BP's data reinforce this point: when national energy production and consumption figures are ranked, advanced economies consistently occupy the upper tiers.[5] To illustrate these patterns more concretely, the tables below—drawn from BP's 2023 dataset—list the twenty leading countries in both energy consumption and production, ordered from the highest to the lowest values. A comparison of these figures with earlier years shows how sharply national totals have expanded. A more comprehensive dataset, which includes regional aggregates as well as the full country rankings, is provided in the appendix.

Table 1. Energy Consumption by Country (1965 – 2023)[6]

ENERGY CONSUMPTION (eksajoules)	YEARS									
COUNTRIES	1965	1975	1985	1995	2005	2015	2020	2021	2022	2023
China	5,53	13,25	22,14	37,27	75,70	126,49	149,38	157,85	160,26	170,74
USA	51,98	69,55	72,66	87,64	96,89	92,69	88,64	93,44	95,42	94,28
India	2,23	3,50	5,70	10,67	16,59	28,55	31,78	34,51	36,37	39,02
Russian Federation	-	-	34,40	27,73	27,01	28,55	29,08	30,01	31,08	31,29
Japan	6,59	14,87	16,13	21,28	22,87	19,31	17,37	18,13	18,02	17,40
Canada	5,00	8,24	10,29	12,17	13,66	14,47	13,76	13,92	14,30	13,95
Brazil	0,99	2,88	4,94	6,89	9,28	12,66	12,22	12,85	13,44	13,87
Iran	0,35	1,17	2,32	3,81	6,99	9,85	12,20	11,96	12,48	12,71
South Korea	0,27	0,96	2,25	6,32	9,45	11,91	12,05	12,62	12,75	12,43
Saudi Arabia	0,85	0,91	2,63	4,07	6,52	11,00	10,39	10,73	11,34	11,60
Germany	10,69	13,55	15,45	14,31	14,27	13,61	12,40	12,76	12,29	11,41
Indonesia	0,30	0,58	1,49	3,13	5,10	6,72	7,79	7,97	10,05	10,11
France	4,85	7,32	8,70	10,46	11,35	10,16	8,79	9,34	8,27	8,66
Mexico	1,06	2,14	4,08	5,18	7,27	7,94	7,35	7,83	8,18	8,45
Türkiye	0,33	0,84	1,39	2,56	3,59	5,72	6,56	7,02	7,10	7,00
UK	8,34	8,60	8,61	9,19	9,77	8,21	7,10	7,17	7,27	6,95
Australia	1,53	2,61	3,23	4,16	5,08	5,76	5,71	5,72	5,98	6,02
Italy	3,34	5,69	5,89	6,97	7,92	6,53	5,95	6,37	6,19	5,95
Spain	1,21	2,65	3,32	4,39	6,37	5,66	5,12	5,51	5,73	5,66
UAE	^	0,09	0,73	1,75	2,54	4,42	4,34	4,49	4,88	5,13

As the table above demonstrates, the countries that consume the most energy are overwhelmingly advanced economies or large emerging markets—

[5]The detailed table is provided in Appendix 1.

[6] Author's calculations based on BP data. For detailed information, see:https://www.bp.com/en/global/corporate/energy-economics/webcast-and-on-demand.html

a pattern that reflects the well-documented link between development and energy use. To satisfy this demand, states draw on an array of sources, and the composition of their output is largely determined by the raw-material endowment of the region in which they are located. Nations rich in primary resources exploit those advantages directly, while those without sizeable deposits strive to expand capacity by tapping favourable natural conditions—hydrological flows, solar irradiation, wind corridors, and the like.

The tables that follow detail the volumes each country produces from the main energy sources and chart how those figures have changed over time. Concentrating on the fuels that dominate global supply, they show that the economies with the highest consumption also tend to rank near the top in production.

Table 2. Electricity Generation by Country (1985 – 2023, terawatt-hours)[7]

ELECTRICITY GENERATION (terawatt-hours)	YEARS										
COUNTRIES	1985	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
China	410,7	621,2	1007,0	1355,6	2500,3	4207,2	5814,6	7779,1	8534,2	8848,7	9456,4
USA	2657,2	3232,8	3567,3	4052,3	4322,8	4394,3	4349,9	4287,6	4400,9	4537,7	4494,0
India	186,4	287,8	427,1	571,4	704,5	937,5	1322,1	1581,9	1695,5	1829,3	1958,2
Russian Federation	962,0	1082,2	860,0	877,8	954,1	1038,0	1067,5	1085,4	1157,1	1166,9	1178,2
Japan	672,0	881,5	1010,9	1099,7	1153,1	1156,0	1030,1	1011,0	1034,7	1040,6	1013,3
Brazil	193,7	222,8	275,6	348,9	403,1	515,8	581,2	628,8	656,1	677,2	710,0
Canada	459,0	480,6	557,9	603,8	620,5	607,0	661,1	653,9	649,9	658,9	633,2
South Korea	62,7	118,5	203,5	290,4	389,5	495,0	547,8	577,1	607,8	624,6	617,9
France	344,5	420,8	494,3	540,0	576,1	569,3	571,6	524,3	547,2	466,5	519,7
Germany	522,5	549,9	536,8	576,6	622,7	632,8	647,0	574,7	587,1	577,9	513,7
Saudi Arabia	51,7	79,9	109,9	138,7	191,1	248,8	350,6	380,9	392,9	401,3	422,9
Iran	38,9	57,7	84,4	119,3	177,1	235,7	280,2	337,2	356,4	367,1	382,9
Mexico	96,2	117,6	150,4	203,6	248,0	275,6	310,3	325,7	330,0	340,1	354,9
Indonesia	16,4	33,1	54,1	93,3	127,6	169,8	234,0	291,8	309,1	333,5	350,6
Türkiye	34,2	57,5	86,2	124,9	162,0	211,2	261,8	306,7	334,7	328,4	328,0
UK	298,1	319,7	337,4	377,1	398,4	382,1	338,9	314,7	308,9	322,0	285,6
Taiwan	55,6	90,2	133,1	184,8	227,5	247,1	258,1	280,0	291,0	288,2	282,1
Spain	126,6	151,9	167,1	224,5	294,1	300,4	281,0	263,4	274,3	292,5	282,0
Vietnam	5,1	8,7	14,6	26,6	52,1	91,7	161,9	244,0	253,6	265,1	276,4
Avustralya	123,7	155,7	175,2	216,8	230,7	251,0	254,0	265,2	267,5	272,9	273,1

[7] Author's calculations based on BP data. For detailed information, see:https://www.bp.com/en/global/corporate/energy-economics/webcast-and-on-demand.html

The electricity-generation table shows that the five largest producers are also the five largest consumers of energy, and even the ordering of those countries is identical. A further point that stands out is the near-universal increase in national generating capacity over time, a trend that can be linked to both technological progress and population growth. Renewable-energy output is presented in a separate table; because global interest in renewables has surged only in recent years, comprehensive figures are available for a shorter period.

Here again, China and the United States occupy the top two positions—just as they do in the previous tables. The same pattern reappears in the nuclear-energy rankings, reproduced below, where China and the United States likewise lead the field.

Table 3. Renewable Energy Production by Country (2022 – 2023) [8]

RENEWABLE ENERGY (PRODUCTION BY RESOURCE) (terawatt/hours)	2022					2023				
COUNTRIES	Wind	Solar	Hydro	Other Renewable Energy Sources	Total	Wind	Solar	Hydro	Other Renewable Energy Sources	Total
China	762,7	427,3	1298,1	182,5	**2670,6**	885,9	584,2	1226,0	198,1	**2894,1**
USA	438,7	207,2	251,3	71,5	**968,6**	429,5	240,5	236,3	67,3	**973,7**
Brazil	81,6	30,1	427,1	55,0	**593,9**	95,5	51,5	428,7	55,8	**631,5**
Canada	38,4	7,1	397,7	9,1	**452,3**	38,9	7,6	364,2	10,4	**421,2**
India	70,0	95,2	174,9	38,6	**378,7**	82,1	113,4	149,2	37,3	**382,0**
Germany	124,8	60,3	17,6	51,9	**254,6**	142,1	61,2	19,6	49,5	**272,4**
Japan	9,4	91,1	74,9	37,8	**213,2**	10,0	97,0	74,5	42,0	**223,5**
Russian Federation	4,2	2,4	197,7	0,8	**205,1**	4,7	2,6	200,9	0,8	**209,1**
Norway	14,8	0,3	127,6	0,2	**143,0**	14,0	0,5	136,1	0,3	**150,9**
Spain	62,8	35,7	17,6	6,8	**122,8**	64,2	46,8	25,5	5,4	**142,0**
France	37,9	19,1	44,3	9,7	**111,0**	52,3	22,2	55,5	9,7	**139,8**
Türkiye	34,9	16,9	66,8	19,2	**137,8**	34,1	20,5	63,9	19,5	**137,9**
UK	80,3	13,3	5,6	35,8	**135,0**	82,0	13,8	5,2	34,0	**135,0**
Vietnam	9,1	25,8	95,9	0,4	**131,1**	11,4	25,7	80,9	0,9	**118,8**
Sweden	33,1	2,0	69,8	13,1	**117,9**	34,3	3,1	66,0	11,3	**114,8**
Italy	20,5	28,1	28,4	23,5	**100,5**	23,5	31,2	38,9	20,3	**114,0**
Australia	30,1	37,5	16,7	3,2	**87,4**	31,9	45,0	15,3	3,1	**95,2**
Mexico	20,5	20,3	35,6	6,7	**83,1**	21,7	27,1	20,4	7,1	**76,3**
Venezuela	^	^	68,5	-	**68,5**	^	^	65,6	-	**65,6**
Indonesia	0,4	0,4	27,3	37,3	**65,4**	0,5	0,7	24,6	39,4	**65,2**

[8] Author's calculations based on BP data. For detailed information, see: https://www.bp.com/en/global/corporate/energy-economics/webcast-and-on-demand.html

Table 4. Nuclear Energy Production by Country (1965 – 2023)[9]

NUCLEAR ENERGY PRODUCTION (terawatt/hours)	YEARS														
COUNTRIES	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
USA	3,8	23,0	181,6	264,3	403,9	607,2	708,8	793,6	823,1	849,4	839,1	831,5	820,7	812,1	816,2
China	-	-	-	-	-	-	12,8	16,7	53,1	74,7	171,4	366,2	407,5	417,8	434,7
France	0,9	5,7	18,2	61,3	224,1	314,1	377,2	415,2	451,5	428,5	437,4	353,8	379,4	294,7	338,2
Russian Federation	-	-	-	-	99,3	118,3	99,5	130,7	149,4	170,4	195,5	215,9	222,4	223,7	217,4
South Korea	-	-	-	3,5	16,7	52,9	67,0	109,0	146,8	148,6	164,8	160,2	158,0	176,1	180,5
Canada	0,1	1,0	12,6	38,0	60,5	72,5	97,2	72,3	91,4	90,0	101,1	97,5	92,0	86,6	89,0
Japan	^	4,6	25,1	82,6	159,6	194,6	286,9	319,1	293,0	292,4	4,5	43,0	61,2	51,8	77,5
Spain	-	0,9	7,5	5,2	28,0	54,3	55,5	62,2	57,5	61,6	57,3	58,3	56,6	58,6	56,8
Ukraine	-	-	-	-	53,3	76,2	70,5	77,3	88,8	89,2	87,6	76,2	86,2	62,1	52,4
Sweden	^	0,1	12,0	26,5	58,6	68,2	69,9	57,3	72,7	57,7	56,3	49,2	53,0	51,9	48,4
India	-	1,3	2,1	2,4	4,5	6,4	7,6	15,8	17,7	23,1	38,3	44,6	43,9	46,2	48,2
UK	15,1	26,0	30,3	37,0	61,1	65,7	89,0	85,1	81,6	62,1	70,3	50,3	45,9	47,7	40,7
Finland	-	-	-	7,0	18,9	19,2	19,2	22,5	23,3	22,8	23,2	23,3	23,6	25,3	34,2
Belgium	-	0,1	6,8	12,5	34,6	42,7	41,4	48,2	47,6	47,9	26,1	34,4	50,3	43,9	32,9
UAE	-	-	-	-	-	-	-	-	-	-	-	1,6	10,5	20,1	32,3
Czech Republic	-	-	-	-	2,4	12,6	12,2	13,6	24,7	28,0	26,8	30,0	30,7	31,0	30,4
Switzerland	-	1,8	7,8	14,3	22,4	23,5	24,7	26,3	23,2	26,5	23,3	23,0	18,5	23,1	23,3
Pakistan	-	-	0,6	0,1	0,4	0,4	0,5	0,9	2,5	2,5	4,3	9,5	15,7	22,2	22,4
Slovakia	-	-	0,2	4,5	9,4	12,0	11,4	16,5	17,7	14,6	15,1	15,4	15,7	15,9	18,3
Taiwan	-	-	-	8,2	28,7	32,9	35,3	38,5	40,0	41,6	36,5	31,4	27,8	23,8	17,8

For conventional energy sources such as oil and natural gas, production tends to rise in direct proportion to a country's in-situ reserves or its ability to secure access to them; unsurprisingly, the tables that follow confirm that states possessing substantial hydrocarbon endowments rank highest in output.

[9] Author's calculations based on BP data. For detailed information, see: https://www.bp.com/en/global/corporate/energy-economics/webcast-and-on-demand.html

Table 5. Oil Production by Country (1965 – 2023)[10]

OIL PRODUCTION (thousand barrels per day)	YEARS									
COUNTRIES	1965	1975	1985	1995	2005	2015	2020	2021	2022	2023
USA	9014	10008	10580	8322	6901	12782	16493	16693	17844	19358
Saudi Arabia	2219	7216	3601	8974	10839	11998	11039	10954	12191	11389
Russian Federation	-	-	10863	6236	9598	11087	10666	11000	11202	11075
Canada	920	1735	1813	2402	3041	4388	5130	5414	5575	5653
Iran	1908	5387	2205	3744	4217	3853	3230	3766	3945	4662
Iraq	1313	2271	1425	530	1833	3986	4114	4102	4520	4355
China	227	1548	2508	2993	3642	4309	3901	3994	4111	4198
UAE	282	1664	1211	2444	2945	3876	3679	3640	4020	3922
Brazil	96	177	561	715	1706	2525	3030	2991	3112	3502
Kuwait	2371	2132	1127	2130	2669	3069	2721	2706	3036	2908
Mexico	362	806	2912	3055	3766	2587	1910	1926	1943	2040
Norway	-	189	823	2903	2983	1953	2018	2036	1906	2022
Kazakhstan	-	-	485	450	1294	1672	1796	1805	1771	1891
Qatar	233	437	315	461	1148	1844	1715	1697	1743	1772
Nigeria	274	1783	1499	1949	2482	2199	1894	1678	1445	1540
Algeria	570	1025	1087	1310	1990	1558	1332	1353	1443	1408
Libya	1220	1514	1025	1439	1745	437	420	1286	1143	1271
Angola	13	158	232	633	1269	1796	1325	1177	1191	1150
Argentina	276	406	491	758	842	646	721	797	955	1074
Oman	-	341	502	868	774	981	951	971	1064	1049

[10] Author's calculations based on BP data. For detailed information, see: https://www.bp.com/en/global/corporate/energy-economics/webcast-and-on-demand.html

Table 6. Natural Gas Production by Country (1970 – 2023)[11]

NATURAL GAS PRODUCTION (billion cubic meters)	YEARS								
COUNTRIES	1970	1980	1990	2000	2010	2020	2021	2022	2023
USA	571,5	525,1	483,4	518,6	575,2	924,8	944,5	993,4	1035,3
Russian Federation	-	-	599,6	537,1	598,4	638,4	702,1	618,4	586,4
Iran	3,5	4,5	24,7	56,3	143,9	235,8	242,8	247,7	251,7
China	2,9	14,4	15,4	27,4	96,5	194,0	209,2	221,8	234,3
Canada	54,0	71,2	103,4	176,3	149,6	165,6	172,3	184,8	190,3
Qatar	1,0	4,9	6,5	25,8	123,1	174,9	177,0	178,5	181,0
Australia	1,7	11,1	20,6	31,2	52,6	145,7	147,9	154,2	151,7
Norway	-	24,9	25,3	49,4	106,2	111,7	114,5	123,0	116,6
Saudi Arabia	1,5	9,2	31,8	47,3	83,3	113,1	114,5	116,7	114,1
Algeria	2,4	15,4	51,7	91,9	77,4	81,4	101,1	97,6	101,5
Malaysia	-	2,6	18,0	49,7	65,1	73,1	79,0	83,0	81,1
Turkmenistan	-	-	79,2	42,4	40,1	66,0	79,3	78,3	76,3
Indonesia	1,3	18,8	44,5	70,7	87,0	64,7	64,4	62,8	64,3
Egypt	0,1	2,1	7,8	20,2	59,0	58,5	67,8	64,5	57,1
UAE	0,8	7,3	19,6	37,4	50,0	53,7	53,1	54,2	55,6
Uzbekistan	-	-	36,8	50,9	57,1	47,1	50,9	48,9	44,2
Nigeria	0,1	1,6	3,8	11,2	30,9	49,4	52,4	47,1	43,7
Oman	-	0,6	2,4	10,3	25,7	36,9	40,3	42,1	43,2
Argentina	5,9	8,2	17,3	36,4	39,0	38,3	38,6	41,7	41,6
Mexico	11,0	25,1	26,4	33,4	51,2	35,5	32,1	33,7	35,6

The detailed tables reveal that states concentrate on a variety of energy sources in their quest for secure supplies, and that output from these sources has continued to rise year after year. The energy generated serves multiple ends: above all, it sustains individual lives and the very survival of the state; it meets citizens' needs and raises their welfare; it undergirds policies designed to preserve political power; and it fuels industrialisation, investment, and a host of other developmental activities.

[11] Author's calculations based on BP data. For detailed information, see: https://www.bp.com/en/global/corporate/energy-economics/webcast-and-on-demand.html

2. ENERGY AND MILITARISM IN A POLITICAL-ECONOMY PERSPECTIVE

From humanity's earliest encounters with nature to the rise of organised states, history is marked by struggle—first against the environment and later against other human groups. In those contests people joined forces to create armies and fashioned weapons to tilt the balance in their favour. Whenever notions such as soldier, army or war arise, the closely allied concept of *militarism* comes quickly to mind. Etymologically rooted in the Latin *militaris* (Online Etymology Dictionary, n.d.), militarism is defined in standard references as "the belief that a country must maintain powerful armed forces and be prepared to use them to secure political or economic advantage" (Cambridge, n.d.). The Turkish Language Association adds that it entails a condition in which "military power dominates to an excessive degree, every problem is approached through military means, and the armed forces are accordingly accorded priority" (TDK, n.d.).

Taken together, these definitions make clear that militarism is not confined to the purely military sphere; it also shapes domains central to state governance. Measuring how inclined a government is toward militarism is therefore difficult, and scholars typically rely on the scale of resources channelled into the armed forces as an indirect gauge. The literature treats such investment as the engine of *militarisation*, a wider process that can include the allocation of capital, labour and scientific effort to weapons, troops, and arms transfers; the buttressing of military-backed regimes; the pursuit of domestic or foreign objectives by force; the forging of alliances and counter-alliances; direct intervention, aggression or war; and even the occupation of foreign territory under guardianship or colonial rule (Naidu 1985, 4).

A rigorous understanding of militarism and militarisation therefore begins with an examination of defence spending. The most comprehensive longitudinal data are provided by the Stockholm International Peace Research Institute (SIPRI). The tables that follow draw on SIPRI's figures to trace national military expenditures over time and supply the empirical basis for the analysis that ensues.

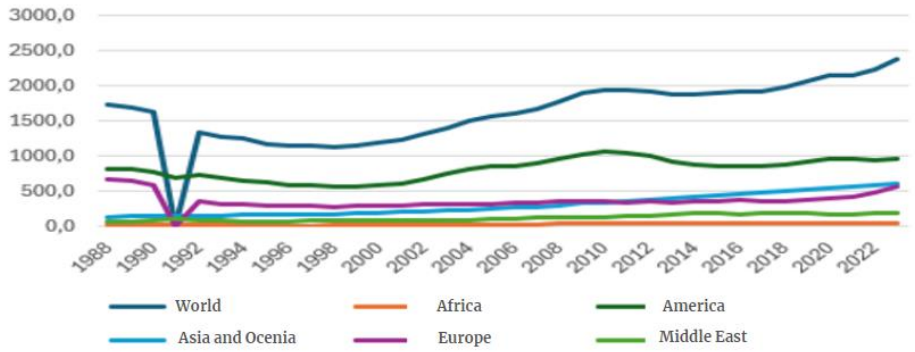

Figure 3. Military Expenditure by Region (in US billion dollars)[12]

The chart above, constructed from SIPRI data, traces year-by-year military spending for the world as a whole and for each major region. Because the series is not cumulative, each point represents expenditure in a single year. As the trend line makes clear, global outlays on defence have risen markedly since the early 2000s.

Drawing again on SIPRI figures, the table below ranks states by the size of their military budgets in the most recent year for which data are available—2023. It lists the thirty largest spenders in descending order.

[12] Author's calculations based on SIPRI data. For detailed information, see: https://www.sipri.org/databases/armsindustry

Table 7. Military Expenditures by Country (in US million dollars) [13]

COUNTRIES	YEARS										
	1960	1970	1980	1990	2000	2010	2015	2020	2021	2022	2023
USA	47346,6	83408,0	143688,4	325129,3	320086,3	738005,0	633829,6	778397,2	806230,2	860692,2	916014,7
China	-	-	-	9926,3	22237,1	105522,6	196538,8	257973,4	285930,5	291958,4	296438,6
Russia	-	-	-	0,0	9228,2	58702,2	66421,8	61712,5	65907,7	102366,6	109454,4
India	681,8	1833,0	5420,8	10537,0	14287,5	46090,4	51295,5	72937,1	76348,5	79976,8	83574,6
Saudi Arabia	140,9	471,6	20724,5	16355,5	19964,3	45244,5	87185,9	64558,4	63194,7	70920,0	75813,3
UK	5129,9	6792,1	28360,2	43545,1	39343,7	63979,1	59990,2	58332,4	65136,2	64081,6	74942,8
Germany	2751,2	5805,3	25125,8	39834,7	26497,6	43025,9	38170,0	53318,7	56513,6	56153,1	66826,6
Ukrain	-	-	-	-	1136,7	3729,5	3502,7	6838,8	6898,1	41183,9	64753,2
France	3260,1	4941,1	22198,2	35774,4	28403,1	52044,1	45647,5	52747,1	56647,0	53638,7	31301,3
Japan	480,6	1575,3	9711,7	28800,5	45509,7	54655,5	42106,1	51396,5	50957,5	46880,2	50161,1
South Korea	275,6	386,4	3980,7	10110,7	13801,1	28175,2	26570,8	46117,1	50873,8	46365,4	47925,6
Italy	1009,3	2216,8	7915,7	20734,6	19878,7	32020,8	22180,8	32929,1	36232,7	34691,9	35528,9
Australia	459,8	1277,4	3657,9	6704,2	7273,8	23217,7	24046,2	27300,9	32718,1	32445,3	32340,0
Poland	3550,0	8525,0	1506,2	1540,7	3146,1	8790,2	10212,8	13718,3	15295,5	15341,3	31649,9
Israel	190,3	1259,6	4120,8	6528,8	8327,5	13875,2	16457,1	21816,6	24341,0	23406,1	27498,5
Canada	1702,4	1889,2	4744,4	11414,6	8299,4	19315,7	17937,6	23082,8	25362,2	25567,9	27221,5
Spain	232,8	859,1	5508,4	11695,0	10273,8	19710,8	15187,2	17431,8	19544,5	20306,6	23699,1
Brazil	382,7	1026,2	2259,3	9236,3	11344,0	34002,9	24617,7	19591,2	19187,1	20542,1	22887,5
Algeria	43,1	98,8	890,2	904,3	1881,2	5671,3	10412,7	9708,3	9112,5	9145,8	18264,0
Holland	454,7	1079,9	5269,3	7420,8	5971,8	11220,5	8667,8	13085,7	14395,7	13632,4	16624,8
Taiwan	-	-	0,0	8701,1	8800,6	9092,3	9803,3	12029,6	13932,7	15261,4	16612,8
Türkiye	468,8	564,9	2672,0	5315,4	9993,7	17650,5	15668,8	17478,4	15567,4	10779,9	15827,9
Singapore	-	103,6	560,1	1801,9	4330,7	8108,9	9383,8	9801,6	11017,6	12034,0	13200,7
Mexico	84,0	176,8	810,4	1210,9	3031,5	4789,0	5468,8	8044,9	8680,8	10065,3	11825,9
Colombia	76,0	162,7	611,2	890,0	3027,9	10422,1	9127,2	9554,1	10180,1	9661,0	10701,1
Iran	98,7	620,1	4874,9	16474,4	8327,1	13561,3	10588,8	3335,7	5680,0	7334,0	10283,1
Indonesia	-	-	2114,5	1614,0	1129,5	4663,4	7595,0	9387,0	8802,5	10133,9	9480,8
Swedish	526,8	1118,2	3791,8	5913,1	4764,3	5885,9	5386,9	6271,3	7582,6	7722,5	8754,9
Norway	148,1	388,4	1668,7	3394,9	2922,3	6498,7	5815,2	7225,2	8435,1	8697,8	8668,6
Pakistan	208,8	635,3	1429,3	2810,1	2973,1	5974,6	9506,4	10241,0	11649,4	10358,1	8521,2

*Figures shown in **red** indicate data points for which SIPRI reports incomplete information and should therefore be regarded as highly uncertain.
Figures shown in **blue are based on SIPRI estimates.

As the table indicates, the five largest defence spenders in 2023 were, in order, the United States, China, Russia, India, and Saudi Arabia. Because military outlays correlate with factors such as a country's size, economic capacity, and population, a more nuanced comparison requires expressing expenditure as a share of national output.

[13] Author's calculations based on SIPRI data. For detailed information, see .https://www.sipri.org/databases/armsindustry

Accordingly, a second table ranks the same countries by military spending as a percentage of gross domestic product; the top twenty are listed in descending order. Both tables draw on the latest SIPRI data (2023).

Table 8. Military Expenditure as a Percentage of GDP (by Country) [14]

COUNTRIES	2023
Algeria	8,17%
Saudi Arabia	7,09%
Russia	5,86%
Israel	5,32%
Poland	3,83%
USA	3,36%
Colombia	2,87%
Pakistan	2,80%
Singapore	2,66%
India	2,44%
UK	2,26%
Taiwan	2,17%
Iran	2,06%
France	2,06%
Australia	1,92%
China	1,67%
Norway	1,61%
Italy	1,61%
Holland	1,53%
Germany	1,52%

*Figures shown in **blue** are based on SIPRI estimates

Another indicator that sharpens the analysis is defence spending expressed as a share of total government expenditure. Using this metric, the countries in the first table were re-ranked, and a new list of the twenty states devoting the largest budgetary proportions to the military was produced. Interpreting those figures requires careful attention to each country's security environment in the year covered by the data. It is therefore unsurprising that Ukraine tops the ranking, given its ongoing war with Russia.

[14] Author's calculations based on SIPRI data. For detailed information, see: https://www.sipri.org/databases/ armsindustry

Equally striking, however, is the presence of several states that, despite being at peace, still channel a remarkably high fraction of their public budgets into defence.

Table 9. Military Expenditure as a Percentage of Government Expenditure (by Country) [15]

COUNTRIES	2023
Ukrania	58,17%
Saudi Arabia	24,04%
Algeria	19,34%
Singapore	18,03%
Russia	16,14%
Israel	14,59%
Pakistan	14,45%
Taiwan	13,64%
Iran	13,53%
USA	9,06%
Colombia	8,31%
India	8,15%
Poland	8,12%
UK	5,15%
Australia	5,06%
China	4,97%
Norway	4,00%
Indonesia	3,92%
France	3,57%
Holland	3,39%

*Figures shown in **blue** are based on SIPRI estimates.

The table shows that the United States and China once again occupy the top two positions—just as they do in the earlier energy tables—and that many of the other countries prominent in those energy rankings also register very high military outlays.

Political economy, by bringing together otherwise separate lines of inquiry, makes it easier to make sense of such overlaps: it highlights the complex, reciprocal ties that can arise among seemingly disparate concepts when they are evaluated along the axes of power, interest, and security.

[15] Author's calculations based on SIPRI data. For detailed information, see:https://www.sipri.org/databases/armsindustry

Within this framework, diverse phenomena can be examined in a genuinely multidimensional way.

Given energy's enduring importance throughout human history, situating it within the field of political economy and relating it to other key variables—militarism foremost among them—is entirely appropriate. Access to resources, the transport of those resources, and the security risks that surround both factors shape states' foreign policies and military strategies. Accordingly, any analysis of the energy–militarism nexus must rest not only on economic logic but also on considerations of geopolitical rivalry, threat perception, and military capability.

Because energy issues are inseparable from constraints on supply and from the vulnerabilities of transport networks, they must be assessed in conjunction with the policies states pursue. As noted above, the militarist tendencies generated by a quest for power and security readily spill over into the energy sphere: governments establish forward deployments, build bases, and guard pipelines and sea-lanes. In the case of conventional fuels in particular, states often feel compelled to adopt explicit military doctrines. Seen in this light, the relationship between energy and militarism stands out as a core question of political economy—one that helps illuminate both the international struggle for power and the domestic forces that shape it.

CONCLUSION

The framework of International Political Economy (IPE) provides a powerful analytical lens through which the intertwined dynamics of energy and militarism can be more comprehensively understood. This study has demonstrated that the relationship between these two domains is not incidental but structurally embedded within the mechanisms through which states pursue power, sustain security, and cultivate economic resilience. Energy is not merely a technical or economic issue—it is a strategic asset deeply implicated in geopolitical rivalries and military doctrines. Likewise, militarism extends beyond battlefield engagements to encompass a broader spectrum of state behavior, including the protection of energy infrastructure, the projection of force in resource-rich regions, and the securitisation of energy policy narratives.

Empirical evidence presented throughout this article—particularly in the comparative tables on energy consumption, production, and military expenditure—demonstrates that the world's leading energy consumers and producers also occupy top positions in military investment. This pattern, visible across both developed and emerging economies, reinforces the argument that energy security and militarisation are co-constitutive processes. The cases of the United States and China illustrate this vividly: both countries dominate global energy and defence rankings, suggesting a feedback loop wherein strategic military planning informs energy policy and vice versa.

Importantly, this nexus is not restricted to the great powers. Medium-sized states, and even those with limited indigenous energy resources, find themselves drawn into this matrix of interdependence due to their geopolitical location, alliance commitments, or role as transit states. For instance, countries located along strategic chokepoints—such as the Strait of Hormuz, the Suez Canal, or the Turkish Straits—often become arenas for militarised competition regardless of their domestic energy profiles. This highlights the necessity of examining not only national capabilities but also spatial and structural variables when assessing the energy–militarism relationship.

Furthermore, the increasing global attention to energy transition and decarbonisation introduces new dimensions into this interaction. As states invest heavily in renewable energy infrastructure—often in geographically exposed or politically sensitive areas—the potential for militarisation persists or even intensifies. The securitisation of clean energy corridors, offshore wind farms, and rare-earth mineral supply chains may reproduce older militaristic patterns under a new technological guise. At the same time, fossil-fuel-dependent states may adopt aggressive military postures to protect declining rents or assert influence over dwindling reserves, especially in regions such as the Arctic, the South China Sea, or Central Asia.

Future research should build on this study by incorporating both historical and forward-looking dimensions. Key trajectories might include:

- Comparative studies of how energy crises (e.g., the 1973 oil shock, the 2022 Russia–Ukraine war) precipitate or escalate militarised responses;
- Investigations into the role of military-industrial complexes in shaping national energy policy;

- Analyses of how the discourse of energy security is framed in militarised terms in domestic policy debates;
- Regional case studies, particularly in conflict-prone energy zones such as the Middle East, East Africa, or the South Caucasus;
- And the impact of military alliances—such as NATO or bilateral security agreements—on the configuration of energy infrastructure.

Ultimately, this study affirms that energy and militarism cannot be analytically or empirically disentangled. Their interrelationship must be examined not only through the lens of economics or conflict studies, but through a broader IPE framework that integrates strategic, spatial, and institutional considerations. As global energy systems evolve and geopolitical fault lines shift, understanding this nexus becomes increasingly urgent—not only for scholars and policymakers but for the long-term stability of the international system itself.

Appendix 1. Energy Consumption by Year [16]

ENERGY CONSUMPTION (eksajoules)	YEARS													
COUNTRIES/REGIONS	1965	1975	1985	1995	2005	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total Asia Pacific	18,91	40,49	58,93	97,11	157,10	229,36	231,54	241,10	251,16	259,38	258,34	272,15	278,81	291,77
China	5,53	13,25	22,14	37,27	75,70	126,49	127,00	131,94	138,27	144,68	149,38	157,85	160,26	170,74
Total North America	58,04	79,93	87,03	104,99	117,81	115,10	115,07	115,76	119,25	118,40	109,75	115,20	117,90	116,68
USA	51,98	69,55	72,66	87,64	96,89	92,69	92,62	92,97	96,37	95,68	88,64	93,44	95,42	94,28
Total Europe	44,82	64,25	85,81	85,21	92,07	84,05	85,06	86,19	86,21	84,90	79,16	83,01	79,60	77,85
Total CIS	24,90	40,70	43,14	34,18	33,78	36,27	37,15	37,52	39,05	38,82	37,78	39,25	40,43	40,72
Total Middle East	1,94	3,44	8,31	14,39	22,85	34,82	36,05	36,59	36,65	37,17	36,51	37,27	39,29	40,46
India	2,23	3,50	5,70	10,67	16,59	28,55	29,83	30,96	32,72	33,54	31,78	34,51	36,37	39,02
Russian Federation	-	-	34,40	27,73	27,01	28,55	29,11	29,29	30,36	30,13	29,08	30,01	31,08	31,29
Total South and	4,92	8,57	12,33	17,66	23,12	29,57	29,44	29,65	29,37	29,19	26,92	28,99	30,37	31,28
Total Africa	2,58	4,37	8,05	10,27	13,63	18,16	18,67	19,29	19,77	20,20	19,14	20,75	20,95	20,87
Japan	6,59	14,87	16,13	21,28	22,87	19,31	19,06	19,28	19,14	18,74	17,37	18,13	18,02	17,40
Canada	5,00	8,24	10,29	12,17	13,66	14,47	14,34	14,54	14,72	14,64	13,76	13,92	14,30	13,95
Brazil	0,99	2,88	4,94	6,89	9,28	12,66	12,36	12,47	12,51	12,72	12,22	12,85	13,44	13,87
Iran	0,35	1,17	2,32	3,81	6,99	9,85	10,39	10,78	11,15	11,75	12,20	11,96	12,48	12,71
South Korea	0,27	0,96	2,25	6,32	9,45	11,91	12,27	12,40	12,61	12,47	12,05	12,62	12,75	12,43
Saudi Arabia	0,85	0,91	2,63	4,07	6,52	11,00	11,45	11,45	11,17	10,68	10,39	10,73	11,34	11,60
Germany	10,69	13,55	15,45	14,31	14,27	13,61	13,83	14,00	13,64	13,30	12,40	12,76	12,29	11,41
Indonesia	0,30	0,58	1,49	3,13	5,10	6,72	6,83	7,08	7,75	8,28	7,79	7,97	10,05	10,11
France	4,85	7,32	8,70	10,46	11,35	10,16	9,96	9,92	10,04	9,83	8,79	9,34	8,27	8,66
Mexico	1,06	2,14	4,08	5,18	7,27	7,94	8,11	8,26	8,15	8,07	7,35	7,83	8,18	8,45
Turkey	0,33	0,84	1,39	2,56	3,59	5,72	6,01	6,43	6,44	6,66	6,56	7,02	7,10	7,00
UK	8,34	8,60	8,61	9,19	9,77	8,21	8,08	8,10	8,09	7,92	7,10	7,17	7,27	6,95
Australia	1,53	2,61	3,23	4,16	5,08	5,76	5,78	5,77	5,85	6,05	5,71	5,72	5,98	6,02
Italy	3,34	5,69	5,89	6,97	7,92	6,53	6,56	6,64	6,67	6,55	5,95	6,37	6,19	5,95
Spain	1,21	2,65	3,32	4,39	6,37	5,66	5,70	5,77	5,86	5,70	5,12	5,51	5,73	5,66
UAE	^	0,09	0,73	1,75	2,54	4,42	4,59	4,38	4,14	4,39	4,34	4,49	4,88	5,13
Thailand	0,11	0,40	0,69	2,21	3,68	4,96	5,06	5,16	5,32	5,33	4,95	4,99	5,00	5,01
Vietnam	0,11	0,25	0,22	0,46	1,33	2,98	3,24	3,47	3,90	4,33	4,34	4,35	4,48	4,89
South Africa	1,28	1,99	3,29	4,02	4,68	5,10	5,34	5,32	5,12	5,35	5,01	5,06	4,87	4,85

*** Energy consumption by year (Top 30[17] countries/regions)**

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[16] Author's calculations based on BP Statistical Review of Energy data. For detailed information, see: https://www.bp.com/en/global/corporate/search-results.html?q=all%20data&hPP=10&idx=bp.com&p=0&fR%5BbaseUrl%5D%5B0%5D=%2F

[17] Compiled by ranking the top 30 countries/regions according to 2023 energy consumption figures.

Appendix 2. Electricity Generation by Country [18]

ELECTRICITY GENERATION (terawatt-hours)	YEARS														
COUNTRIES/REGIONS	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total Asia Pacific	1724,9	2469,6	3395,6	4286,5	5971,8	8259,0	10445,4	10982,6	11611,9	12407,3	12811,6	12997,7	14002,9	14543,4	15282,0
China	410,7	621,2	1007,0	1355,6	2500,3	4207,2	5814,6	6133,2	6604,4	7166,1	7503,4	7779,1	8534,2	8848,7	9456,4
Total North America	3212,4	3831,0	4275,6	4859,7	5191,2	5276,8	5321,3	5337,4	5302,5	5475,3	5414,7	5267,2	5380,9	5536,8	5482,0
USA	2657,2	3232,8	3567,3	4052,3	4322,8	4394,3	4349,9	4348,9	4303,8	4464,5	4414,1	4287,6	4400,9	4537,7	4494,0
Total Europe	2883,9	3211,6	3278,9	3619,4	3958,6	4064,8	3983,1	4022,0	4061,9	4065,0	3997,2	3884,2	4041,3	3899,4	3805,1
India	186,4	287,8	427,1	571,4	704,5	937,5	1322,1	1401,7	1471,3	1579,2	1622,1	1581,9	1695,5	1829,3	1958,2
Total CIS	1213,7	1363,7	1068,3	1071,7	1180,6	1284,0	1340,9	1369,3	1383,0	1416,4	1426,4	1400,0	1491,2	1505,8	1524,8
Total South and	408,7	508,6	646,4	808,8	943,3	1140,5	1299,0	1306,6	1305,8	1314,9	1332,4	1321,6	1379,3	1407,7	1464,5
Total Middle East	183,5	258,2	354,4	478,3	658,5	892,6	1134,4	1166,8	1246,2	1254,7	1295,9	1309,8	1361,9	1392,2	1463,4
Russian Federation	962,0	1082,2	860,0	877,8	954,1	1038,0	1067,5	1091,0	1091,2	1109,2	1118,1	1085,4	1157,1	1166,9	1178,2
Japan	672,0	881,5	1010,9	1099,7	1153,1	1156,0	1030,1	1063,7	1076,9	1082,9	1047,4	1011,0	1034,7	1040,6	1013,3
Total Africa	259,0	318,8	362,7	440,2	560,5	672,9	790,4	799,6	826,6	849,7	869,2	852,1	891,1	902,7	902,9
Brazil	193,7	222,8	275,6	348,9	403,1	515,8	581,2	578,9	589,3	601,4	633,3	628,8	656,1	677,2	710,0
Canada	459,0	480,6	557,9	603,8	620,5	607,0	661,1	668,2	669,6	661,5	656,0	653,9	649,9	658,9	633,2
South Korea	62,7	118,5	203,5	290,4	389,5	495,0	547,8	561,0	576,4	592,9	586,8	577,1	607,8	624,6	617,9
France	344,5	420,8	494,3	540,0	576,1	569,3	571,6	556,2	554,0	573,9	562,7	524,3	547,2	466,5	519,7
Germany	522,5	549,9	536,8	576,6	622,7	632,8	647,0	649,2	652,3	641,4	608,2	574,7	587,1	577,9	513,7
Saudi Arabia	51,7	79,9	109,9	138,7	191,1	248,8	350,6	357,7	395,0	374,8	378,5	380,9	392,9	401,3	422,9
Iran	38,9	57,7	84,4	119,3	177,1	235,7	280,2	286,1	305,2	312,4	318,9	337,2	356,4	367,1	382,9
Mexico	96,2	117,6	150,4	203,6	248,0	275,6	310,3	320,3	329,1	349,3	344,6	325,7	330,0	340,1	354,9
Indonesia	16,4	33,1	54,1	93,3	127,6	169,8	234,0	247,9	254,7	283,8	295,4	291,8	309,1	333,5	350,6
Türkiye	34,2	57,5	86,2	124,9	162,0	211,2	261,8	274,4	297,3	304,8	303,9	306,7	334,7	328,4	328,0
UK	298,1	319,7	337,4	377,1	398,4	382,1	338,9	339,2	338,2	333,7	327,1	314,7	308,9	322,0	285,6
Taiwan	55,6	90,2	133,1	184,8	227,5	247,1	258,1	264,1	270,3	275,5	274,2	280,0	291,0	288,2	282,1
Spain	126,6	151,9	167,1	224,5	294,1	300,4	281,0	274,6	275,6	274,5	267,5	263,4	274,3	292,5	282,0
Vietnam	5,1	8,7	14,6	26,6	52,1	91,7	161,9	179,2	194,7	217,2	236,9	244,0	253,6	265,1	276,4
Australia	123,7	155,7	175,2	216,8	230,7	251,0	254,0	258,2	259,0	262,6	265,9	265,2	267,5	272,9	273,1
Italy	185,7	216,6	241,5	276,6	303,7	302,1	283,0	289,8	295,8	289,7	293,9	280,5	289,1	284,0	265,3
South Africa	143,5	167,2	186,7	210,7	244,9	259,6	250,4	253,1	255,4	256,3	252,6	239,5	244,3	234,8	224,4
Egypt	30,3	42,0	50,7	73,3	104,9	144,4	181,8	188,2	193,2	199,4	200,6	198,6	209,7	216,7	220,1

*** Electricity generation by year (Top 30[19] countries/regions)**

[18] Author's calculations based on BP Statistical Review of Energy data. For detailed information, see: https://www.bp.com/en/global/corporate/search-results.html?q=all%20data&hPP=10&idx=bp.com&p=0&fR%5BbaseUrl%5D%5B0%5D=%2F

[19]Compiled by ranking the top 30 countries/regions according to 2023 electricity-generation figures.

Appendix 3: Renewable Energy Production by Year [20]

RENEWABLE ENERGY (PRODUCTION BY RESOURCE) (terawatt/hours)	2022					2023				
COUNTRIES/REGIONS	Wind	Solar	Hydro	Other Renewable Energy Sources	Total	Wind	Solar	Hydro	Other Renewable Energy Sources	Total
Total Asia Pacific	901,4	734,6	1907,1	358,5	3901,6	1045,2	927,7	1788,2	380,6	4141,7
China	762,7	427,3	1298,1	182,5	2670,6	885,9	584,2	1226,0	198,1	2894,1
Total Europe	555,1	249,4	564,1	239,2	1607,8	614,1	294,9	638,7	221,6	1769,3
Total North America	497,6	234,5	684,6	87,3	1504,0	490,1	275,3	620,9	84,8	1471,1
Total South and Central America	117,9	56,7	745,1	81,5	1001,1	134,2	82,6	749,9	83,0	1049,7
USA	438,7	207,2	251,3	71,5	968,6	429,5	240,5	236,3	67,3	973,7
Brazil	81,6	30,1	427,1	55,0	593,9	95,5	51,5	428,7	55,8	631,5
Canada	38,4	7,1	397,7	9,1	452,3	38,9	7,6	364,2	10,4	421,2
India	70,0	95,2	174,9	38,6	378,7	82,1	113,4	149,2	37,3	382,0
Germany	124,8	60,3	17,6	51,9	254,6	142,1	61,2	19,6	49,5	272,4
Total CIS	6,9	5,2	248,2	1,5	261,8	8,8	6,0	253,0	1,5	269,3
Japan	9,4	91,1	74,9	37,8	213,2	10,0	97,0	74,5	42,0	223,5
Total Africa	24,3	17,8	156,3	8,4	206,8	27,8	19,2	161,6	9,7	218,4
Russian Federation	4,2	2,4	197,7	0,8	205,1	4,7	2,6	200,9	0,8	209,1
Norway	14,8	0,3	127,6	0,2	143,0	14,0	0,5	136,1	0,3	150,9
Spain	62,8	35,7	17,6	6,8	122,8	64,2	46,8	25,5	5,4	142,0
France	37,9	19,1	44,3	9,7	111,0	52,3	22,2	55,5	9,7	139,8
Türkiye	34,9	16,9	66,8	19,2	137,8	34,1	20,5	63,9	19,5	137,9
UK	80,3	13,3	5,6	35,8	135,0	82,0	13,8	5,2	34,0	135,0
Vietnam	9,1	25,8	95,9	0,4	131,1	11,4	25,7	80,9	0,9	118,8
Sweden	33,1	2,0	69,8	13,1	117,9	34,3	3,1	66,0	11,3	114,8
Italy	20,5	28,1	28,4	23,5	100,5	23,5	31,2	38,9	20,3	114,0
Australia	30,1	37,5	16,7	3,2	87,4	31,9	45,0	15,3	3,1	95,2
Other Asia Pacific	0,5	2,0	93,0	0,7	96,2	0,6	2,6	91,4	0,7	95,2
East Africa	2,8	1,7	79,6	7,3	91,3	2,6	1,9	82,1	8,5	95,2
Mexico	20,5	20,3	35,6	6,7	83,1	21,7	27,1	20,4	7,1	76,3
Other South America	5,2	0,9	54,2	3,3	63,6	5,2	1,0	60,5	4,0	70,8
Total Middle East	4,8	23,7	18,2	0,3	47,0	5,1	35,9	27,6	0,3	68,9
Venezuela	^	^	68,5	-	68,5	^	^	65,6	-	65,6
Indonesia	0,4	0,4	27,3	37,3	65,4	0,5	0,7	24,6	39,4	65,2

*** Renewable energy production by year (Top 30[21] countries/regions)**

[20] Author's calculations based on *BP Statistical Review of Energy* data. For more information, see:https://www.bp.com/en/global/corporate/search-results.html?q=all%20data&hPP=10&idx=bp.com&p=0&fR%5BbaseUrl%5D%5B0%5D=%2F

[21] Compiled by ranking the top 30 countries/regions according to 2023 renewable energy production figures

Appendix 4: Nuclear Energy Production by Year[22]

NUCLEAR ENERGY PRODUCTION (terawatt/hours)	YEARS														
COUNTRIES/REGIONS	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Total North America	4,0	24,0	194,2	302,4	464,4	682,6	814,5	874,1	925,3	945,3	951,8	940,1	924,6	909,6	917,6
USA	3,8	23,0	181,6	264,3	403,9	607,2	708,8	793,6	823,1	849,4	839,1	831,5	820,7	812,1	816,2
Total Asia Pacific	^	5,9	27,9	96,8	209,9	287,1	410,2	500,0	553,1	582,9	419,7	655,0	714,1	737,8	781,1
Total Europe	19,7	44,6	116,7	236,5	695,5	894,5	977,1	1048,6	1109,9	1031,8	968,0	833,0	882,3	742,2	735,9
China	-	-	-	-	-	-	12,8	16,7	53,1	74,7	171,4	366,2	407,5	417,8	434,7
France	0,9	5,7	18,2	61,3	224,1	314,1	377,2	415,2	451,5	428,5	437,4	353,8	379,4	294,7	338,2
Total CIS	1,9	4,4	28,6	73,9	104,6	118,3	99,9	132,7	152,2	172,9	198,3	219,0	230,2	231,2	231,8
Russian Federation	-	-	-	-	99,3	118,3	99,5	130,7	149,4	170,4	195,5	215,9	222,4	223,7	217,4
South Korea	-	-	-	3,5	16,7	52,9	67,0	109,0	146,8	148,6	164,8	160,2	158,0	176,1	180,5
Canada	0,1	1,0	12,6	38,0	60,5	72,5	97,2	72,3	91,4	90,0	101,1	97,5	92,0	86,6	89,0
Japan	^	4,6	25,1	82,6	159,6	194,6	286,9	319,1	293,0	292,4	4,5	43,0	61,2	51,8	77,5
Spain	-	0,9	7,5	5,2	28,0	54,3	55,5	62,2	57,5	61,6	57,3	58,3	56,6	58,6	56,8
Ukraine	-	-	-	-	53,3	76,2	70,5	77,3	88,8	89,2	87,6	76,2	86,2	62,1	52,4
Sweden	^	0,1	12,0	26,5	58,6	68,2	69,9	57,3	72,7	57,7	56,3	49,2	53,0	51,9	48,4
India	-	1,3	2,1	2,4	4,5	6,4	7,6	15,8	17,7	23,1	38,3	44,6	43,9	46,2	48,2
UK	15,1	26,0	30,3	37,0	61,1	65,7	89,0	85,1	81,6	62,1	70,3	50,3	45,9	47,7	40,7
Total Middle East	-	-	-	-	-	-	-	-	-	-	3,5	8,0	14,1	26,7	38,9
Finland	-	-	-	7,0	18,9	19,2	19,2	22,5	23,3	22,8	23,2	23,3	23,6	25,3	34,2
Belgium	-	0,1	6,8	12,5	34,6	42,7	41,4	48,2	47,6	47,9	26,1	34,4	50,3	43,9	32,9
UAE	-	-	-	-	-	-	-	-	-	-	-	1,6	10,5	20,1	32,3
Czech Republic	-	-	-	-	2,4	12,6	12,2	13,6	24,7	28,0	26,8	30,0	30,7	31,0	30,4
Total South and Central	-	^	2,5	2,3	9,1	9,5	9,6	12,2	16,7	21,7	21,8	24,1	24,9	22,0	23,5
Switzerland	-	1,8	7,8	14,3	22,4	23,5	24,7	26,3	23,2	26,5	23,3	23,0	18,5	23,1	23,3
Pakistan	-	-	0,6	0,1	0,4	0,4	0,5	0,9	2,5	2,5	4,3	9,5	15,7	22,2	22,4
Slovakia	-	-	0,2	4,5	9,4	12,0	11,4	16,5	17,7	14,6	15,1	15,4	15,7	15,9	18,3
Taiwan	-	-	-	8,2	28,7	32,9	35,3	38,5	40,0	41,6	36,5	31,4	27,8	23,8	17,8
Bulgaria	-	-	2,6	6,2	13,1	14,7	17,3	18,2	18,7	15,2	15,4	16,6	16,5	16,5	16,2
Hungary	-	-	-	-	6,5	13,7	14,0	14,2	13,8	15,8	15,8	16,1	16,0	15,8	15,9
Brazil	-	-	-	-	3,4	2,2	2,5	6,0	9,9	14,5	14,7	14,1	14,7	14,6	14,5
Mexico	-	-	-	-	-	2,9	8,4	8,2	10,8	5,9	11,6	11,2	11,9	10,8	12,4

*** Nuclear energy production by year (Top 30[23] countries/regions)**

[22] Author's calculations based on *BP Statistical Review of Energy* data. For more information, see: https://www.bp.com/en/global/corporate/search-results.html?q=all%20data&hPP=10&idx=bp.com&p=0&fR%5BbaseUrl%5D%5B0%5D=%2F

[23] Compiled by ranking the top 30 countries/regions according to 2023 nuclear energy production figures.

Appendix 5: Oil Production by Year [24]

OIL PRODUCTION (thousand barrels per day)	YEARS									
COUNTRIES/REGIONS	1965	1975	1985	1995	2005	2015	2020	2021	2022	2023
Total North America	10296	12549	15305	13779	13707	19756	23533	24033	25361	27050
USA	9014	10008	10580	8322	6901	12782	16493	16693	17844	19358
Total CIS	4858	9916	11870	7168	11687	13966	13468	13806	13933	13868
Saudi Arabia	2219	7216	3601	8974	10839	11998	11039	10954	12191	11389
Russian Federation	-	-	10863	6236	9598	11087	10666	11000	11202	11075
Total South and Central	4334	3697	3721	5779	7337	7991	6086	6111	6626	7368
Total Asia Pacific	899	3808	5918	7271	7991	8378	7449	7366	7252	7275
Total Africa	2232	5068	5369	7050	9771	8123	6998	7360	7063	7228
Canada	920	1735	1813	2402	3041	4388	5130	5414	5575	5653
Iran	1908	5387	2205	3744	4217	3853	3230	3766	3945	4662
Iraq	1313	2271	1425	530	1833	3986	4114	4102	4520	4355
China	227	1548	2508	2993	3642	4309	3901	3994	4111	4198
UAE	282	1664	1211	2444	2945	3876	3679	3640	4020	3922
Brazil	96	177	561	715	1706	2525	3030	2991	3112	3502
Total Europe	786	1072	4565	6643	5851	3602	3612	3436	3214	3225
Kuwait	2371	2132	1127	2130	2669	3069	2721	2706	3036	2908
Mexico	362	806	2912	3055	3766	2587	1910	1926	1943	2040
Norway	-	189	823	2903	2983	1953	2018	2036	1906	2022
Kazakhstan	-	-	485	450	1294	1672	1796	1805	1771	1891
Qatar	233	437	315	461	1148	1844	1715	1697	1743	1772
Nigeria	274	1783	1499	1949	2482	2199	1894	1678	1445	1540
Algeria	570	1025	1087	1310	1990	1558	1332	1353	1443	1408
Libya	1220	1514	1025	1439	1745	437	420	1286	1143	1271
Angola	13	158	232	633	1269	1796	1325	1177	1191	1150
Argentina	276	406	491	758	842	646	721	797	955	1074
Oman	-	341	502	868	774	981	951	971	1064	1049
Venezuela	3503	2422	1744	2959	3302	2864	680	678	735	853
Colombia	203	164	183	591	526	1006	781	736	754	777
India	62	171	627	774	755	904	795	770	739	728

*** Oil production by year (Top 30[25] countries/regions)**

[24] Author's calculations based on *BP Statistical Review of Energy* data. For more information, see: https://www.bp.com/en/global/corporate/search-results.html?q=all%20data&hPP=10&idx=bp.com&p=0&fR%5BbaseUrl%5D%5B0%5D=%2F

[25] Compiled by ranking the top 30 countries/regions according to 2023 oil production figures.

Appendix 6: Natural Gas Production by Year [26]

NATURAL GAS PRODUCTION (billion cubic meters)	YEARS								
COUNTRIES/REGIONS	1970	1980	1990	2000	2010	2020	2021	2022	2023
USA	571,5	525,1	483,4	518,6	575,2	924,8	944,5	993,4	1035,3
Total CIS	187,5	412,2	731,0	644,2	739,5	808,4	891,2	807,6	773,6
Total Middle East	10,3	34,2	100,7	204,1	474,6	667,9	687,4	701,7	712,7
Total Asia Pacific	15,1	71,8	149,3	277,5	488,1	656,3	680,0	687,8	691,8
Russian Federation	-	-	599,6	537,1	598,4	638,4	702,1	618,4	586,4
Total Africa	3,0	24,8	72,2	135,1	201,5	231,9	266,7	255,8	253,6
Iran	3,5	4,5	24,7	56,3	143,9	235,8	242,8	247,7	251,7
China	2,9	14,4	15,4	27,4	96,5	194,0	209,2	221,8	234,3
Total Europe	104,9	228,6	243,2	309,9	310,1	219,1	211,1	220,2	204,3
Canada	54,0	71,2	103,4	176,3	149,6	165,6	172,3	184,8	190,3
Qatar	1,0	4,9	6,5	25,8	123,1	174,9	177,0	178,5	181,0
Total South and Central America	18,7	35,3	60,2	101,7	160,4	156,6	158,5	163,6	162,0
Australia	1,7	11,1	20,6	31,2	52,6	145,7	147,9	154,2	151,7
Norway	-	24,9	25,3	49,4	106,2	111,7	114,5	123,0	116,6
Saudi Arabia	1,5	9,2	31,8	47,3	83,3	113,1	114,5	116,7	114,1
Algeria	2,4	15,4	51,7	91,9	77,4	81,4	101,1	97,6	101,5
Malaysia	-	2,6	18,0	49,7	65,1	73,1	79,0	83,0	81,1
Turkmenistan	-	-	79,2	42,4	40,1	66,0	79,3	78,3	76,3
Indonesia	1,3	18,8	44,5	70,7	87,0	64,7	64,4	62,8	64,3
Egypt	0,1	2,1	7,8	20,2	59,0	58,5	67,8	64,5	57,1
UAE	0,8	7,3	19,6	37,4	50,0	53,7	53,1	54,2	55,6
Uzbekistan	-	-	36,8	50,9	57,1	47,1	50,9	48,9	44,2
Nigeria	0,1	1,6	3,8	11,2	30,9	49,4	52,4	47,1	43,7
Oman	-	0,6	2,4	10,3	25,7	36,9	40,3	42,1	43,2
Argentina	5,9	8,2	17,3	36,4	39,0	38,3	38,6	41,7	41,6
Mexico	11,0	25,1	26,4	33,4	51,2	35,5	32,1	33,7	35,6
Azerbaijan	-	-	9,7	5,2	16,3	25,9	31,8	34,1	35,6
Other Africa	0,1	0,8	3,0	6,2	18,2	29,9	30,1	32,0	35,0
UK	10,9	36,4	47,6	113,5	57,9	39,6	32,8	38,1	34,5
India	0,6	1,1	11,6	25,4	47,4	23,8	28,5	29,8	31,6

*** Natural gas production by year (Top 30[27] countries/regions)**

[26] Author's calculations based on *BP Statistical Review of Energy* data. For more information, see: https://www.bp.com/en/global/corporate/search-results.html?q=all%20data&hPP=10&idx=bp.com&p=0&fR%5BbaseUrl%5D%5B0%5D=%2F

[27] Compiled by ranking the top 30 countries/regions according to 2023 natural gas production figures.

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CHAPTER 2

THE GEOPOLITICAL ECONOMY OF ENERGY TRANSITIONS: STRATEGIC RIVALRIES AND COOPERATION IN THE 21ST CENTURY

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INTRODUCTION

The global energy system is undergoing an unprecedented transformation (Caineng et al., 2023; Cherp et al., 2011; Zakeri et al., 2022). Accelerated by mounting concerns over climate change, fossil fuel depletion, energy security, and technological disruption, the 21st century has seen a decisive shift in policy agendas, investment flows, and industrial strategies across both advanced and developing economies (Bulfone, 2023). Energy transitions—defined not merely as a shift from fossil fuels to renewables, but as a broader restructuring of production, distribution, and governance of energy systems—have emerged as one of the defining political-economic challenges of our time (Wahlund & Palm, 2022). Energy extends beyond being a mere commodity; it serves as an enabler of sovereignty, a driver of geopolitical influence, and a fundamental element of industrial competitiveness (Pirani, 2021). Historically, transitions in dominant energy regimes—from biomass to coal, coal to oil, and now oil to renewables—have always entailed deep reorganizations of global power structures (Newell, 2021). The current wave of energy transition is distinct in that it is unfolding within a multipolar world economy, characterized by intensified rivalry between the United States, China, and the European Union, each seeking to shape the future energy order according to their strategic, economic, and normative preferences (Chen & Wu, 2024).

From the United States' Inflation Reduction Act (IRA) and strategic decoupling from Chinese solar supply chains, to China's Belt and Road Initiative (BRI) and dominance in rare earth mineral processing, and the European Union's Carbon Border Adjustment Mechanism (CBAM) aimed at protecting its green industrial base, energy policy has increasingly become a platform for techno-industrial competition and geopolitical signaling(Ambec, 2022; Kleimann et al., 2023; Schulhof et al., 2022). These developments point to the emergence of what some scholars term a "geopolitical economy of energy transitions," where the interplay between state interests, transnational capital, resource control, and institutional engineering is reconfiguring the global political economy.

At the same time, this competitive dynamic is not occurring in isolation from the rest of the world. Global South countries, long positioned as passive recipients of energy technologies and investment, are now playing an increasingly active role. Nations across Africa, Latin America, and Southeast Asia are simultaneously sites of resource extraction, zones of clean energy infrastructure deployment, and arenas where strategic alignments are formed(Apergi et al., 2024; Minas et al., 2024). In some cases, they are leveraging their critical resource endowments to extract geopolitical rents or to attract preferential financing from competing major powers. Thus, the geopolitical economy of energy transitions is both global and asymmetric: contested, negotiated, and uneven.

As illustrated in Figure 1, the global green energy supply chain is marked by a distinct geography of roles and flows. Upstream extraction is concentrated in resource-rich countries in the global south, such as cobalt mining in the Democratic Republic of the Congo and lithium production in Chile and Australia. China plays an important role as the processing and manufacturing hub, controlling significant segments of solar photovoltaic, battery production, and critical mineral refining. It serves as the central node connecting the raw material sources to downstream actors. Currently, the United States (US) and Germany establish themselves as leaders in technology standards, policy structures, and strategic management of supply chains. This spatial configuration reflects the asymmetric structure of global energy transitions, characterized by the flow from extraction through production to regulatory influence (Gawusu et al., 2022; Verpoort et al., 2024).

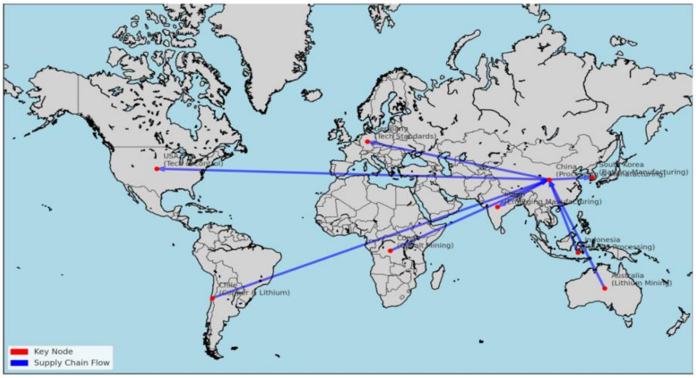

Figure 1: Geographical Distribution of Key Nodes in the Global Green Energy Supply Chain, *International Energy Agency (2023), USGS Mineral Commodity Summaries, and Bloomberg NEF 2023 Report.*

The study aims to examine the manner in which strategic rivalry and selective collaboration among leading powers affect the pathways, velocities, and patterns of global energy transitions. This objective is achieved by grounding the analysis within the theoretical construct of the geopolitical economy, which highlights the structural interplay of national strategies, capital accumulation, and institutional power on a global scale. This perspective moves beyond deterministic models of energy transition. Instead, it foregrounds the contested nature of global governance and the political embeddedness of energy systems. The study is structured as follows: Section 2 develops a theoretical framework grounded in geopolitical economy linking energy, national power, and global structural asymmetries. Section 3 analyzes the strategic configurations of the US, China, and the European Union in the current energy transition, with a particular emphasis on policy tools, supply chain security, and institutional exports. Section 4 concludes by summarizing key findings and offering policy implications for energy governance and development pathways in a fragmented geopolitical environment.

Before turning to the theoretical framework, it is helpful to visualize the strategic narrative frameworks adopted by the major powers. The following word cloud illustrates the dominant keywords appearing in recent energy policy discourse in China, the US and the European Union, highlighting divergent emphases and strategic framings between geopolitical actors.

Figure 2: Strategic Framing of Energy Transitions in Policy Discourse.
Source: *keyword frequency analysis from official policy documents, including the EU Green Deal communication (2023), the US. Inflation Reduction Act policy briefs (2023) and China's dual carbon targets reports (2023).*

1. THEORETICAL FRAMEWORK: GEOPOLITICAL ECONOMY AND ENERGY TRANSITIONS

As global energy transformation increasingly becomes an important part of national strategic games, it is necessary to build a systematic analytical framework to reveal the political and economic dynamics behind it. Based on geopolitical economics, this section will explore how state-capital relations, structural power, and global asymmetric patterns shape the energy transformation paths of different countries. This study emphasizes the core role of sovereignty, national interests, and material power in the formulation of energy strategies. Furthermore, this section combines dependency theory with emerging analytical perspectives on green capitalism and re-industrialization to provide a theoretical basis for the specific comparison of energy strategies of major countries.

1.1 The Geopolitical Economy Perspective: States, Capital, and Structural Power

The geopolitical economy perspective offers a structuralist approach to analyzing the political underpinnings of energy transitions (Kuzemko et al., 2025). Moving away from the liberal international political economy models that emphasize free markets and collaborative institutions, geopolitical economy theory highlights the pivotal role of states as influential actors in molding the structures of global production, trade, and finance (Shahzad, 2022). It highlights the tension and codependence between nation states and transnational capital, particularly during systemic shifts in energy regimes.

A central analytical tool in this perspective is Susan Strange's notion of structural power—the ability not to command directly, but to shape the frameworks within which others operate (Belli, 2022; May, 1996). Structural power manifests in four domains: production, finance, security, and knowledge. In the context of energy transitions, it underpins how states define standards, control access to technologies and resources, and institutionalize new regimes of legitimacy in climate governance (Malkin, 2022). This act of defining the standard has become evident when examining the major powers' deployment of strategic tools. The US has embedded clean-tech re-industrialization within its Inflation Reduction Act (IRA), using tax incentives to repatriate green manufacturing and reduce dependence on Chinese supply chains (Bistline et al., 2023). The EU is promoting the external expansion of environmental regulation through the Carbon Border Adjustment Mechanism (CBAM), intending to spread its environmental regulations to the world (Magacho et al., 2024). At the same time, China has strengthened the green financing component of its Belt and Road Initiative and has made energy transformation a future development priority (Blanchard, 2021).

As shown in Table 1, China, the US and Europe pursue geopolitical energy dominance through these strategies. From this perspective, energy transformation is not only a technological change, but also a fierce reshaping and competition for the existing political and economic order. We find that competition between countries is not only reflected in emission reduction targets, but also in the control of global rules, financing channels, and industrial standards. The analytical framework of geopolitical economics enables us to understand the specific connotations of this competition deeply.

Table 1: Comparative Use of Structural Tools in Energy Geopolitics

Actor	Industrial Strategy Tool	Structural Power Target	Intended Geoeconomic Outcome
China	Green BRI, critical mineral control	Infrastructure and finance	South-South leadership, market dominance
USA	IRA subsidies and domestic content rules	Regulatory and trade standards	Norm diffusion, institutional leverage
EU	CBAM, ESG taxonomy, Green bonds	Regulatory and Trade Standards	Norm diffusion, institutional leverage

Source: *official policy documents from China (Green BRI White Papers), the United States (Inflation Reduction Act), and the European Union (CBAM and Green Taxonomy Frameworks), all released.*

1.2 Energy, National Security and Economic Sovereignty

In contemporary geopolitics, energy is no longer simply an economic input but a foundation for national security. This repositioning not only recognizes the historical intertwining of energy and power but also reflects the new pressures brought about by the energy transition. The strategic importance of energy has historically been primarily reflected in the acquisition of fuels such as oil and natural gas, as these resources are crucial to military operations, industrial development, and geopolitical negotiations (Farghali et al., 2023; Zhou et al., 2021). Critical minerals such as lithium, cobalt, and rare earth elements, which are indispensable for batteries, solar panels, and wind turbines, have become the new strategic assets. Consequently, securing access to these inputs has become central to national defense strategies and economic planning in major powers.

This evolving energy-security nexus has led to the reemergence of strategic autonomy as a key policy goal. The 2022 strategic roadmap of the European Union explicitly identifies energy resilience as a security imperative, while the US has linked clean energy manufacturing to national security under the Defense Production Act. China's dual-circulation strategy similarly prioritizes reducing reliance on foreign technological and energy inputs, with the aim of consolidating its self-reliant industrial base while maintaining global market integration.

In this context, energy security is no longer defined solely by the volume or price stability of imported fuels, but by control over **technological value chains**, regulatory frameworks, and infrastructure sovereignty(Håkansson, 2022). The concept of *economic sovereignty*—the ability of a state to govern its economy free from external coercion—is increasingly applied to green technologies (Guedel & Viles Jr, 2021; Savanovic, 2014). For instance, concerns about dependency on Chinese photovoltaic modules or Western battery technologies have prompted re-shoring efforts and the promotion of indigenous innovation in multiple countries.

In addition, energy securitization intersects with cyber and infrastructure threats. Smart grids, hydrogen storage systems, and electric vehicle charging infrastructure are not only technological systems, but also critical assets vulnerable to sabotage or foreign control. As a result, energy policy is being "hardwired" into national security doctrines, with implications for how states collaborate or compete in international forums such as the International Energy Agency or the Clean Energy Ministerial (Bauerle Danzman & Meunier, 2024; Rose, 2021). Ultimately, the convergence of energy transition and national security discourse reflects a broader shift toward strategic statecraft in global economic governance. Energy is no longer treated as a neutral domain of supply and demand, but as a contested arena where sovereignty, resilience, and control over future capabilities are negotiated. This securitized framework has far-reaching consequences: it legitimizes industrial intervention, shapes international alliances, and contributes to the fragmentation of global energy governance into regional and bilateral blocs.

1.3 Dependency Theory and Re-industrialization Logics in the Energy Transition

Energy transition, as a systemic transformation of economies, involves not only the replacement of fossil fuels with renewables but also a fundamental restructuring of global value chains and the redistribution of technological sovereignty (Pearse, 2021). Within this process, developing countries often face the dual challenges of *new forms of dependency* and *green lock-in traps*, where they are positioned as raw material suppliers or testbeds for green projects, but remain excluded from the command centers of technological development and institutional agenda-setting (Babayomi et al., 2022). These asymmetries can be understood as a contemporary manifestation of classic Dependency Theory in the green energy context.

Originating in Latin American development thought, Dependency Theory argues that the global economic system is divided into core and periphery, where the periphery's reliance on external capital, technology, and markets impedes autonomous industrialization. In fossil fuel regimes, this took the form of raw resource exports and high-value product imports. In the green energy regime, dependency appears in new forms—*technological dependency* (for example, reliance on imported solar or battery components), *data dependency* (for example, smart grid platforms controlled by foreign software providers), and *standard dependency* (for example, foreign ESG disclosure requirements) (Antunes de Oliveira, 2022; Velasco, 2002).

Many resource-rich countries in Africa and Latin America—home to lithium, cobalt, and nickel—have little industrial capacity to process or add value to these critical minerals (Hendrix, 2022). As a result, they remain locked into the low-value segments of the green supply chain, reproducing patterns of unequal exchange. The value-added flows largely to the Global North, where green tech R&D, manufacturing, and finance are concentrated. Meanwhile, industrialized economies are pursuing *green re-industrialization* as a strategy to reassert manufacturing leadership in the post-carbon era. This is evident in three dimensions (Afanasyev & Shash, 2024; Frattini et al., 2024). First, policy tools such as the US **Inflation Reduction Act (IRA)** and the EU's **Net-Zero Industry Act (NZIA)** promote domestic, low-carbon, and smart manufacturing. Second, regulatory frameworks such as carbon border taxes, ESG taxonomies, and green product standards function as barriers to entry for exporters from developing economies. Third, climate finance mechanisms—often dominated by rating agencies and banks based in the Global North—reinforce institutional asymmetries in access to capital, pricing power, and project eligibility.

Nevertheless, some Global South countries are actively seeking to overcome dependency traps. India's National Green Hydrogen Mission combines domestic electrolyze R&D with strategic South–South partnerships, including hydrogen export deals with Gulf countries. Chile and Argentina are reforming mining permit systems to retain more value in-country through local processing(Alshareef, 2024). China has integrated its dual-carbon goals with the Belt and Road Initiative (BRI) by promoting green industrial parks, technology transfer, and finance mobilization in other developing regions. These strategies reflect an emergent discourse of "green developmental sovereignty"—the notion that Global South countries should not merely be passive recipients of green technologies and investments, but active participants in shaping green rules, financing arrangements, and innovation trajectories (Carmody, 2020). This shift challenges the traditional core-periphery divide and offers an alternative pathway for inclusive and cooperative green globalization. Therefore, energy transitions do not inherently produce more equitable global structures. Without institutional reforms and proactive strategies, the green economy can reinforce existing asymmetries or create new forms of dependency. A fair and inclusive energy transition must address these structural risks and promote re-industrialization that is not only national but transnational in its cooperative logic.

1.4 Applicability and Limitations of Geopolitical Economy Theories in Global Energy Policy

Geopolitical economics provides a powerful analytical perspective for understanding the strategic dynamics behind the global energy transition, enabling scholars and policymakers to view energy as a core vehicle for power, sovereignty, and competition (Amineh & Guang, 2017). Different from the mainstream economic model that emphasizes efficiency and market equilibrium, geopolitical economics emphasizes the role of industrial policy, technological dominance and geopolitical competition in energy governance (Scholvin & Wigell, 2018).

This theoretical framework is particularly suitable for explaining some important phenomena, such as clean energy technology trends and national-led industrial strategies in response to energy transition (Kuzemko et al., 2025; Mohapatra, 2017). However, the geopolitical economics framework also has certain limitations, especially when dealing with the complexity of the contemporary global energy landscape. Early dependency theory often portrayed the "global South" as a peripheral region that passively accepted external structural constraints. However, recent cases have shown that peripheral countries are increasingly shaping their role in green transformation through proactive strategies. Therefore, the classic geopolitical economics theory needs to be updated in a timely manner to meet the needs of the current era.

In addition, simply understanding the global power structure as a binary "core-periphery" model does not meet the requirements of the complex network composed of cooperation, competition and hybrid governance in the contemporary world (Yang et al., 2023). For example, Chinese and European companies often find themselves simultaneously in competition and collaboration in the global electric vehicle and battery markets. These relational dynamics defy simplistic polarization and require more flexible analytical tools. Furthermore, while the geopolitical economy is analytically strong in capturing economic and strategic logics, it tends to pay insufficient attention to the ecological, normative, and ethical dimensions of energy governance. Issues such as environmental justice, intergenerational responsibility, and climate equity remain underexplored within its core formulations.

Ultimately, as the governance of energy transitions towards greater polycentrism—encompassing an expanding involvement of subnational actors, international institutions, and civil society networks—the state-centric predisposition inherent in numerous geopolitical economic analyses might constrain its ability to encapsulate novel forms of authority and institutional experimentation comprehensively. Urban centers, development banks, philanthropic alliances, and platforms with diverse participants are increasingly instrumental in defining energy strategies, thus questioning the exclusive dominance of sovereign states as the main designers of energy systems.

Table 2: Analytical Strengths and Limitations of Geopolitical Economy

Analytical Dimension	Applicability	Limitations
Explanatory Power	Reveals strategic motivations in energy policy and statecraft	Neglects non-state actors and polycentric governance patterns
Historical Depth	Links energy transitions to historical shifts in global power	Underestimates emergent agency in the Global South
Structural Understanding	Highlights asymmetries in technology, finance, and resource access	Tends to reproduce binary core–periphery models
Policy Insights	Supports rationale for national industrial policy and re-industrialization	Lacks attention to justice, ethics, and ecological dimensions
Integrative Potential	Foundational for Synthesis with Other Political Economy Frameworks	Original formulations are rigid and slow to adapt.

Source*: Author's synthesis based on geopolitical economy literature and analytical framework developed in this study.*

To clearly delineate these strengths and limitations, Table 2 presents a comparative summary of the analytical capabilities and shortcomings of the geopolitical economy approach when applied to energy policy. Tables in this format underscore central aspects such as explanatory capacity, historical context, and policy understanding, also pointing out where theoretical refinement is required, such as in ecological integration and the handling of agency. Furthermore, as demonstrated in Figure 3, the changing dynamics of global energy governance require an integrated theoretical framework that extends beyond the initial concept of a geopolitical economy. By integrating complementary perspectives from development studies, climate governance, and environmental political theory, it becomes possible to build a more holistic framework capable of addressing the multilevel, multifactor nature of contemporary transitions. This conceptual model reflects a growing consensus that normative, institutional, and relational dimensions must balance structural analysis.

Figure 3: Nested Theoretical Framework for Analyzing Global Energy Transitions
Source: *Author's visualization based on literature.*

2. STRATEGIC RIVALRIES IN THE ENERGY TRANSITION ERA

As global energy transformation continues to increase as a core issue of national strategy, it is particularly important to understand the strategic choices and policy tools of different countries. This section systematically compares the strategic layout and game mode of the three major economies of China, the United States, and Europe in the process of energy transformation to analyze how the parties can achieve the reconstruction of energy dominance through policy design and international cooperation. In addition, the section will end with a discussion of how the global South countries pursue energy autonomy and development rights in this reconstruction process.

2.1 United States: Decarbonization, Supply Chain Realignment, and the IRA Doctrine

In recent years, the US has made major adjustments to its energy and industrial policies, establishing clean energy as a dual core pillar that takes into account environmental responsibility and geostrategic considerations (Church et al., 2023). This policy shift is most intuitively reflected in the Inflation Reduction Act (IRA) passed in 2022, which provides huge financial support for clean energy technology research and development, green manufacturing upgrades, and climate resilience building. In addition to climate goals, the document embeds decarbonization into a broader national agenda, including economic security, technological leadership, and strategic competition with China, marking a fundamental shift in US industrial policy (Jaffe, 2023).

Among the most contentious aspects of the IRA is its clear decoupling strategy. While ostensibly technology-neutral, the act implicitly discourages reliance on Chinese suppliers by requiring North American sourcing for critical minerals and battery components. This act has been interpreted as a deliberate effort to desinicize the clean energy supply chain, reshaping global trade flows in lithium, cobalt, and rare earths.

The US allies, such as Canada, South Korea, and members of the Indo-Pacific Economic Framework, have been selectively integrated into these value chains, reinforcing a climate-industrial alliance architecture.

Currently, the US has increased its deployment of export controls, investment screening, and strategic mineral reserves to protect its clean energy dominance. In 2023, the Department of Defense designated certain green technologies as 'critical to national security', allowing exceptional procurement and financing tools under the Defense Production Act. These measures underscore the increasing securitization of energy policy, embodying a convergence of climate objectives and geopolitical considerations, which contest traditional demarcations between economic and defense policy.

However, the unilateral and subsidy-heavy nature of the IRA has generated significant friction with traditional allies, particularly the European Union, which has criticized the act for its trade-distorting effects. This tension illustrates the broader dilemma of fragmentation in global climate governance, as major powers increasingly prioritize national competitiveness over coordinated decarbonization. The US model, while ambitious in scale and industrial depth, risks undermining global equity and norm convergence if not complemented by international cooperation frameworks.

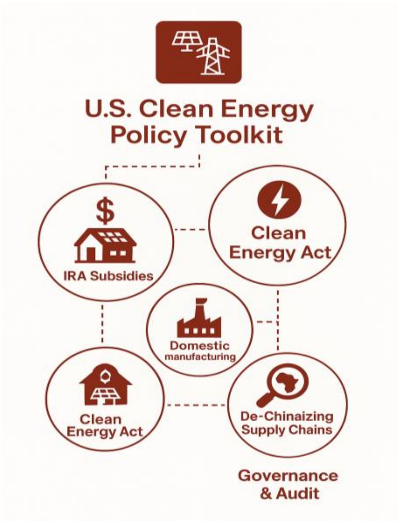

Figure 4: The US Clean Energy Policy Toolkit.
Source: *Author's elaboration based on US clean energy policies and publicly available policy analysis.*

In summary, the clean energy strategy of the US exemplifies a paradigm shift: from market-driven environmentalism to a security-oriented, industrially embedded transition model. Through the IRA and related policy frameworks, the US aspires not only to mitigate emissions but also to overhaul global energy supply chains, reinforce technological sovereignty, and fortify its leadership position in the post-carbon era. This approach marks a clear return to strategic statecraft in the age of climate change. The strategic structure of the US clean energy policy instruments is summarized in Figure 4.

2.2 China: Green Manufacturing Hub, Resource Security, and Infrastructure Diplomacy

China has firmly established itself as the world's leading producer of clean energy technologies, transforming from a participant to a key architect of the emerging global energy order. As of 2023, China accounted for over 80% of global solar photovoltaic (PV) production and nearly 70% of lithium-ion battery output. It also plays a dominant role in the upstream supply chains of critical minerals such as rare earths, lithium, cobalt, and graphite (IEA, 2023). This dominance is not incidental but the result of deliberate state-led strategies involving industrial policy, financial subsidies, and infrastructure-driven diplomacy(Raimi et al., 2024).

At the center of China's energy strategy are its 'dual carbon' goals, namely reducing carbon emissions by 2030 and achieving carbon neutrality by 2060. Unlike Western models that rely primarily on market-based mechanisms, China's path toward decarbonization is characterized by the leadership of governmental planning and the coordination of industrial activities. This is implemented through 5-year plans, green special-purpose bonds, clusters of state-owned enterprises (SOEs), and designated innovation zones. The resulting vertically integrated value chain spans resource extraction, processing, manufacturing, and deployment, enabling China to achieve scale efficiency, cost advantages, and systemic control over supply chain resilience.

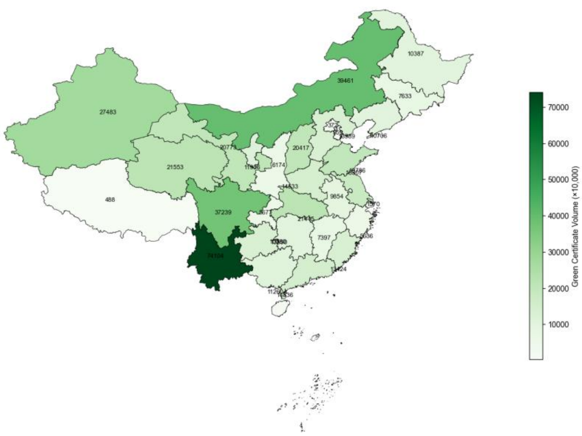

Figure 5 Provincial Distribution of Green Certificate Issuance in China (2024)
Data source: *National Energy Administration of China(2024)*

To visualize the spatial distribution of this strategy, Figure 5 illustrates the issuance of Green Electricity Certificates (GECs) in Chinese provinces in 2024. These certificates, which are part of China's renewable energy quota system, indicate the scale of green electricity generated in different regions. As shown in the map, western and northwest provinces such as Yunnan, Xinjiang, Inner Mongolia, Sichuan, and Gansu lead the way in certificate issuance. These regions possess abundant renewable resources: hydropower, wind and solar, and are central to national strategies such as West-East power transmission and the development of large-scale clean energy bases. Thus, the distribution of GECs not only reflects regional differences in renewable energy production but also illustrates the broader spatial logic of China's coordinated energy and security strategy. China's green manufacturing capacity is closely linked to its broader resource security strategy. Through outbound investment by SOEs, long-term contracts, and domestic refining capacity, China has secured access to key strategic minerals in regions such as Latin America and Africa. These efforts support downstream value capture and reduce dependence on external suppliers.

China's approach to the energy transition is also marked by a strong orientation towards the external infrastructure, especially under the Belt and Road Initiative (BRI). Over the past decade, China has financed and constructed hundreds of renewable energy projects abroad, particularly in Asia, Africa, and the Middle East. These projects often go beyond solar or wind installations to include supporting infrastructure such as transmission networks, storage systems, and digital management platforms, thus exporting Chinese technical standards and institutional models. According to China's National Energy Administration, more than 40% of China's energy investments in BRI countries in 2023 were allocated to renewable energy. A 2023 report titled 'Innovative Mechanisms to Advance Sustainable Development under the BRI', released on the 10th anniversary of the initiative, highlights the growing role of green cooperation. It notes that global low-carbon energy investment in 2022 reached parity with fossil fuel investment, each totaling around USD 1.1 trillion. The majority of these flows went into renewable energy (USD 495 billion) and electrified transport (USD 466 billion) (Mahmood et al., 2024; Senadjki et al., 2022).

China's policy banks, such as the China Development Bank and the Export-Import Bank of China, play a critical role by offering concessional loans, export credits and tied aid. These financing instruments embed Chinese technologies, labor systems, and governance norms into the energy infrastructures of partner countries, fostering a form of institutional path dependence and improving China's structural role in global green development. In summary, China's energy transition strategy reflects the logic of a developmental state: enhancing national capabilities through the integration of green industry upgrading, resource control and infrastructure diplomacy. In comparison, China pays more attention to the construction of an integrated production system and cooperation with countries in the "global south". It is undeniable that China has become one of the core forces in shaping the rules and material basis of the global energy transition.

2.3 European Union: Green Deal, CBAM, and Standard-Setting Diplomacy

The European Union (EU) has become a pioneer in building a global low-carbon transition system and regulatory framework. Based on the European Green Deal, the EU's strategic goal is to achieve climate neutrality by 2050 through a set of legislative and financial instruments. The most prominent of these is the implementation of the Carbon Border Adjustment Mechanism (CBAM) (Dominioni et al., 2025). CBAM represents a landmark shift in global climate governance. It is designed to prevent carbon leakage by levelling the playing field between domestic EU producers—subject to carbon pricing under the EU ETS—and foreign producers exporting goods to the EU. Initially covering sectors such as cement, steel, aluminum, fertilizers, electricity, and hydrogen, CBAM requires importers to report embedded emissions and purchase CBAM certificates that reflect the EU carbon price (Clora et al., 2023).

Figure 6 illustrates the operational logic of the CBAM system. The process begins by assessing whether a product falls within the scope of the CBAM. If so, the embedded emissions must be calculated, either using verified actual emissions data or default values. The responsibility then falls on authorized CBAM declarants within the EU to submit quarterly reports and, starting in 2026, to surrender corresponding CBAM certificates. As the diagram shows, even if a foreign exporter is not directly liable, they are expected to respond to information requests from their EU buyers, reflecting the indirect extraterritorial reach of the regulation. The phased implementation of CBAM signals the strategic use of regulatory tools by the EU to project climate norms worldwide. Unlike traditional trade barriers, CBAM is justified on environmental grounds and is structured to comply with World Trade Organization (WTO) rules. Nevertheless, its practical implications are far-reaching: it effectively externalizes EU carbon pricing to third countries, particularly developing and export-oriented economies that rely on energy-intensive exports to Europe.

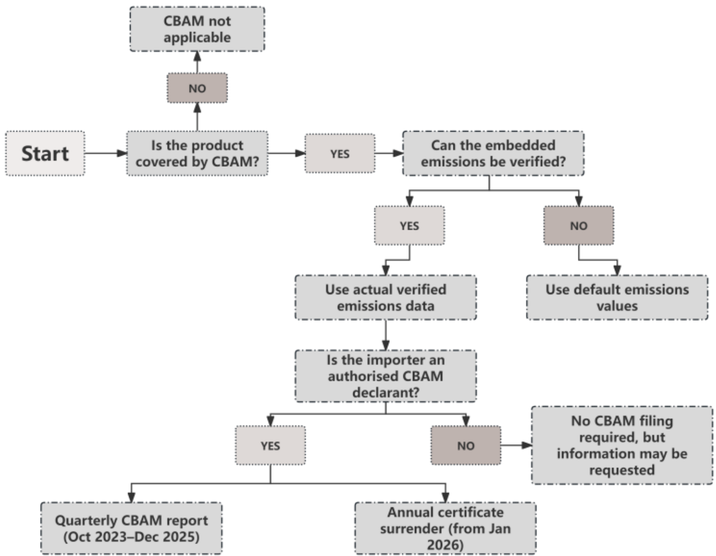

Figure 6. Operational Flow of the EU Carbon Border Adjustment Mechanism (CBAM)

***Source*：** *Author's diagram based on official CBAM guidelines and explanatory materials from One Click LCA (Ramachandran, 2024).*

The CBAM framework also strengthens the role of the EU as a standard-setting power. Through its taxonomy regulation, sustainable finance disclosure rules, and renewable energy benchmarks, the EU is shaping global expectations of what constitutes environmentally sustainable activity. For example, EU green taxonomy alignment is becoming a prerequisite for cross-border green bond issuance and investment fund labeling in global markets. The US opted for an industrial policy-driven strategy focused on subsidies and incentives for decarbonization, as exemplified by the Inflation Reduction Act. In contrast, the EU emphasizes normative and regulatory governance, emphasizing the spread of rules, transparency mandates, and conditions linked to market access. This divergence in approach may lead to transatlantic frictions. However, it also opens up space for complementary leadership in global green governance. Despite this, CBAM faces challenges that are both technical and political. Many developing countries view the mechanism as a form of "green protectionism" that could constrain their industrial development. Within the EU, concerns remain about administrative capacity, carbon cost pass-through, and sectoral exemptions. Furthermore, global supply chains can become fragmented if different carbon standards emerge in different jurisdictions.

In conclusion, EU climate diplomacy exemplifies a form of regulatory multilateralism. In this access, the EU market is leveraged to promote climate compliance beyond its borders. By embedding carbon accounting requirements into trade infrastructure, the EU is not only defending its domestic climate ambition but also reshaping the logic of international commerce in the age of decarbonization.

2.4 The Global South and the Struggle for Energy Sovereignty

While the US, China, and the European Union are actively shaping the contours of the global energy transition through industrial policy, supply chain realignment, and regulatory projection, **countries in the Global South face a dual challenge**: securing access to affordable clean energy while avoiding structural subordination in the emerging green order. Rather than passive recipients of external strategies, many developing countries are now repositioning themselves as **critical resource holders, testing grounds for technology deployment, and geopolitical swing actors.**

Countries in the Global South abundant in resources, including Chile (lithium), the Democratic Republic of Congo (cobalt), Indonesia (nickel), and Namibia (rare earths), have started to exploit these mineral reserves using strategies such as selective nationalization, export restrictions, and policies aimed at increasing value. Since 2020, Indonesia has implemented a ban on the export of raw nickel, promoting the upgrading of the local refining industry by restricting the export of primary minerals, and thereby attracting investment in the battery manufacturing industry. This move reflects the strategic demand of resource-rich countries to increase the added value of the industrial chain. The African Union advocates the construction of a unified strategic framework for battery minerals, explicitly proposes to prevent the risk of "green colonialism", and emphasizes the protection of the value distribution rights of raw material producers in the global clean energy transition.

At the same time, governments in the global South are increasingly calling for a "just energy transition." This call is particularly evident in the Just

Energy Transition Partnership (JETP) between South Africa and the European Union and the Group of Seven (G7), which provides concessional financing in exchange for South Africa's commitment to phase out coal. However, critics point out that such agreements often lack enforceable provisions for local value creation and social protection.

In addition, the expansion of the Carbon Border Adjustment Mechanism (CBAM) and green trade conditions promoted by the EU and other developed countries also pose a severe challenge. Many exporting countries from Asia, Africa and Latin America generally lack the required technical capabilities and certified carbon emission data, making it difficult to meet the compliance requirements of these mechanisms, thus raising concerns about de facto "green protectionism". In response, countries such as India and Brazil have called for the promotion of the coordination and unification of technology transfer and carbon accounting standards under the framework of the World Trade Organization (WTO).

The global green financing system is still fragmented, and the total amount of financing is far from sufficient. In practice, many developing countries are forced to rely on high-cost debt instruments, which severely limit their fiscal space for renewable energy infrastructure or green industrial policies. Institutions such as the Green Climate Fund (GCF) and multilateral development banks are also under pressure to reform access standards and increase concessional financing. Against this background, the demand for "energy sovereignty" has once again become a core concern of the global South. Energy sovereignty not only means the right to access energy, but also emphasizes the control of production means, financing mechanisms and governance structures.

Ultimately, the Global South is not a homogeneous group, and its member states vary significantly in terms of institutional capacity, resource endowments, and strategic positions. However, one thing they have in common is that they are all trying to avoid being marginalized in the green transformation process. Whether through critical mineral diplomacy, local manufacturing initiatives, or calls for climate finance reform, these countries are actively seeking greater room for action and autonomy in a highly asymmetric global landscape.

CONCLUSION AND POLICY IMPLICATIONS

The global energy transition, while driven by climate imperatives and technological progress, is increasingly shaped by strategic rivalries and structural asymmetries in the international political economy. This article has analyzed the evolving energy strategies of the US, China, and the European Union, each of which seeks to assert its leadership in shaping the norms, technologies, and supply chains of the low-carbon future. At the same time, the agency of countries in the global South – once considered peripheral –has grown in importance, both as sources of critical resources and as arenas of contestation and alignment.

From the lens of geopolitical economy, energy transitions are not merely technical shifts in energy systems, but reconfigurations of power relations among states, markets, and capital. The US emphasizes security-driven decoupling and fiscal subsidies; China adopts a developmental model rooted in industrial policy, global infrastructure expansion, and resource diplomacy; the European Union attempts to project regulatory power through mechanisms such as the CBAM and the Green Deal. These divergent approaches reflect not only institutional differences but also competing visions for the future architecture of the global energy order.

Importantly, these strategic paths are not mutually exclusive. As shown throughout this study, elements of cooperation—such as climate finance, green technology partnerships, or coordinated infrastructure investments—continue to emerge, especially where national and global interests converge. However, these instances are increasingly embedded within a realist context of selective engagement, securitization of supply chains, and techno-industrial competition.

For policymakers, several implications arise:

First, energy transition strategies must be understood not in isolation but as geopolitical instruments. Nations must strengthen their institutional capacity to assess and navigate the externalities of foreign climate and industrial policies on domestic development. **Second, the Global South must move beyond passive recipient status by building institutional leverage, such as through resource-backed investment frameworks, South-South cooperation, and participation in standard-setting processes.** Enhancing policy coherence across ministries (energy, foreign affairs, finance) is key to maximizing energy sovereignty. **Third, multilateral frameworks must evolve**

to accommodate asymmetries in capacity and interests. Existing platforms such as the G20, IEA or new Climate Clubs must embed mechanisms that address technology access, just transition financing, and inclusive governance -lest they become arenas of exclusion and soft power projection. **Finally, future research must pay more attention to the interaction between structural power and emerging technologies.** How digitalization, AI, and green finance shape not only markets but also geopolitical alignments remains a critical area of inquiry.

In summary, the change of the 21st century in energy sources is equally concerned with governance as it is with the methods of its execution. Viewing this transition through the lens of geopolitical economy provides a more comprehensive and nuanced framework for both understanding and action. It uncovers a global order undergoing change, where cooperation and competition coexist as dynamics that define the shape of a world moving towards decarbonization.

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CHAPTER 3

THE GEOPOLITICS OF OIL AND STRATEGIC RIVALRIES IN THE PERSIAN GULF: SAUDI-IRANIAN COMPETITION AND THE SECURITY OF ENERGY CORRIDORS

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INTRODUCTION

The Persian Gulf occupies a central place in global energy politics due to its vast reserves of oil and natural gas, its strategic maritime chokepoints, and its historical entanglement in geopolitical rivalries. With nearly 48% of the world's proven crude oil reserves located in the Gulf Cooperation Council (GCC) states and Iran, the region plays a critical role in global energy markets (BP, 2023). The major exporters such as Saudi Arabia, Iran, Iraq, Kuwait, and United Arab Emirates all contribute to a large portion of world crude oil exportation, so the Persian Gulf is the only source of energy importation in Asia, Europe and other regions of the world (U.S. Energy Information Administration [EIA], 2023).

The most crucial marine choke-point and passage of oil is the Strait of Hormuz. This small strait is a strategic energy route into the energy supply of the world, with oil pills flowing in the region at a ratio of about 1 in 5 (EIA, 2023). In like manner Bab el-Mandeb Strait which links Red Sea and the Arabian Sea is becoming prominent with the increase of trade between Europe and Asia. These corridors are among the most strategic ones because of their importance related to the supply of energy; hence, their breach, associated with warfare or threats by players who operate in the region, is likely to result in volatile prices and endanger energy security.

Also, the centralization of the energy infrastructure in a politically volatile region poses a significant threat to the world supply chain. Historical events like those revealing the flawed nature of oil infrastructure like the 2019 drone and missile attacks against the Saudi oil plant known as Abqaiq, blamed on Iranian proxy units, demonstrated that conflicts have the potential of spilling over the markets of other countries (Fulton, 2020). The geopolitical importance of the Persian Gulf is also influenced by the presence of external powers and this has expanded to the United States, China and the European Union whose strategic interest is to ensure that energy resources move freely.

Energy security concerns have also driven the militarization of the Persian Gulf. The presence of the U.S. Fifth Fleet in Bahrain, multilateral initiatives like Operation Sentinel, and increased naval exercises among Gulf states underscore the securitization of energy transit (Cordesman, 2020). Thus, the Persian Gulf's geopolitical role transcends regional boundaries, positioning it at the heart of international strategic calculations.

The modern contours of the Saudi-Iranian rivalry emerged starkly after Iran's 1979 Islamic Revolution. The revolution not only overthrew the pro-Western Shah but also introduced a new theocratic model of governance based on the concept of velayat-e faqih (guardianship of the Islamic jurist), which fundamentally challenged the monarchical and religious legitimacy of the House of Saud (Gause, 2014). Iran's revolutionary regime sought to export its ideology across the Muslim world, directly threatening the status quo in the Gulf monarchies, particularly Saudi Arabia.

This ideological divergence was quickly politicized into competing visions of regional leadership. Iran positioned itself as the vanguard of anti-imperialism and Islamic resistance, supporting Shi'a movements and opposition groups in Bahrain, Lebanon, and Saudi Arabia's Eastern Province. In contrast, Saudi Arabia adopted a defensive posture, framing itself as the guardian of Sunni orthodoxy and the two holy mosques, while aligning more closely with the United States and promoting Wahhabi ideology as a counterweight (Wehrey, 2013).

The rivalry intensified during the 1980s with the Iran-Iraq War (1980–1988), during which Saudi Arabia and other Gulf monarchies provided financial and political support to Saddam Hussein's regime, fearing the spread of Iranian revolutionary fervor. The war became a proxy arena for Saudi-Iranian competition, laying the groundwork for enduring strategic distrust (Takeyh, 2009). Although the end of the war in 1988 created a temporary lull, tensions resurfaced with new dimensions in the post-2003 period following the U.S. invasion of Iraq, which empowered Shi'a political groups aligned with Tehran.

The rivalry has since expanded beyond ideological and theological differences to encompass strategic competition over influence in fragile states such as Yemen, Syria, Iraq, and Lebanon. In each of these theaters, both Iran and Saudi Arabia have supported rival factions, turning domestic conflicts into arenas of regional contestation (Mabon, 2018). The Saudi-led intervention in Yemen (2015–present), aimed at countering the Iranian-aligned Houthi movement, is a stark example of how the ideological divide has transformed into an overt geopolitical rivalry with direct implications for regional stability and maritime security.

The Saudi-Iranian rivalry is deeply rooted in the post-1979 transformation of the Middle East's political order. While it began as an ideological contest, it has evolved into a broader struggle for regional primacy, heavily influenced by energy geopolitics, sectarian mobilization, and external interventions.

The study seeks to examine the geopolitical aspect of oil in the development of the Saudi Arabia and Iranian rivalry and to review the impact of this rivalry to the security of energy corridors in the region and the world. It aims to address two important questions how the geopolitics of oil has helped to escalate the Saudi-Iranian strategic rivalry, and what do the consequences of this rivalry hold in terms of securing vital sea chokepoints, especially Strait of Hormuz.

1. THE STRATEGIC IMPORTANCE OF THE PERSIAN GULF

The fastest and largest oil and gas continues to render Persian Gulf strategic importance, which can be considered a vital artery to the energy needs of the world. The strategic importance of geopolitical significance also increases because of the existence of main maritime choke points like the Strait of Hormuz where a significant percentage of oil exports are dispersed across the globe.

1.1 Overview of Oil and Natural Gas Reserves in the GCC and Iran

The Gulf Cooperation Council (GCC) which consists of Saudi Arabia, the United Arab Emirates (UAE), Kuwait, Qatar, Oman and Bahrain in addition to Iran is one of the richest energy zones on the planet. These states produce together a significant part of the proven oil and natural gas reserves of the world, providing them with fantastic power in the world energy markets. By 2023, the GCC countries also have the world proven oil reserves of crude oil totaling about 29.3 percent or Iran on its own has about 9.3 percent thus being ranked fourth in the world (BP, 2023).

Saudi Arabia is the biggest single owner of crude oil reserves in the GCC at approximately 17.2 percent of the world total and this is followed by Kuwait at 6.1 percent, and the UAE at 5.7 percent (Organization of the Petroleum Exporting Countries [OPEC], 2023). The reserves of Iran (around 208.6 billion barrels) are higher than those of some individual GCC countries and demonstrate its primal place in the international oil industry. In terms of natural gas, Qatar and Iran jointly dominate the South Pars/North Dome field, the largest natural gas field in the world. Iran possesses around 17.3% of global proven natural gas reserves, while Qatar holds about 12.5% (BP, 2023).

These vast hydrocarbon resources form the backbone of the region's political economy and international influence. Energy rents have allowed these states to finance extensive welfare systems, modernize infrastructure, and project influence abroad through sovereign wealth funds and foreign policy instruments (Luciani, 2019). Moreover, the geographical concentration of reserves in a relatively small area raises the strategic importance of the region in terms of both supply and market volatility.

The abundance of reserves has also led to a high dependency on fossil fuel exports for most of these states. According to the International Monetary Fund (IMF), oil and gas account for over 70% of total government revenues in countries like Saudi Arabia, Kuwait, and Qatar (IMF, 2022). This dependency, while a source of wealth and geopolitical power, also renders the region vulnerable to fluctuations in global oil prices and increasing international pressure for energy transition.

1.2 Share of Global Oil Exports via the Persian Gulf

The Persian Gulf serves as the principal conduit for a substantial share of global crude oil exports. As of 2023, approximately 21% of global petroleum liquids consumption—nearly 21 million barrels per day (b/d)—passed through the Strait of Hormuz, a critical maritime chokepoint linking the Persian Gulf to the Arabian Sea (U.S. Energy Information Administration [EIA], 2023). This includes not only crude oil but also refined petroleum products and natural gas liquids, primarily destined for markets in Asia, particularly China, India, Japan, and South Korea.

The leading exporters in the region—Saudi Arabia, Iraq, the UAE, Kuwait, and Iran—rely heavily on this maritime corridor. Saudi Arabia alone exports more than 7 million b/d, much of which flows through the Persian Gulf, despite alternative routes like the East-West pipeline to the Red Sea. The UAE and Kuwait, similarly, transport the majority of their oil exports through this waterway. Even with growing investments in pipeline infrastructure designed to bypass maritime chokepoints, the Gulf remains the default export route due to its cost efficiency and established infrastructure (Fattouh & El-Katiri, 2015).

Iran's role in global exports has been significantly constrained by international sanctions, particularly those imposed by the United States in response to its nuclear program. However, even under sanction regimes, Iran has continued limited oil exports, mainly to China, using a combination of tanker fleets and covert shipping practices (Tabatabai, 2021). The strategic control Iran exercises over the northern coast of the Strait of Hormuz provides Tehran with leverage over this critical artery, a factor that has led to repeated tensions with the United States and GCC states.

Given this critical dependence, any disruption in maritime security—whether from conflict, piracy, or infrastructure sabotage—can have immediate and profound effects on global oil prices. This dynamic was evident in incidents such as the 2019 attacks on oil tankers and the temporary shutdown of Saudi Aramco's Abqaiq processing facility, both of which triggered sharp spikes in oil futures (Fulton, 2020). The concentration of oil and gas reserves in the GCC and Iran, coupled with the region's dominant share of global energy exports via the Persian Gulf, underscores the strategic centrality of this region in global energy security. Any developments—economic, political, or military—that affect the Persian Gulf inevitably carry global implications.

2. MARITIME CHOKEPOINTS

A number of Maritime chokepoints including the Strait of Hormuz, Bab el-Mandeb, and the Suez Canal are pivotal to the energy flow in the world. These straits are very prone to geopolitical tensions and their security becomes important to transport oil and gas without any break in the transportation.

2.1 The Strait of Hormuz: Geostrategic Bottleneck

Strait of Hormuz is a body of waters between the Persian Gulf and the Gulf of Oman and the Arabian Sea through which a large part of the Logistic Services and other business markets cross. It is very well known that it is one of the most important chokepoints in the world energy geopolitics. The fact is that the strait is not wider than 21 nautical miles at the narrowest point, which is why it is the only sea communication channel of a significant part of Middle Eastern oil supply, which makes it an irreplaceable source of energy in the world economy (U.S. Energy Information Administration [EIA], 2023). An estimated 21 million barrels of oil on a daily basis or 21 percent of the total petroleum liquids consumption around the world pass this strait and mostly comprises big oil producing countries such as Saudi Arabia, Iraq, United Arab Emirates (UAE), Kuwait, and Iran (BP, 2023).

The strategic importance of the Strait of Hormuz is further enhanced by the reality that a disruption in shipping, as a result of upheavals in this corridor, might cause instant increase in world oil prices and jeopardize the energy security of key consumers and consumers especially in Asia. What complexifies its strategic considerations is its location near the coastlines of the Iran and the Gulf Cooperation Council (GCC) nations. The military forces of Iran are mainly congregated in this region, and naval elements of the Islamic Revolutionary Guard Corps (IRGC) are often highlighted in periods of conflict with the western world or the GCC adversaries (Fulton, 2020).

Iran has issued more than one threat to close the Strait in reaction against economic sanctions and military deployments in the region, which have been described as geopolitical signalling. Although this would be economically and militarily expensive, the mere threat should act as a method of strategic deterrence. An example is the tensions of the 20112012 Threat by the Iranians to close up the strait as a protest against the sanctions imposed by the United States and the EU that saw the rise of the war-games by both the regional and external powers (Tabatabai, 2021).

One of the aspects surrounding the importance of the strait is the strategic location in regards to naval deployment by extra-regional powers mainly the United States and its allies who keep a constant military presence in the strait to protect the freedom of navigation. This ever-present layer of armor and warfare serves only to pad the belief that Strait of Hormuz is not a trade route, but a geostrategic fault line at which energy security, military capability and diplomatic stand are converging.

2.2 Vulnerability of Global Oil Supply Chains

The nature of the global oil supply chain is highly exposed since it is concentrated along waterways, concentrated hubs of production, and a well-consolidated supply chain network. A case in point is the Strait of Hormuz which is one of the weak links of the immense part of the world energy trade. Phyiscal concentration of oil flows in a small number of chokepoints and combined with geopolitical competition and unstable regions, as well as asymmetric risks, makes the international energy market vulnerable to disturbances (O'Sullivan, 2019).

Events to do with this vulnerability can be traced in the recent history. In 2019, the petrol tanker attacks in the Gulf of Oman and the drone attacks at the Saudi Aramco oil processing facility in Abqaiq served as reminders of how non-state actors or state proxies could disrupt global supply chains with limited resources and asymmetric means (Bronk & Wright, 2019). Such incidents brought about temporary fluctuations to oil prices, confidence in the supply, and people demanded more resilience in the international energy infrastructure.

Further, oil supply chain is not only susceptible to physical attacks but also to cyber-attacks because more and more critical infrastructure, such as drilling platforms and pipeline control systems are becoming digitalized and networked. The systemic risk of energy networks can be illustrated by the Colonial Pipeline cyberattack in the United States in 2021 though not a part of the Persian Gulf (Friedman, 2021).

Countries that import energy, especially in Asia and Europe, have reacted by securing more sources of supply, expanding strategic petroleum stocks and engaging in building alternative transport, such as pipelines that do not affect maritime choke points. As an example, the Habshan-Fujairah pipeline of the UAE and the East-West Pipeline of Saudi Arabia are designed to serve as failsafe in the event of unease in the Strait of Hormuz (Fattouh & El-Katiri, 2015). These measures however only help in partially countering the underlying risk since the global oil market is closely connected.

To conclude, the minute nature of global energy security can be highlighted by the fact Strait of Hormuz is of geostrategic significance and the vulnerability associated with the use of global oil supply chains. Any disturbance in the Gulf region resonates well beyond the region and, thus, multilateral frameworks are the solution to prevent the consequences of such a disturbance by securing the transit of energy and finding the cause of creating the whole situation of geopolitical tensions.

3. GREAT POWER INTERESTS AND MILITARY ENGAGEMENT IN THE PERSIAN GULF: A COMPARATIVE PERSPECTIVE

The Persian Gulf holds a central place in global energy geopolitics due to its vast hydrocarbon reserves and strategic maritime chokepoints, notably the Strait of Hormuz. Major powers such as the United States, China, Russia, and the European Union (EU) maintain strategic interests in the region, primarily driven by concerns over energy security, freedom of navigation, and regional stability. These interests are manifested through military presence, defense agreements, and economic partnerships with Gulf Cooperation Council (GCC) states and Iran (Goldwyn & Fickling, 2022; Leverett & Mann, 2020).

Table 1: Strategic Interests and Military Presence in the Persian Gulf

Country	Primary Interests	Military Presence	Security Partnerships
United States	i. Securing energy flow and maritime navigation ii. Containing Iran iii. Counterterrorism	i. Fifth Fleet based in Bahrain ii. Al Udeid Air Base in Qatar iii. Naval/Air facilities in UAE and Kuwait	i. Long-term defense agreements with Saudi Arabia, UAE, Bahrain, and Qatar ii. NATO+GCC strategic dialogues
China	i. Energy imports (Gulf supplies ~40% of China's oil) ii. BRI investments iii. Avoiding U.S. dominance	i. No permanent base (except Djibouti outside Gulf) ii. PLA Navy port visits and escort missions	i. Strategic partnerships with Iran (25-year deal) ii. Growing commercial and military cooperation with Saudi Arabia, UAE
Russia	i. Expanding influence in a multipolar order ii. Arms sales iii. Counterbalancing U.S. and NATO influence	i. No bases, but naval presence in regional drills ii. Coordination with Iran in Syria and Gulf security affairs	i. Defense cooperation with Iran ii. Expanding dialogue with UAE and Saudi Arabia post-OPEC+
European Union	i. Securing energy diversification ii. Protecting shipping lanes iii. Nuclear non-proliferation (JCPOA)	i. Maritime awareness missions (e.g., EMASoH led by France) ii. Small-scale naval deployments	i. Strategic dialogues via E3 (France, UK, Germany) ii. Bilateral military relations (especially France-Gulf)

United States

The United States has long maintained the most extensive military footprint in the Persian Gulf. Since the Carter Doctrine of 1980, the U.S. has perceived any threat to the flow of oil from the Gulf as a threat to its national interest (Brands, 2020). Through Central Command (CENTCOM), it operates major air and naval bases in Bahrain, Qatar, and Kuwait, and maintains troops and missile defense systems in Saudi Arabia. Energy security, counterterrorism, and deterrence against Iran are the pillars of its Gulf policy.

China

China's growing dependence on Gulf oil—approximately 40% of its imports—has increased its interest in regional stability (BP, 2023). However, Beijing's approach remains primarily economic and non-military. The 25-year strategic agreement with Iran, energy investments in Iraq, and infrastructure projects under the Belt and Road Initiative (BRI) highlight its strategic calculus (Fulton, 2020). China avoids direct military entanglements but promotes maritime security cooperation and political neutrality.

Russia

Russia's interests are rooted in arms sales, regional influence, and strategic balancing. Although lacking formal military bases in the Gulf, Russia maintains naval engagement through joint exercises, particularly with Iran (Weitz, 2022). It also plays a critical role in OPEC+ energy negotiations, aligning interests with Saudi Arabia on oil pricing and production strategies. Moscow's Gulf engagement supports its broader Middle East strategy aimed at reducing Western dominance.

European Union

The EU's presence in the Persian Gulf is less military and more diplomatic and economic. Through the European Maritime Awareness in the Strait of Hormuz (EMASoH), led by France, the EU contributes to regional maritime security (Adebahr, 2021). Energy security, non-proliferation—especially concerning Iran's nuclear program—and trade form the core of EU interests. France and the UK, as individual EU member states (or former member in case of the UK), maintain military ties with Gulf states.

Great power engagement in the Persian Gulf underscores the region's strategic value in global energy security and international politics. While the U.S. continues to dominate militarily, China and Russia are pursuing more subtle influence strategies, and the EU maintains a presence through diplomacy and multilateral missions. The convergence and divergence of these powers' interests complicate Gulf security dynamics, especially amid ongoing Saudi-Iranian rivalries and global shifts in energy geopolitics.

4. OIL GEOPOLITICS AND STRATEGIC CALCULATIONS

Oil is not just a commodity of an economic nature, but also a strategic commodity that influences veering out of national security policies and that of regional power. In the Middle East production and pricing, as well as transport routes, have become the main component in the strategic equations of key regional powers such as Saudi Arabia and Iran.

4.1 Oil as a Tool of National Power: Pricing, Supply, and Influence in OPEC

Oil is not merely an economic commodity; it is a strategic asset and an instrument of national power, particularly in the Middle East. The ability to control oil pricing and supply provides states, especially rentier monarchies such as Saudi Arabia, the leverage to influence both regional dynamics and global markets. By virtue of possessing vast petroleum reserves and playing central roles in organizations like the Organization of the Petroleum Exporting Countries (OPEC), Gulf states, and Iran utilize oil as a mechanism to exert geopolitical influence and protect national interests.

Oil-producing states wield significant influence through their capacity to increase or cut oil production, thereby affecting global supply and market prices. This influence is central to the foreign policy strategies of countries like Saudi Arabia and Iran, which use oil as both a deterrent and an economic weapon.

Saudi Arabia, possessing over 17% of the world's proven oil reserves, acts as a "swing producer," adjusting its output to stabilize or influence prices in accordance with political and economic objectives (Baumeister & Kilian, 2016). For instance, during the 2014 oil price crash, Riyadh maintained high production levels, which some analysts interpret as an attempt to undercut U.S.

shale producers and contain Iranian economic gains following the Joint Comprehensive Plan of Action (JCPOA) (Krane & Monaldi, 2017).

Iran, despite sanctions, has historically attempted to leverage oil by threatening supply routes such as the Strait of Hormuz or forming bilateral deals to circumvent restrictions. These tactics reflect oil's embeddedness in national security and strategic policy, turning economic tools into instruments of political signaling (Fattouh & Economou, 2018).

OPEC remains the central platform through which oil-producing nations coordinate production levels and pricing strategies. Established in 1960, OPEC includes several key Gulf states—Saudi Arabia, the UAE, Kuwait, and Iran—and collectively controls about 80% of the world's proven crude oil reserves (OPEC, 2023).

Saudi Arabia's leadership within OPEC is unmatched. It has traditionally shaped production quotas and mediated internal disputes, reinforcing its geopolitical clout (Colgan, 2014). OPEC+—which includes Russia and other non-OPEC producers—emerged in response to volatility and showcases the strategic realignment of energy geopolitics where alliances transcend ideological lines.

While OPEC's market share has been challenged by U.S. shale and renewables, its policy decisions still significantly impact global oil prices. These fluctuations influence inflation, currency valuation, and energy security globally, thus positioning oil-rich states as key actors in international political economy (Mitchell, 2011).

Control over oil pricing and supply grants Gulf states and Iran substantial leverage in international affairs. Their influence within OPEC, coupled with their ability to manipulate production and shape market dynamics, underscores oil's role as a geopolitical tool. As energy transitions accelerate and competition over strategic resources intensifies, the political utility of oil will continue to evolve, but its centrality to national power remains profound.

4.2 Infrastructure Vulnerabilities and Diversification Strategies in the Persian Gulf

The Persian Gulf's energy infrastructure is highly vulnerable to geopolitical tensions and asymmetric warfare. A prominent example is the September 2019 drone and missile attacks on Saudi Aramco's Abqaiq and Khurais facilities, which temporarily disrupted nearly 5.7 million barrels per day—about 5% of the global oil supply (Blas & Nair, 2019). These attacks, attributed to Iran-backed Houthi rebels or potentially to Iran itself, exposed the fragility of critical oil infrastructure despite significant investments in defense.

Such incidents underscore the strategic risks facing Gulf energy exporters. Despite advanced air defense systems, the attackers exploited vulnerabilities in detection and interception, especially from low-flying drones and cruise missiles. These developments have heightened global concern over energy security, insurance premiums on Gulf shipping, and the risk of escalation in a region already marred by proxy conflicts (EIA, 2020).

Another critical point of vulnerability is Iran's recurring threat to block the Strait of Hormuz, through which approximately 20–30% of global oil exports pass (U.S. Department of Energy, 2021). Any disruption here could lead to a severe spike in global oil prices, impacting economies far beyond the Middle East. While full closure is unlikely due to military retaliation risks, even periodic threats or limited blockades increase geopolitical risk premiums and complicate global supply chains.

In response to these vulnerabilities and fluctuating oil demand, both Saudi Arabia and Iran have embarked on energy and economic diversification strategies.

Saudi Arabia launched Vision 2030, a comprehensive reform agenda aimed at reducing the kingdom's dependency on oil revenues. A major milestone was the 2019 Initial Public Offering (IPO) of Saudi Aramco, which raised $25.6 billion—making it the world's largest IPO (Young, 2020). The goal was to attract foreign investment and channel revenues into sectors like tourism, technology, and manufacturing. The Vision 2030 initiative also includes the development of renewable energy projects and NEOM, a futuristic economic zone aimed at diversifying Saudi income streams and creating employment opportunities for a young population.

Iran, meanwhile, has faced significant constraints due to U.S.-led sanctions, especially after the U.S. withdrawal from the Joint Comprehensive Plan of Action (JCPOA) in 2018. In response, Tehran has pivoted towards Asian markets, particularly China and India, for oil exports—often under barter or non-dollar arrangements to circumvent sanctions (Vakil, 2020). The 25-year strategic agreement with China, signed in 2021, represents a major move in this direction, encompassing energy, infrastructure, and technology cooperation (Shariatinia, 2021). Additionally, Iran has expanded domestic refining capacity to reduce reliance on crude exports and develop petrochemical exports instead.

Both countries demonstrate how energy producers adapt their strategies to mitigate geopolitical and economic shocks. While the effectiveness of these policies remains contingent on global market dynamics and political developments, diversification is no longer optional but a strategic necessity.

5. MILITARIZATION AND SECURITY OF ENERGY CORRIDORS

The maritime military balance in the Persian Gulf is shaped significantly by the asymmetrical capabilities of the Islamic Revolutionary Guard Corps Navy (IRGCN) and the Royal Saudi Naval Forces (RSNF). The IRGCN, established in the 1980s, operates independently from Iran's regular navy and is tasked with asymmetric naval warfare in the Persian Gulf and Strait of Hormuz. It specializes in fast-attack craft, swarm tactics, anti-ship cruise missiles, and mine-laying operations, making it a central component of Iran's anti-access/area denial (A2/AD) strategy (Cordesman & Toukan, 2019).

The IRGCN frequently engages in harassment of U.S. and allied naval vessels, signaling Iran's readiness to escalate tensions if its strategic interests are threatened. Its decentralized command structure and emphasis on unconventional tactics contrast sharply with the more conventional and hierarchical structure of the RSNF. Iran's naval doctrine emphasizes rapid, localized attacks to disrupt maritime traffic and pressure adversaries (Eshel, 2020).

In contrast, the RSNF, traditionally oriented toward coastal defense and lacking blue-water capability, has undergone modernization in line with Saudi Vision 2030. Major procurements include Multi-Mission Surface Combatant (MMSC) vessels from the U.S. and Avante-class corvettes from Spain, designed to improve maritime situational awareness and interdiction capabilities (International Institute for Strategic Studies [IISS], 2021). However, RSNF capabilities remain limited in countering IRGCN's irregular strategies, particularly in narrow and congested waters like the Strait of Hormuz.

5.1 Gulf Maritime Coalitions

In response to the increasing threats to maritime security in the Persian Gulf, particularly following the 2019 tanker attacks, international actors have intensified coalition-building efforts. The most prominent initiative is the International Maritime Security Construct (IMSC), launched in September 2019 under U.S. leadership. Its operational arm, Operation Sentinel, aims to ensure freedom of navigation and enhance deterrence against asymmetric threats through patrols, surveillance, and vessel escorts (U.S. Naval Forces Central Command, 2021).

Members of IMSC include the United States, United Kingdom, Saudi Arabia, Bahrain, and the United Arab Emirates, among others. Unlike NATO-style mutual defense pacts, IMSC operates on a voluntary participation basis and emphasizes maritime domain awareness, de-escalation, and multilateral confidence-building. This coalition represents a strategic response to Iranian maritime provocations and underlines the shared interest of Western and Gulf states in protecting critical energy corridors (Jones, 2020).

Iran, however, has criticized IMSC and instead proposed a regional maritime security initiative called the "Hormuz Peace Endeavor" (HOPE), promoting Gulf-only security arrangements without Western involvement (Tabatabai, 2020). This reflects the broader strategic divergence between Iran and GCC states, where Iran views foreign coalitions as threats to its sovereignty, while Gulf monarchies perceive them as essential for deterrence and protection.

5.2 Cybersecurity and Oil Infrastructure

In the digital age, cyber threats have emerged as a significant risk to the energy security of Persian Gulf states, particularly those heavily reliant on oil and gas exports like Saudi Arabia, the UAE, and Iran. These states manage vast and complex digital infrastructures that control oil production, refining, and distribution networks—making them attractive targets for cyberattacks by state and non-state actors alike. Cybersecurity vulnerabilities in these systems can lead to significant economic, political, and strategic disruptions (Brenner, 2022).

Energy infrastructure is particularly exposed due to its increasing automation and dependence on Industrial Control Systems (ICS) and Supervisory Control and Data Acquisition (SCADA) systems. These platforms, if compromised, can allow attackers to manipulate operational settings, disrupt refinery output, cause environmental disasters, or cripple national economies. The Gulf region's strategic role in global energy markets magnifies the implications of such cyberattacks, as disruptions could affect global oil prices and supply chains (Kostyuk & Zhukov, 2019).

One of the most infamous cyberattacks on critical energy infrastructure in the Gulf was the Shamoon virus, which targeted Saudi Aramco in August 2012. The malware erased data on approximately 30,000 workstations, replacing it with an image of a burning American flag and causing operational delays. Although production was not disrupted due to the isolation of ICS systems, the psychological and financial impact was significant (Bronk & Tikk-Ringas, 2013). This attack demonstrated that non-kinetic methods could inflict considerable damage on state-owned enterprises without the use of conventional weapons.

The Shamoon attack was widely attributed to Iran, particularly in retaliation for the 2010 Stuxnet attack on Iranian nuclear facilities, allegedly conducted by the U.S. and Israel (Zetter, 2014). The cyber-kinetic rivalry between Saudi Arabia and Iran has since intensified, with multiple instances of retaliatory digital operations. Shamoon reappeared in modified forms in 2016 and 2017, targeting Saudi government agencies and companies, further reflecting the persistence and evolution of cyber threats in the region (Lee & Assante, 2016).

More recently, cyber espionage campaigns have targeted Saudi Aramco's supply chain, with actors leveraging phishing attacks and malware to gain access to contractor networks. These efforts reflect a growing sophistication and strategic intent in targeting not just the primary energy producers but also their operational ecosystems (FireEye, 2021).

Cybersecurity remains a top priority for Gulf states. Saudi Arabia has established the National Cybersecurity Authority (NCA), while the UAE has invested in AI-based threat detection systems. However, the pace of digital transformation continues to outstrip security measures, making energy infrastructure an enduringly vulnerable domain.

6. SECURITY ARCHITECTURE IN THE PERSIAN GULF: THE GCC FRAMEWORK AND MARITIME SECURITY INITIATIVES

The Gulf Cooperation Council (GCC), established in 1981, serves as a political and security alliance among six Gulf monarchies—Saudi Arabia, the United Arab Emirates, Kuwait, Qatar, Bahrain, and Oman. Although originally conceived to foster economic cooperation and collective self-defense, the GCC's security role has gained importance due to regional threats, including Iranian expansionism, terrorism, and maritime vulnerabilities (Ulrichsen, 2020).

Despite its stated goals, the GCC has faced internal divisions—most notably the 2017 Qatar diplomatic crisis, which undermined collective security cohesion. Nevertheless, shared concerns about Iranian influence, the threat of asymmetric warfare, and cyber vulnerabilities have led to renewed calls for joint military capabilities, intelligence-sharing, and regional missile defense systems (Fulton & Krieg, 2019). The Peninsula Shield Force, the GCC's military wing, has been activated in limited instances—such as during the 2011 Bahrain unrest—but remains underdeveloped as a true joint deterrent force.

In recent years, Saudi Arabia and the UAE have led calls for expanding the GCC's security mandate beyond traditional military threats to include energy infrastructure protection, cybersecurity, and maritime security, reflecting a more multidimensional conception of Gulf security.

6.1 US-Led and Multilateral Maritime Security Initiatives

Given the Persian Gulf's centrality to global energy flows, particularly through the Strait of Hormuz, major powers—most prominently the United States—have long maintained a naval presence to deter threats to maritime trade. The U.S. Fifth Fleet, based in Manama, Bahrain, leads these efforts, conducting patrols, joint exercises, and anti-piracy operations. The U.S. Navy's Combined Maritime Forces (CMF) and the International Maritime Security

Construct (IMSC) have been key to facilitating multinational cooperation (Sharafedin, 2019).

The IMSC, launched in 2019 in response to attacks on commercial vessels allegedly by Iran, includes Bahrain, Saudi Arabia, the UAE, the UK, and Australia, and aims to protect the freedom of navigation in key chokepoints. Meanwhile, European powers launched the EMASoH (European Maritime Awareness in the Strait of Hormuz) initiative, centered around France's leadership, which operates a parallel but complementary framework (European Council on Foreign Relations [ECFR], 2020).

Such initiatives are indications of an increasing multilateralization of maritime security in the Gulf, but Western-led initiatives have not coordinated well with GCC member states. What is more, even such new players as China and India have expressed interest in keeping Gulf maritime routes safe to assure their needs in energy resources, which further complicates the strategic landscape.

The strategic value of the Persian Gulf has led to intra-regional and extra-regional involvement on the need to increase security in the region. Even though the GCC security system is still limited by the existing political rifts, it is gradually progressing toward a higher level of integration. At the same time the U.S. -led and multilateral maritime security operations are so important that they are significant to the flow of oil and stability of the region. In the future, the efficiency of these mechanisms is going to require diplomatic coordination, technological modernization, and alignment in a multipolar security environment.

6.2 Impact on Bab el-Mandeb Strait

Owing to the current conflict between Yemen and the rest of the world, a strategic location has been attached to the Bab el-Mandeb Strait, which is a narrow corridor between the Red Sea and the Gulf of Aden. The strait is also important in energy markets in Europe and Asia, with around 6.2 million barrels of crude oil and refined petroleum products flowing through the strait every day (U.S. Energy Information Administration [EIA], 2021). The action against Iran-backed Houthi rebels by the Saudi-led coalition has increased the risk in this corridor with possible consequence to the freedom of navigation and world energy supply.

The Houthis have evinced asymmetric maritime force, such as drone boats, anti-ship missiles, and sea mines. The 2018 Iran-claimed Houthis attack on two Saudi oil tankers in the Red Sea made Saudi Arabia temporarily stop oil transportation via Bab el-Mandeb (Reuters, 2018). These events highlight that the struggle in Yemen has made the maritime insecurity a regional issue, spilling out of the Strait of Hormuz and into the potential redundancy routes that export Gulf energy.

6.3 Strait of Hormuz Crisis (2018–2020)

In 2018-2020, the Strait of Hormuz where, according to estimates, about 20 percent of the world oil remains, became the center of the renewal of the crisis between the U.S. and Iran that had erupted after Washington abandoned the Joint Comprehensive Plan of Action (JCPOA) and restored sanctions against Iran (Fulton & Krieg, 2019). To fight back, Iran had its own policy of maximum resistance and carried out seizures of tankers, sabotage activities as well as military brinkmanship within and around the strait.

Other notable ones were the British-owned Stena Impero being impounded by the Islamic Revolutionary Guard Corps (IRGC) in July 2019, in response to the ship impounded by UK authorities near Gibraltar. In addition, there were incidences of suspected Iranian limpet mines attacks on tankers in the Gulf of Oman in the middle of 2019 (International Crisis Group [ICG], 2020). Such operations created significant changes in world oil prices and led to the deployment of the U.S. military forces worldwide as the part of the International Maritime Security Construct (IMSC) in the name of Operation Sentinel.

Regional actors responded with both diplomatic and military strategies. While the United Arab Emirates initiated de-escalation talks with Iran, others bolstered naval readiness. Simultaneously, European powers launched EMASoH (European Maritime Awareness in the Strait of Hormuz), emphasizing non-escalatory surveillance and naval escort missions (ECFR, 2020). These varied responses highlight the geopolitical complexity of securing maritime corridors in times of political confrontation.

7. STRATEGIC FORECAST AND POLICY IMPLICATIONS

The 2023 diplomatic breakthrough between Saudi Arabia and Iran, mediated by China, marked a significant shift in Gulf geopolitics and raised cautious optimism for regional de-escalation. The agreement to re-establish diplomatic relations and reopen embassies after a seven-year rupture (BBC, 2023) represents a departure from the zero-sum rivalries that have characterized their interactions since the 1979 Iranian Revolution. China's role reflects the shifting global balance, as Beijing positions itself as a credible security broker in the Middle East (Aljazeera, 2023).

The rapprochement has potential implications for energy security, especially in strategic maritime chokepoints like the Strait of Hormuz and the Bab el-Mandeb. Confidence-building measures and diplomatic normalization could reduce the frequency of proxy confrontations and threats to commercial shipping, including Houthi missile attacks and IRGC naval harassment. However, analysts caution that deep-seated ideological, geopolitical, and sectarian divides may persist, necessitating robust verification mechanisms and third-party monitoring (Fulton & Krieg, 2023).

Energy security in the Persian Gulf will remain a global concern, even amid warming regional relations. The maritime domain remains vulnerable to asymmetric threats, cyberattacks, and proxy disruptions. Therefore, policy analysts and defense strategists emphasize the need for a multilateral maritime governance framework—one that includes not only regional states but also extra-regional stakeholders such as the EU, U.S., China, and India (Llewellyn & Kienzle, 2022).

A comprehensive risk assessment architecture is vital to forecast and mitigate future disruptions. The episodic closure or militarization of the Strait of Hormuz, for example, could impact 20% of global oil flows (EIA, 2021). Thus, energy-importing nations are increasingly investing in redundant routes, stockpiling reserves, and exploring alternative supply chains via pipelines and overland transport corridors.

The evolving strategic environment has empowered Gulf middle powers—notably Saudi Arabia, the UAE, and Qatar—to assert foreign policy autonomy beyond traditional U.S. security guarantees. Saudi Arabia's outreach to China, Iran, and even Syria reflects a desire to shape a multipolar Gulf order based on balancing rather than bandwagoning (Ulrichsen, 2023). Similarly, Iran's deepening ties with Russia and China and its eastward energy diplomacy underscore its intent to offset Western containment.

These trends indicate a transitional phase in the Gulf's regional order, marked by fluid alliances, issue-based coalitions, and strategic hedging. For policy makers, this necessitates a reassessment of traditional security paradigms. Engagement strategies should be built around regional inclusivity, economic interdependence, and collective risk management, with particular attention to climate change, cyber threats, and energy diversification.

CONCLUSION

The geopolitical landscape of the Persian Gulf is intricately shaped by the dynamics of oil politics, strategic rivalries, and shifting regional alliances, with Saudi Arabia and Iran emerging as the principal actors influencing the security and stability of vital energy corridors. The competition between these two regional powers extends far beyond ideological divergence; it is rooted in divergent strategic visions, geopolitical aspirations, and the pursuit of regional hegemony. The control over vast hydrocarbon resources and critical maritime chokepoints such as the Strait of Hormuz and the Bab el-Mandeb imbues the Persian Gulf with immense global significance, rendering its security a matter of international concern. In this context, oil is not merely a commodity but a tool of national power, employed to exert influence in global markets, shape the behavior of adversaries, and secure strategic leverage within multilateral institutions such as OPEC.

The rivalry has manifested through both direct and proxy conflicts, ranging from naval confrontations and cyberattacks to regional wars like that in Yemen, where control over maritime routes and energy infrastructure remains a strategic imperative. This competitive environment has led to a fragile security order in the Gulf, characterized by asymmetry, persistent volatility, and the risk of miscalculation. Despite occasional diplomatic engagements and third-party mediation efforts, particularly the recent China-brokered rapprochement, the underlying tensions and strategic mistrust continue to undermine the prospects for durable peace and cooperative energy governance.

Moreover, the involvement of global powers such as the United States, China, and Russia has added layers of complexity to the regional security architecture. Each power's pursuit of energy security and military presence in the Gulf reinforces the perception of external interference and perpetuates the arms race among regional actors. Efforts to diversify energy sources, modernize military capabilities, and secure infrastructure through cyber and technological means reflect a growing recognition among Gulf states of the multifaceted threats to energy corridors. Yet these efforts remain largely unilateral or aligned with great power interests, rather than grounded in a shared regional vision for collective security.

The future of the Persian Gulf's energy security lies in the ability of regional states to transition from confrontational postures to cooperative frameworks. This requires political will, confidence-building measures, and a commitment to institutional mechanisms that prioritize stability over rivalry. Strategic foresight must guide policy choices, particularly as new variables such as climate change, digital warfare, and global energy transitions begin to redefine the contours of Gulf geopolitics. Ultimately, the Saudi-Iranian competition, while deeply entrenched, is not immutable. Its trajectory will depend on the interplay of domestic reforms, regional diplomacy, and international engagement aimed at fostering a resilient and inclusive order that secures not only the flow of oil but also the long-term peace and prosperity of the Gulf region.

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CHAPTER 4

SCIENCE-BASED ETHICS ON GLOBAL ENERGY MANAGEMENT

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INTRODUCTION

The energy issue at a local and global level is related to public demands for a quality of life (Hatzopoulos J. N., 2023), either directly, such as home gas and electricity, or car transportation, or indirectly, as used by the industry to develop products for public consumption. Therefore, to support democracy, the public must have the first word on energy matters in a bottom-up approach. This does not happen, and a few individuals who are considered elite (The Guardian 2006, Muhammad Yunus, 2017) are the ones who manage energy matters in a top-down approach, attempting to increase their profits. Either approach could work perfectly right if guided by proper ethical rules that establish a balance between the price paid by the consumer and the profits made by the elite. Such rules exist and vary in bias among different community groups, often leading to conflicts and fighting among them, which in turn allows the elite to maximize their profits. Most elite methods on significant issues, such as energy, are based on the divide-and-conquer strategy, which they achieve by manipulating public opinion (Dr. Chiva Ayyadurai, 2025) in a way that different public groups have opposing ethical biases on specific ideological or religious issues, causing them to turn against each other. Examining global energy sources reveals that conflicts and wars are prevalent almost everywhere. If people are united, they can have more active participation in local and international issues that support the quality of life (Hatzopoulos J. N., 2023). Science-based ethics is a solution to this problem because science provides solutions with minimal bias, which have wider acceptance, and all related questions are concluded through a well-documented scientific debate involving participants from all interested sides. In addition, science can continually update itself over time through the integration of theoretical and technological advancements. Therefore, people need to be united through proper education to minimize their biases and to understand universal values and ethics that help them avoid being lured by the bait of fabricated ideologies and religions that turn them against one another. For this reason, we will develop two models of ethical value development: One, called internal balance, concerns the human mind and its functioning state, as developed by Plato (The Republic), and the other, called external balance, concerns human error, based on the concept of virtue, as developed by Aristotle (The Nikomachaean Ethics). Consequently, considering human beings as the unit for the bottom-up approach, we attempt to use these two models to derive science-based ethics that educate people to minimize bias and unite them in facing global issues, such as energy. Furthermore, we will explain what education is and what its opposite, anti-education, is that the elite is pursuing. Finally, we will use the system's approach to evaluate top-down and bottom-up approaches, as well as internal and external balance.

1. SCIENCE BASED ETHICS

Ethics generally deal with issues of what is correct, what is error, what is good, and what is wrong (Britanica). In the present study, we raised an ethical question about which approach is better for managing energy issues: the bottom-up approach or the top-down approach? To answer this question, we stated in the Introduction that we are looking for proper ethical rules that establish a balance between the price paid by the consumer and the profits made by the elite.

Therefore, balance is the most critical rule in Nature that contains all other rules regarding the healthy function of most objects in Nature, including human beings. The principle of balance can be scientifically expressed through mathematical equations, and in fact, most scientific analyses are based on equations. We also have to realize that it is not accidental that Themis, the Goddes of justice, being blind, holds a balance to identify the guilty one who disturbs the balance and does the punishment with the sword (see Fig.1).

Fig. 1. Themis the Goddes of justice.

We have to realize that there are laws and rules in Nature, the Laws being mandatory and the rules having tolerance limits and exceptions (Hatzopoulos, 2022). If someone declares that he does not recognize the gravity law and falls on a cliff, he will suffer directly the consequences.

On the other hand, the rule of balance applies to the Earth's orbit around the Sun as a balance of two forces: one attractive due to gravity, one repulsive due to the rotation around the Sun. The orbit is maintained within tolerance limits but never being the same. The rule of balance applies to the health conditions of the human body, such as stomach acid levels, heartbeats, and blood pressure; all of these must be within tolerance limits, except in extreme situations, like the heartbeats of athletes. We must also realize that there is a reason that rules have tolerance limits and exceptions to permit diversity and evolution of objects in Nature.

Ancient Greek philosophers made such observations on Natural rules to develop universally accepted values with minimal bias. All such values are based on two scientifically defined ethical models. The one created by Plato considers the human soul to be composed of three parts: logic, desire, and anger. We assume, in this study, the soul to be the human mind. Therefore, the human mind is composed of those three parts. Plato considers a healthy mind or an educated person to be one in which logic is in charge and balances desire and anger (The Republic). The effort of a person to maintain this mind condition, which we call internal balance, defines education. Internal balance, as a scientifically developed ethical tool, helps us identify those who disrupt the internal balance, the guilty ones.

The second model developed by Aristotle concerns the human actions defining human behavior. Such actions shall not be deficit or excessive but must follow the mid-space of virtue (The Nikomachaean Ethics). Aristotle's example of the mid-space of virtue is about courage, as a virtue must be located in a mid-space between cowardice and recklessness. A cowardly action is a deficit, and a reckless action is excess. The effort of a person to act within the mid-space of virtue defines the virtuous, and we call it external balance. External balance, as a scientifically developed ethical tool, helps us identify the acceptably correct human action. Based on this concept, we can model human error, where if the error of a human action falls within the mid-space of virtue limits, the action is considered acceptably correct. If it is outside such limits, the action is considered wrong. Defining the mid-space of virtue limits requires a broader consensus obtained through democratic procedures (Hatzopoulos 2004, 2009, 2014).

Internal balance can be illustrated using Plato's example, as shown in Fig. 2 (Phaedron), where desire is a blind horse, anger is a crazy horse, and logic is the coachman who tries to guide the horses toward the virtuous direction. Suppose we want to express internal balance with mathematics.

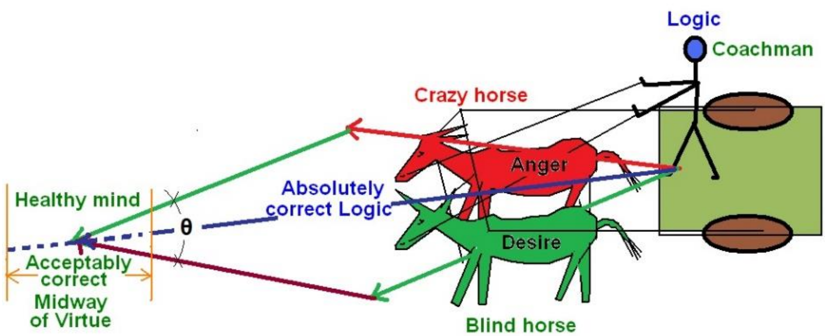

Fig. 2. Illustration of internal balance. Source: Plato, Phaedron, Hatzopoulos, 2009.

Plato's example (see Fig.2) tells us that it is a vector addition of two forces, one being the desire, the other the anger, and the sum of them the logic. We may add graphically such forces as shown in Fig. 2 or analytically using Equation 1 (Hatzopoulos, 2014):

$$L_B^2 = D^2 + A^2 + D \cdot A \cdot \cos(\theta) \qquad (1)$$

Where LB is the balancing Logic, D is Desire, and A is Anger, θ is the angle between these two forces.

Furthermore, we consider the mind space as a three-dimensional space with axes of desire (D), anger (A), and logic (L), as shown in Fig. 3. Notice that L is the current logic, and LB is the balancing logic. This coordinate system, whether it is rectangular or not, is to be defined by further research. We assume here that it is rectangular.

Regarding Fig 2, a current mind state MS is mathematically expressed by three coordinates MS(D, A, L). Forces D and L define the balancing logic LB from Equation 2 (Hatzopoulos, 2014):

$$L_B^2 = D^2 + A^2 + D \cdot A \cdot \cos(\theta) \qquad (1)$$

Then, human error EH can be calculated from Equation 3:

$$E_H = L - L_B \qquad (3)$$

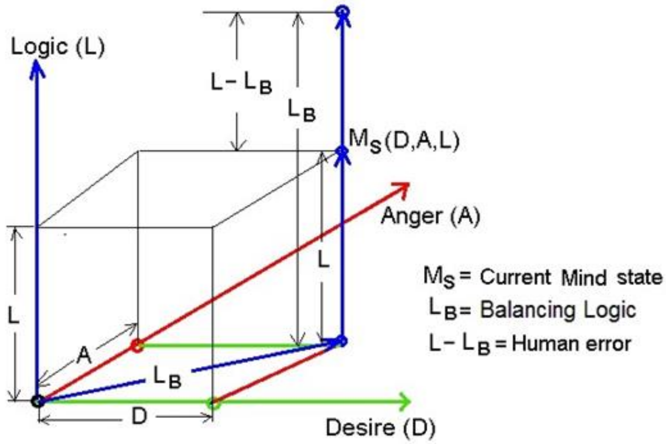

Fig. 3. The mind space. (Hatzopoulos, 2014)

Notice that quantities L, D, A, LB, EH can be quantized, and if they are measured in different units, they can be normalized (Hatzopoulos J. N., N. J., Hatzopoulos, 2024, p.81) to be dimensionless and compatible. The meaning of Equation 3 is to indicate whether or not the Logic mind component is in charge of the mind and how far away it is from being in charge. It is also an indication that the person is educated or not.

External balance can be illustrated in Fig. 4, where a person without physical limitations walks in a street of flat terrain and meets an obstacle that is necessary to raise the foot to pass over the obstacle. There is an "optimum" or perfect height to raise the foot, i.e., the average of all possible correct attempts (optimum correct).

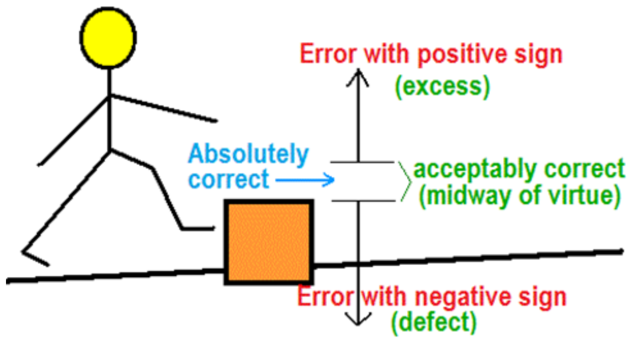

Fig. 4. Human error as defined by Aristotle's mid-space of virtue. (Hatzopoulos 2004, 2009, 2014).

However, raising the foot a little higher or a little lower from the optimum height, the action is considered to be acceptably correct because, in this range, there is no false step. If the height of the foot is lower than the obstacle height, then there is a false step, and the action may be considered an error with a negative sign. If the height of the foot is much higher than the obstacle height, then there is a false step, and the action may be considered an error with a positive sign. The mid-space, which is regarded as correct, is the error variance of the neuron structure (Hatzopoulos, 2014) responsible for raising the foot, and it is pretty similar to the mid-space of virtue as defined by Aristotle.

Therefore, one may observe the following:

(a) The boundaries of wrong and right are pretty straightforward and can be precisely defined.

(b) The function of a neuron network structure responsible for raising the foot has the following characteristics:

a. A nontrained neuron structure (for example, a little kid) the first time that tries to pass the obstacle is likely to have a false step.

b. The next time that it tries to pass the obstacle, it is going to have a better performance, which means that the neuron-based structure can be trained to improve its performance at any desirable level as approaching the optimum.

(c) In the same action, wrong and right (error and correct) coexist, and their boundaries are located at a point where the error value is below a threshold limit.

(d) Correct and error are quantities inverse proportional to each other, which means that in action with a high error value, the correct value is low. In action with a low error value, the correct value is high.

(e) Within the mid-space, there are many options on the way to pass the obstacle correctly, and we may say we have infinite alternatives or, using statistical terms, infinite degrees of freedom.

(f) Freedom may be defined as the alternatives a person has to complete a correct action within well-defined error limits.

(g) Since the magnitude of the error varies from a temporary loss of balance and return to the proper position to a serious injury, then error values may be within the range from zero to minus infinity and from zero to plus infinity.

(i) Bias or deception may be defined if a person knows how to pass the obstacle and on purpose is having a false step.

(j) A nontrained person may be defined as a person who has no physical or other limitations and has a false step in passing the obstacle.

(k) Regarding external balance, an error with a negative sign means a deficient action, an error with a positive sign means an excessive action, and if such error is within the mid-space of virtue limits, the action is accepted as correct or virtuous.

2. EDUCATION AND ANTI-EDUCATION

For most people, education involves acquiring knowledge through memorization and developing specific skills through training, often without giving critical thinking much attention. As we will discuss next, education is something different and has to do with internal balance. We mentioned earlier that an educated person should strive to possess efficient logic, which should be in charge of managing desire and anger. Or to exercise check and balance over desire and anger. Notice that desire and anger are necessary to survive and to perpetuate the species.

Additionally, various emotions, such as joy, happiness, sadness, distress, and fear, depend on the state of desire and anger.

To better understand education, let us consider the opposite of education, or anti-education, where desire and/or anger are in control of the mind and logic is used to achieve their goals.

Unfortunately, such goals have been primarily driven by economic and political power. Furthermore, whoever controls the energy sources can have such economic and political power.

On the other hand, the accumulation of economic power beyond a specific limit does not improve the quality of a person's life; it has no reason to do it, or it does it because logic is not in charge of the mind of that person. The most significant problem arises when a few accumulate wealth from the existing resources, while most of the rest lack the essential things to survive, and they are treated as enslaved people. Therefore, the accumulation of wealth beyond a specific limit deteriorates the quality of life and creates a fear of losing such wealth due to the uprising of enslaved people and, most importantly, because of the rule in Nature that disturbing the balance activates the sward of the goddess of justice (see Fig. 1) and leads to conviction and punishment.

Anti-education was first introduced by Friedrich Nietzsche in 1872. Although he read Plato's books, he, like most people, did not understand the fundamental basis of education, such as internal balance, and instead explained a limited aspect of the anti-education system in a more complicated manner.

We must emphasize that desire and anger are present in most animals, and they are, as we said earlier, essential for animals and humans to survive and reproduce their species. Therefore, the animals, although they have in charge in their mind desire and anger, do not have the logic to support mind decisions that exceed the limits and create, for example, bombs for self-destruction like humans do. All kinds of destruction and self-destruction in humans stem from the promoted anti-education system, where desire and anger dominate the mind and utilize logic to increase destructive power infinitely.

Usually, entieducation also disturbs the external balance, and people do not care about limits because they are not educated to understand what is deficient or excessive action and what the consequences would be of going against the harmony of the rules in Nature by disturbing the external balance.

As explained in Section 2 and regarding Fig. 4, modeling human error would help to create science-based ethics for defining:

(a) Freedom as the alternative actions within the limits of the mid-space of virtue.

(b) Democratic procedures as those that determine the limits of the mid-space of virtue.

(c) Bias and deception.

(d) An inverse proportional relation between right and wrong that coexists in any human action.

External balance could also contribute to a more effective system of justice and a more efficient legislative system. The problem with such systems is that those few with economic and political power influence the legislative process to serve their interests and employ a top-down approach to control and manage the rest of the population, thereby increasing and protecting their profits.

Regarding the functional relation of correct and error, let us assume that X is the error and Y is the correct. The simplest inverse proportional functional relation among them could be:

$$X = 1/Y \qquad (4)$$

We can visualize the relationship between correct and error represented by Equation 4, as shown in Fig. 5. The human error is defined along the X-axis, which is expanded from minus infinity to plus infinity. The correct or virtue is defined along the Y-axis, which is also extended from minus infinity to plus infinity. The values on the Y-axis are considered absolute values, regardless of whether they are positive or negative. According to Aristotle, in the mid-space of virtue, there must be two points (upper and lower limit) along the X-axis to indicate this region. Let us define these points as XL and XR, as shown in Fig. 5. Assuming ξ being a positive threshold value $\xi>0$, then:

$$X_L = -\xi \text{ , } X_R = +\xi$$

Therefore, the midway of virtue or the area of "acceptably correct" is defined between $-\xi$ and $+\xi$, as follows:

$$-\xi \leq X \geq +\xi, \text{ or } X_L \leq X \geq X_R \qquad (5)$$

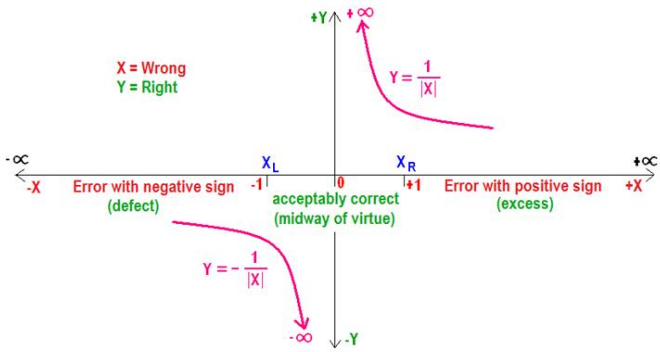

Figure 5. A visual representation of Equation 4. (Hatzopoulos, 2014, 2022)

It is essential to understand that we consider acceptably or correct the region in the X-axis defined by Relation (5). We assume wrong or error all other locations of the X-axis. All locations in the X-axis contain error, but because in the region defined by the relation (5), the error is below a threshold limit (ξ), this region is defined as the acceptably correct region.

We will try now to define precisely the value of the threshold limit ξ. In Fig. 5, the locations XL and XR are boundary locations, separating right and wrong; this means that of these boundaries, X and Y must have the same value (Hatzopoulos J. N., 2008b, pp. 245) or, X=Y and therefore the Equation 4 on these boundaries becomes:

$$X = 1/X \text{ or } X^2 = 1 \text{ and } X = \pm 1 \quad (6)$$

However, the threshold value of ξ is mathematically determined, and ξ=1. Accordingly, the boundary locations along the X-axis become XL = -1 and XR = +1 (see Fig. 5). The value of ±1 indicates the unit of measurement along the X and Y axes.

A closer examination of Fig. 5 indicates that if there is a being committing in all thoughts and actions, zero error could not be a human being and must be a Supreme being having all virtue values ranging from minus infinity to plus infinity. Therefore, human actions that approach zero error also approach the Supreme Being. This also indicates that a Supreme Being has no human weaknesses.

3. TOP-DOWN AND BOTTOM-UP APPROACH

Such approaches are based on the system's theory, as shown in Fig. 6. According to Dr. Chiva Ayyadurai (2023), there are two kinds of systems: one called dam has five parameters: input, output, transportation, processing, and storage. The second one is called the intelligent system and has all five parameters of the dam system plus four additional parameters: goal, controller, disturbances, and feedback.

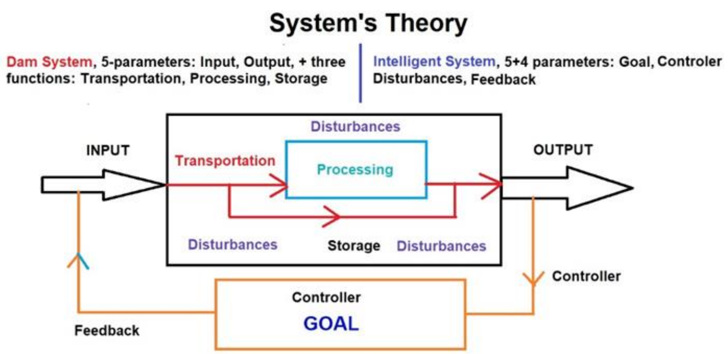

Fig. 6. The system's theory. Source: Dr. Chiva Ayyadurai, 2023.

The top-down approach utilizes an intelligent system, the goal being to maximize profits with minimum disturbances from the citizens. In energy matters, the maximization of profits often leads to rising prices, which can cause public unrest or system disturbances. To face such disturbances, the system controller evaluates the situation and, through the feedback, adjusts the input to minimize disturbances. Input is typically entered through the mainstream media (MSM) (Mainstream Media, 2020) and various clubs controlled by the elite. Output is the reaction of the people and the state of the profits. If the public is educated, they will search and find out whether the price of energy is within the external balance limits. If it is not, they will continue to protest together until they are satisfied. The educated public will not change its actions, regardless of the modifications in input recommended by the system controller. Such modifications (Dr. Chiva Ayyadurai, 2025) could divide people into groups of opposite fabricated ideologies to fight each other, use legislation and police force to limit their protests, use lies and/or computer-generated graphic images (CGI) together with deception techniques to diverge their focus of interest, use paid anti demonstration groups to fight people who demonstrate peacefully and many other methods to have more efficient control over the citizens to minimize disturbances and maximize their profits. It is evident that educated people easily detect such modifications recommended by the controller because they are contrary to science-derived ethical values, such as internal and external balance, and educated people do not create desirable outcomes for the elite. Therefore, the elite must adjust the price of energy by limiting their profits (within the mid-space of virtue – external balance) until the educated public agrees with such an adjustment and stops the uprising.

The bottom-up approach also uses the intelligent system. The goal is to minimize energy prices while maintaining external balance regarding the profits involved. Input encompasses all factors necessary to harness energy sources. Processing derives the costs to obtain the final energy products. It adjusts the price in the output so that the profit for those involved in obtaining the final product is within the mid-space of virtue or the external balance limits. The disturbances typically include unexpected events throughout the process, such as physical hazards, depleted resources, or newly available resources, which the controller evaluates. The controller then recommends modifying the input to account for these new factors.

Furthermore, the internal and external balance could be described by the system's approach using an intelligent system. For internal balance, input is represented by the mind state, which consists of three values: Logic, desire, and anger. The goal is the Logic to be in command and manage desire and anger. Processing uses Equations 2 and 3 to calculate the human error, and if the error is within the mid-space of virtue limits, there is internal balance; if not, the controller (Logic) recommends the adjustment of the mind state and its values of Logic, desire, and anger. Disturbances are anti-education efforts, affecting desire, i.e., through marketing, or affecting anger, i.e., through cowboy movies. Such disturbances are evaluated by the controller (Logic), who recommends adjustment to the mind state inputs accordingly. External balance works as described above for both the top-down approach and the bottom-up approach.

CONCLUSION

Global energy management is a complex and challenging subject that requires innovation to make it more soluble and straightforward. We propose in this study simple ethical scientific models based on the Natural rule of balance, which makes most problems of this kind soluble. Internal and external balance are straightforward models developed by the giants of human intellect, Plato and Aristotle. The former addresses ourselves and a way to domesticate the animal we carry within us, while the latter addresses our actions. The present research demonstrates that all we need to do is take a step forward, utilizing scientific bases such as mathematics, and integrate these two models into all levels of the education system so that it delivers education, not anti-education, as it usually does. Furthermore, these two models must be the basis for all human science and technology fields.

This study also showed that having developed science-based ethics, we can utilize the system's approach to address most global issues, including international energy management, concluding that the bottom-up approach is more effective and just. Therefore, if people are educated and able to understand the anti-education process and stop it, either a bottom-up or top-down approach would lead to similar outcomes.

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CHAPTER 5

COMPLEMENTARITY OF THE STATE AND THE MARKET AS A STRUCTURAL PILLAR OF ENSURING ENERGY SECURITY

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INTRODUCTION

The beginning of the new millennium is accompanied by radical technological transformations. Digitalization of almost all components of human life is combined with a real revolution in the energy sector. The result is a radical restructuring of the institutional architectonics of economic systems (Grytsenko, 2008). The changes cover its elements from the microeconomic to the global level. The threat of increased instability and the emergence of crisis phenomena is growing. It covers all components of the world economy. In these conditions, the tasks of studying the evolution of the role and place of structure-forming pillars to ensure the stability of economic development are updated.

The key and at the same time contradictory role in its provision is played by the state and markets. Since the formation of political economy as a scientific discipline, discussions about its place and role in ensuring the functioning of the economic system have not subsided. Proponents of neoliberal approaches argue that the state impedes economic development due to restrictions on entrepreneurial activity. Proponents of the command-administrative economy criticize markets for irrational use of economic resources. At the same time, historical experience shows that countries with alternative economic models, if necessary, actively strengthen state regulation or introduce market mechanisms. This was the case in the United States during World War II. So it was in the USSR in the 20s of the twentieth century. This is happening in China and Vietnam.

The purpose of the proposed section on the example of the renewable energy sector is to demonstrate the complementarity of the functions of the state and the market as structure-forming pillars of economic development.

1. THE STATE AND THE MARKET AS STRUCTURE-FORMING PILLARS OF ENSURING DEVELOPMENT

The state and the market play a leading role in ensuring the successful functioning of economic systems. This impact can be traced both locally and globally. Their place and role vary significantly in different economic systems. But the presence and complementary relationship of the state and the market remain unchanged as prerequisites for the successful development of the economy.

After all, a person as a subject of economic activity constantly directly and indirectly interacts with other members of society. It receives resources from them to carry out its activities. At the same time, she complements the results of her work for the activities of other people. The cell from which man and society have developed is jointly-divided work. Even simple cooperation is inherently a jointly-divided activity. If the work is performed jointly by several people, it means that all the work is divided between its participants (Grytsenko, 2005).

In the process of economic development is deepening the division of labor. The results of human labor are increasingly mediated by the labor activity of other people. There are such subjects of economic interaction as a private, joint-stock company. The role of their interaction at the local (clusters), sectoral, intersectoral, national, integration level is growing. Digital platform-based value chains and networks are being developed. Ultimately, co-divided relationships in the process of social reproduction acquire a global scale. Independent economic entities - manufacturers of individual components of a product or service can be located anywhere in the world. The division of labor by industry specialization and spatial location is combined with the preservation of the unity of the ultimate goal and the technological integrity of the value chain. The mechanism of ensuring the jointly-divided nature of the production process is preserved and significantly complicated.

It is accompanied by a complication of institutional mechanisms to ensure coordination of activities of economic entities. At the level of interaction between participants in the production process, it is maintained within a single production structure or value chain (network). It is much more difficult to build interaction between manufacturers and consumers. This is due to the contradictory nature of the interests of the parties. Competition of producers for consumers is complemented by competition of potential consumers for goods and services, competition of national economies, integration associations of countries of the world. The development of information technology, the rapid spread of digital platforms significantly transforms the forms, methods, spheres, global consequences of competition (Nosova, Lypov, 2021). The focus of both sides on satisfying individual interest contradicts the need to preserve social unity and support economic development. The economic (direct, individual, utilitarian) motives of maximizing the benefits of producers and minimizing the costs of consumers always lie (and often lost) the ultimate goal of ensuring the life of a participant in a jointly-divided activity. Economic profit is recognized as the end in itself of the activity of an individual entity. Attention to ensuring stability and the growth of general welfare as a common goal of the whole society is lost.

At the institutional level, this contradiction is manifested in the existence of two institutions opposite in function to support social interaction - the ***market*** and the ***state.*** The most effective task of ensuring the exchange of results of economic entities performs the market. Thanks to the freedom of market choice, manufacturers are able to find options to maximize the satisfaction of their own interest. In parallel with the allocation function, markets provide the functions of informing, distributing economic resources, mediation, integrating economic entities, stimulating and regulating their activities, economic selection and improving the economy. The competitive nature of market structures serves as an incentive for "***creative destruction***," the ***constant development of economic systems.***

The flip side of the dominance of market structures is the growth of macroeconomic instability. Periods of "overheating" of the economy alternate with prolonged downturns, incomplete use of labor potential, production capacities, price fluctuations, and inhibition of development. In addition, the result of the functioning of the market mechanism may be the formation of imperfect competition, monopolization of markets. These processes have only intensified in the context of digitalization. It is enough to recall the positions in the global markets of corporations such as Microsoft, Amazon, Meta. In the energy sector, large energy producers are preferred. The structures responsible for the redistribution of energy flows turn into natural monopolies. They get the opportunity to dictate their terms to both consumers and energy producers. Market structures are unable to overcome the problems of negative external effects associated with the production or consumption of goods. Production of public goods remains beyond their competence.

These functions are taken over by the state. It represents the common interests of citizens within the framework of social jointly-divided relations. As an alternative to the market, the state ensures the realization of the interests of society as a whole. Citizens through the state get the opportunity to express their common interests. The state, in turn, represents these interests in relation to each individual subject. Unlike the market, the participants of which are many subjects, the state is a monopoly representative of the interests of all citizens. So, the main function of the state is to embody the common interests of all citizens. *The components of ensuring this function are the subfunctions of the exponent and the representative of common interests. In the economic sphere, they are embodied in common economic interests* (Grytsenko, 2021). The second function of the state has a practical orientation. It is associated with the regulation of the functioning and development of the economy as a whole. This function is oriented to the production of public goods that satisfy common interests and needs. It can be defined as ensuring that the needs of society as a whole are met. Appropriate subfunctions are the *production of public goods and the regulation of the development of society as a whole*. The third function of the state is to protect the public interest. It specifies the second and is a reflection on the conditions of its implementation. The implementation of this function involves monitoring compliance with the rules and norms of activity and the application of sanctions for their violation.

In the energy sphere, these functions are implemented in several directions at once. The state reserves the functions of standardizing and regulating the systems of generation and distribution of energy flows. In most cases, it controls pricing processes in energy markets. In conditions of centralized power generation, depending on the characteristics of the economic model, the state can take over the functions of construction and management of large power plants. It creates and ensures the functioning of the infrastructure for the distribution of energy flows. In the context of the transition to green distributed energy, stimulating its development is of particular importance. Appropriate measures may include the popularization of knowledge about the possibilities of its implementation, financial support for the installation of generation stations. The tasks of restructuring the infrastructure of distribution and management of energy flows are updated. Of particular importance is the creation of a regulatory framework for the functioning of distributed generation.

Taking into account the spheres, methods and conditions for applying the basic functions of the state allows you to deploy and specify them in the form of an interconnected complementary system of functions (Bordenuk, 2005). ***The reconstructive function of the state*** becomes of paramount importance in its structure in the conditions of post-war development and ensuring successful European integration of Ukraine. It in turn includes restorative and constructive subfunctions. Its important component is the restructuring of the energy sector on the basis of strengthening the role and importance of distributed generation. Consequently, the market and the state within the economic system perform their own, specific and irreplaceable functions. At the same time, they remain interconnected, interacting, complementary opposites. This contradiction derives from the development of internal differences in coherently jointly-divided labor as the basis for the existence of society in the conditions of economic management. The opposition market / state acquires the value of a compensatory mechanism. It provides balancing within the economic system of individual interests of business entities and interests of society as a whole. Hence the need for mutual coherence, complementarity of institutions that ensure the integrity of the economic system. The relevance of interaction between the state and the market and in the energy sector remains (Aalto, 2015).

A wide range of tasks facing the state and components of their solution determines a significant variety of approaches to the choice of policies for their solution. Accordingly, scientific approaches, directions, tools for researching renewable energy development policies differ significantly. Ultimately, the central question remains the determination of the role and place of the market and the state in ensuring the functioning of the energy sector. At the initial stage of development of microgrids of distributed generation, the question arises of determining market and regulatory tools to stimulate their development (Cambini at all, 2016).

An in-depth analysis of the experience of policies supporting the development of the energy sector is contained in the joint report The International Renewable Energy Agency (IRENA), The Renewable Energy Policy Network for the 21st Century (REN21) та International Energy Agency (IREA, 2018). A. Nadeem and co-authors attempt to classify technologies, practices, policies to support the development of distributed energy systems. Attention is focused on the technological component of their definition (2023). D. Hess focuses his attention on developing a type of sociotechnical perspective that follows politics into the details of regulatory conflict over system design, analyzing transition politics as a multi-coalition policy field beyond an intra-industry challenger-incumbent relationship, and showing how political conflict includes broader soci etal change issues (2024). A wide spectrum technical, regulatory, market, social and institutional barriers for different types of actors, including technology providers, consumers, Distributed Generation (DG) providers and system operators considered in a collective study F. Norouzi with co-authors (2022). A special place is occupied by the study of socio-economic components of ensuring the energy transition. The focus held under the auspices of European Environment Agency investigation Energy prosumers in Europe revealed tools to activate the transformation of ordinary consumers into participants in renewable energy development programs (Esparrago, 2022). Carlay with coauthors focusing on Public support of energy project in developed in democratic countries (2020). Problems of standardization of energy transition processes in the spotlight of W. Salet (2021). Most studies are comparative. At the same time, the issues of determining the sources of differences between the models of development of renewable generation in different countries and regions of the world remain without attention. In the end, we find them in a different ratio of roles in the economic system of the market and the state.

2. PREREQUISITES FOR COMPLEMENTARITY OF THE MARKET AND THE STATE

According to the French economist, a leading representative of the school of regulation R. Boyer, capitalism cannot be established spontaneously, independently, without state intervention. The market itself is not necessarily capable of generating the institutions necessary for its successful functioning. «Capitalism is not self-implementing», - claims the scientist (1996, p. 5).

Without state control, markets, from an objective mechanism, an instrument of economic interaction can turn into a means of achieving the interests of individual economic entities. They lose their basic function. Already in the mid-1970s, J. Galbraith noted that the market is not only not a controlling force in the economy, but increasingly adapted to the needs of business organizations (Galbraith, 1967).

Dialectics of relations between the state and the market is formed at the level of unity of the object of regulation (interaction of economic entities) and the economic content of the institute (division of labor, cooperation). The state acts on the principle from the whole to the parts that form the market.

The market directs activity in the opposite direction, from parts to whole. From there, the opposite of the spheres of regulation (reproduction of society / movement of resources, goods and services), the prevailing types of relations (hierarchical / horizontal) and transactions (redistribution / exchange), the opposition to ensuring the stability / flexibility of the state of the system. The ability to control unacceptable behavior of economic agents is opposed by its extreme limitations in market conditions. Significant losses in the event of a break in relations are insignificant.

Polanyi's research helps to understand the origins of the formation of complementary relations between the market and the state (Polanyi, 2011). The scientist identifies three forms of integration of society. Where relationships between individuals are grouped on mutuality, reciprocal integration is formed. Where there is a distribution of something between individuals, redistributive integration arises. Frequent barter exchanges between individuals lead to exchange as a form of integration. The simple sum of individual behavioral acts does not create institutional formations capable of ensuring the integration of society. The integrative effect, according to K. Polanyi, is due to the presence of certain institutional structures. It can be symmetrical organizations, centers, and market systems. However, not every exchange ensures the formation of the market. The scientist identifies three of its forms. Simple movement of goods in space from hand to hand (operational exchange). Exchange between owners based on fixed rates (exchange based on the decision). Negotiation-based exchange (integrative exchange). Only exchange in price markets refers to the mechanisms of market integration. Its condition is the orientation of each partner to a mutually acceptable price. A negative component of this type of exchange is the element of antagonism. No community seeking to maintain a sense of solidarity in its members, according to K. Polanyi, can resolve the hidden hostility between them. Hence the general ban in primitive and ancient societies on profit-oriented exchange operations with food. Widespread ban on food trading automatically excludes price setting institutions in relevant markets (Polanyi, 2011). The market in traditional society is seen as a factor that destroys the foundations of social life.

So, the market and the state are the opposite complementary sides of a single social substance. The market functionally complements the state in the field of formation of optimal transaction costs in cooperation between business entities.

This organizational form takes priority in cases where the individualization of interests provides an increase in the social value of economic activity. On the other hand, the need for constant reproduction of society as a single organism determines the need for consideration and respect for the public interest. The state is oriented towards this task. It is designed to ensure harmony between individual and public interests. The market and the state occupy their own niches in the system of social reproduction. Institutional mechanisms for achieving this goal may differ. The origins of these differences are contained in the specifics of the priorities of the social orientations of the value systems of national economic cultures.

3. INSTITUTIONAL COMPLEMENTARITY AS THE BASIS FOR THE FORMATION OF STRUCTURE-FORMING PILLARS OF ECONOMIC DEVELOPMENT

Under institutional complementarity refers to the form of interaction of institutional components of socio-economic systems in which they remain relatively independent, are interdependent and complement each other in the process of reproduction of the economic system as a single social organism. Complementarity supports the systemic unity of structural and functional properties of institutions. It combines different quality components of the characteristics of the life of systems - integration (structural) and differentiation (functional). This contradiction also becomes possible as a result of the integrity of the system and forms new integrative qualities. Systemic unity and integrity are subject to the principle of triple interdependence of F. Aquinas. According to him, *the whole system depends on the parts that make it up, each of the most important parts depends on the system as a whole and on its other parts.* This unity ensures coherent production, distribution, exchange and consumption of economic goods within the economic system.

Structural complementarity (StC) reflects the interconnection of institutional forms of management, is laid at the level of social orientations of the value system and is based on the similarity and complementarity of institutions. In turn, *functional complementarity (FC) characterizes the functional and procedural integrity of the system, based on the principles of* *institutional integrity, coherence and consistency.* General complementarity is the result of complementary interactions regarding independent elements of the institutional system. It characterizes the unity of structural and functional properties of the institutional system. Fig. 1. illustrates the relationship between the nature of complementarity at the system-wide level and the characteristics of economic systems.

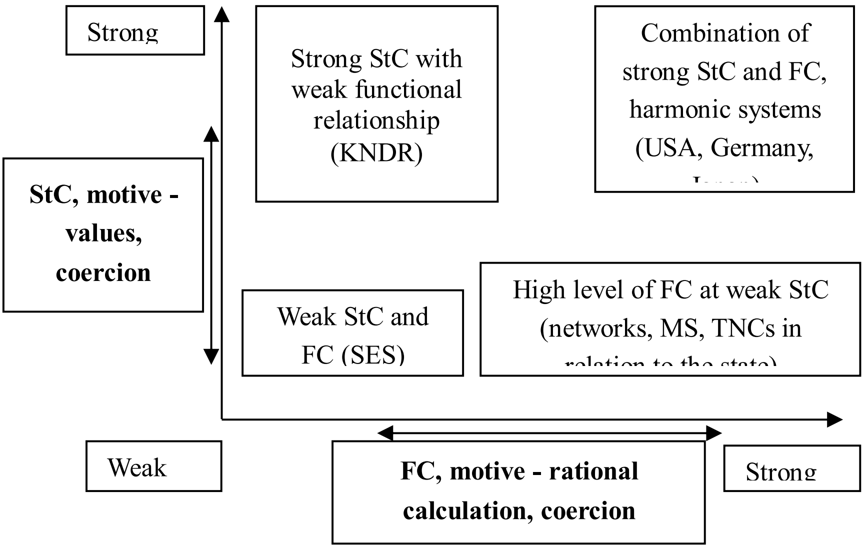

Fig. 1. General complementarity and specificity of economic systems (Lypov, 2011, p. 122.)

In the process of evolution of economic systems, the structure of institutions is consistently complicated. The logic of their formation is built from basic, universal to specialized institutions. *The initial formation sequence is a structural framework for the formation of more complex ones*. Those, in turn, serve as the basis for further complications. A hierarchy of foundations of the institutional system is being formed. The integrity of its layering and diversity is manifested in the form of structural and functional variability (Lypov, 2014). The higher the level of development of society, the greater the complexity and diversity acquire coherently jointly-divided socio-reproductive relations. Institutions that consolidate their character, in turn, are also complicated, their complementary interaction is complicated. Elements of institutional architectonics of economic systems are presented in Table 1.

Table 1 Hierarchy of foundations of institutional architectonics of SES (Lypov, 2013, p. 9.)

Level	An element of institutional architectonics
Nanotconomic	Values
	Individual knowledge, skills, abilities, and organizational routines
	Institutional bodies
Microeconomic	Institutional forms
	Institutional functions
	Collective Conventions
	Institutions
	Organizational forms of coordination and management of transaction costs
Mesoeconomic	Institutional blocks within social spheres
Macroeconomic	Basic institutions of social spheres
Megaeconomic	Socio-economic models
	Integration Unions
	Global economy

Nanoeconomic level of institutional architectonics is composed of values, individual knowledge, skills, abilities and organizational routines. Values are understood as stable, objective subjective-psychological regulatory internal relations of the individual, which determine the worldview, orientation and nature of its economic activity. A significant amount of data on the value orientations of national cultures of management is contained in the research results of G. Hofsted (2010), F. Trompenaars and Ch. Hampden-Turner (2015), R. Inglehart (2005), S. Schwartz (2012). It allows, on the basis of quantitative characteristics, to carry out a qualitative analysis of the influence on the architectonics of institutional systems of dominant value orientations of national cultures of management. Its results demonstrate a significant relationship between values, first of all, their prevailing social orientations and dominant religious denominations, political system, legal systems, models of economic system, competitiveness of the economy (Nosova, Lypov, 2022).

In the energy sector, the advantage in the national culture of the values of communitarianism or individualism plays a decisive role in the formation of the relationship between the roles of the market and the state. The emphasis on communitarian value orientations determines the growing role of the state. It can range from complete market control when the state combines the roles of producer and distributor of energy flows to tight control of energy markets. In turn, the prevalence of individualistic values promotes more active participation of private enterprises in the development of renewable generation.

Significantly complicates the transition to green energy is the need for a thorough restructuring of the system of individual knowledge, skills and abilities of an extremely wide range of business entities. After all, the matter concerns not only specialists working in the energy sector. A significant group of traditional consumers gets the opportunity to retrain as energy producers. And not only for their own needs. They can become prosumers - to offer the energy market surplus own power generation (Esparrago, 2022). The decisive role in accelerating and facilitating this process is played by the state. It informs potential prosumers about new opportunities, provides training for new participants in the energy market. This is combined with the formation of an appropriate regulatory framework, the development of a system of financial support for the installation of renewable generation stations, the restructuring of the infrastructure for the distribution of energy flows.

The emergence and rapid development of distributed generation systems requires restructuring the organization of activities of large traditional energy producers. After all, earlier their role at the stage of creation was focused on the needs of a centralized energy system. Accordingly, there is a need for a significant restructuring of organizational routines. These are internal norms of interaction that operate within a particular enterprise.

The microeconomic level of institutional architectonics consists of institutional forms and functions, institutions, organizational forms of social interaction.

Institutional forms - conditioned by specific socio-economic and technological circumstances of existence of society forms of embodiment of patterns, methods, norms of behavior that regulate the order of social interaction in society. They determine not only the algorithms of social interaction, but also status relations, areas of application, character, measure of responsibility for their failure. Examples of institutional forms in the energy sector can be regulatory documents governing the relations of market participants (laws, rules), organizational forms of activity of their participants (state and local authorities are authorized to deal with energy supply issues, entrepreneurial structures operating in energy markets).

Institutional functions - tasks, roles performed by individual institutions in economic systems; standardized social actions that reflect the interdependence of participants in institutional interaction. Thus, the function of the normative act may be to determine the legal, economic and organizational principles of the functioning of the electricity market, the regulation of relations related to the production, transmission, distribution, purchase and sale, supply of electricity. The function of the state institution is the development, implementation, control of the implementation of regulatory documents. The function of the enterprise is the production, distribution, dispatching of energy flows.

The form and function of the element of the institutional system, institution, represent an example of complementarity, the unity of diverse opposites, which only in combination provide the very possibility of its existence. Function is the mode of existence of the institutional form. The institutional form justifies its existence only as a carrier of a certain function. Only in their unity do they form an integral institutional element, block, subsystem, system. They are complementary, interdependent and complement each other.

The relativity of this interdependence manifests itself, firstly, in the fact that the same institutional form can perform several functions. A good example is money. They combine the functions of a measure of value, a means of circulation, accumulation, payment, world money (Lypov, 2009). In the energy sector, the state, through relevant institutions in various economic models, can take over all or part of the functions to ensure the functioning of the energy sector. Among them are the functions of an investor, lender, owner, manager of energy generation and distribution systems, energy flow manager, energy regulator.

Second, different institutional forms can perform the same function. In the case of the development of renewable energy, the functions of encouraging its development can be performed by green tariffs, dynamic pricing, preferential lending programs, tax holidays, various provisions of regulatory acts on the settlement of relations in the energy sector.

Thirdly, the same functions in different economic systems or in the same system, but at different times, can perform different institutional forms. Depending on the peculiarities of the economic model, both public and private enterprises can act as investors, owners, dispatchers of energy flows. The distribution of these functions between them can vary significantly. A significant reduction in the cost and increase in the efficiency of renewable energy equipment creates the possibility of abandoning green tariffs. Accordingly, dynamic pricing systems receive priority as a tool to stimulate the development of distributed energy generation. Depending on the availability of renewable generation sources, different countries focus on the development of solar, wind, hydrogeneration.

Collective conventions mediate the relationship between values and institutions (Dequech, 2005). They are social arrangements for the acceptance and application of institutions. Awareness and readiness to implement regulations in the energy sector determines the effectiveness of market structures, the amount of costs to ensure control over their implementation by the state.

Institutions are norms of interaction that combine institutional form and function. Examples of institutions operating in the energy sector are the laws of Ukraine On the electricity market, On energy efficiency, On alternative energy sources, On combined production of heat and electricity (cogeneration) and the use of waste energy potential.

It is worth paying attention to a certain terminological confusion found in the writings on institutionalism. Institutions can be understood as norms of interaction between economic entities and organizational forms of their joint activities. In order to avoid complications, we use the term institutions to define regulatory documents governing relations between business entities.

Organizational forms of social interaction are state organizations, non-profit structures, enterprises of various forms of ownership, etc., which ensure coordination of personnel activities and optimization of internal transaction costs in the process of performing tasks that are the purpose of their creation (Coase, 1937). R. Boyer distinguishes as key organizational forms the state, market, hierarchies, local communities, network structures and associations (2005, p. 534). Communities, households, intercompany contracts and digital platforms should be added to these forms. Table 2 presents a classification of organizational forms of social interaction as methods of coordination. The basis of the classification is the nature of the distribution of power and the motivation for interaction.

Table 2: Taxonomy of methods of coordination (Lypov, 2011, p. 222.)

		Nature of power distribution	
		Horizontal	**Vertical**
Motiva-tion interactio ns	**Self-interest**	***Market*** *Intercompany contact* *Plat-forms, networks, associati*	*Firm*
	Соціальні зобов'я-зання	*Домогосподарства* *Local communitie s* *Общини*	***State***

In the energy sector as organizational forms of social interaction act state organizations (ministries, departments, departments), dealing with the problems of regulation and control of energy markets; public and private enterprises providing generation, distribution, dispatching of energy flows, construction and maintenance of energy infrastructure, innovative, investment; local authorities and public organizations dealing with the problems of supporting the development of renewable generation. The peculiarity of the formation of distributed generation is the growth of the role of digital platforms as an organizational form of ensuring the interaction of participants of local micro -networks of renewable generation (Grytsenko, Lypov, 2024, a). They are an effective tool for ensuring the management of information and energy flows between network participants (Fig. 2).

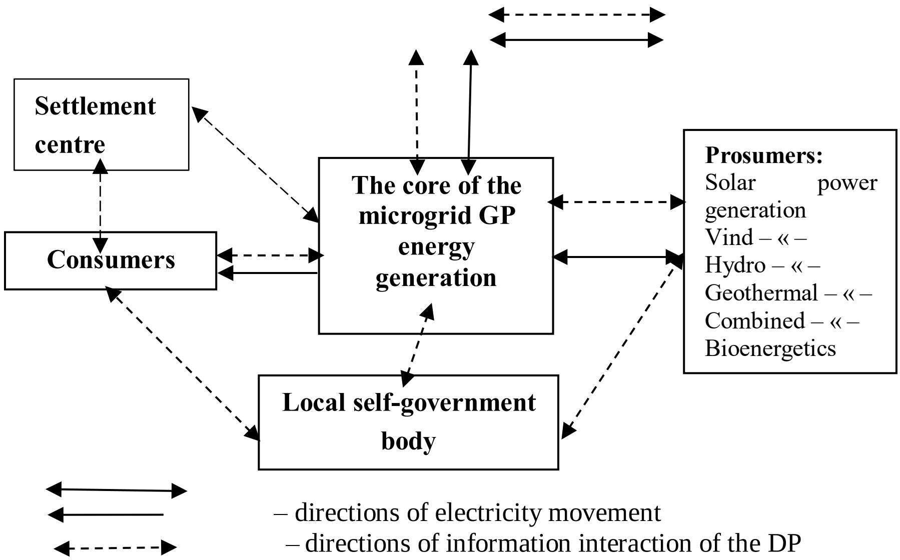

Fig. 2. Structural and functional complementarity of elements of microgrid GP (Grytsenko, Lypov, 2024, b, p. 11.)

Mesoeconomic, sectoral level of institutional architectonics form institutional blocks. Institutional blocks are relatively stable associations of institutions functioning in certain functional spheres of social reproduction. The main institutional blocks in the field of economics include: industrial relations, financial systems, corporate governance, production models, national innovation systems, institutions of the welfare state, training and training of personnel (Lypov, 2013, a; Lypov, 2013, b).

The condition for the successful functioning of the energy sector is the involvement of almost all these institutional blocks. The specifics of distributed generation is the possibility of forming virtual power plants (Abdelkader at all, 2014). The core of the digital platform forms an ecosystem in which the owners of renewable generation equipment - prosumers are participants in the value creation network (Esparrago, 2022). At the same time, representatives of households with renewable generation equipment act as self-employed. Distributed generation microgrid management models differ significantly. It can be an intermediary company that provides interaction between manufacturers and consumers. A variant of such a фstructure are cooperatives of co-owners of energy generation equipment (Grytsenko, 2024, b). The model of the corporation combining production, innovation and investment functions is being developed. Shareholders-investors receive energy at preferential rates.

The macroeconomic level is the basic institutions of the main public spheres. Basic institutions are deep, historically stable and constantly reproduced social relations that ensure vertical (between ideological, political and economic spheres) and horizontal (within each of them) integration of society. The function of basic institutions is to regulate these social subsystems within a single social organism. The basic institutions of the economic sphere include the organization of labor and property relations, money, exchange / redistribution, competition / coordination, encouragement / coercion. The specificity of the model of the economic system in which the system of distributed generation is being developed determines the priority of the basic institutions of hired or corps labor, the degree of concentration of ownership of the relevant equipment, the intensity of state intervention, including price regulation, the nature and intensity of competition in energy markets, the choice of tools to encourage the development of renewable generation.

The global level involves the unification of individual economic systems based on the allocation of key institutional characteristics. It is based on the social orientations of the value system that ultimately determine StC. Table 2 presents the main characteristics of StC models of economic systems (capitalism). Three variants of models of capitalism include market-oriented (MC, Anglo-Saxon countries), mesocorporate (MCC, Asian countries) and social democratic (SDC, European countries) (Table 3).

Table 3: Models of economic systems and their complementary characteristics (Lypov, 2011, p. 238.)

Bnchmarks	Market-oriented capitalism (MC)	Mesocorpo-rate capitalism (MCC)	Social democratic capitalism (SDC)
Countries - samples	Britain, USA, Canada	Japan, Taiwan	Central and Northern Europe
Priority values *	I, MUA, SPD, STO, AA, M	C, GUA, GPD, LTO, M, H, B	I, MUA, HPD, moderate STO, E, H, IA
Basic ideological, political and legal institutions	Subsidiarity, federalism, common law	Communitarianism, unitarianism, mixed law	Corporatism, federalism, civil law with elements of general
Main elements of institutional infrastructure	Market, large corporations,	Large corporations, networks, state, market	Corporations, associations, state, market
Type of StC and the basic principle of its formation	Isomorphism based on I	C-based isomorphism, patriarchal corporatism, solidarism	Polyisomorphism with an emphasis on I, corporatism as a means of combining I and C.

Remarks: * I/C – individualism / collectivism, MRU / NRU – moderate / great uncertainty avoidance, SPD/GPD – slight / great power distance, STO/LTO – short / long-term time orientation (G. Hofstede,); IA/AA – intellectual/affective autonomy, H – harmony, E – egalitarianism, M – masterity, H – hierarchy, B – belonging (Sh. Schwartz).

Consider the possibility of using the proposed structural and functional approach for the study of the patterns of interaction of market and the state as a structure of forming supports of development in modern conditions. Basic institutions are a frame, the long-term basis of the stable existence of society. They determine the choice of variants of specific institutions as well as the nature of their institutional functions. Since complementarity involves the systematic mutual influence of institutions, the relations between market institutions and the state are mutual. But differentiation of structural and functional aspects of interaction allows to identify significant differences in the possibilities of such influence. The vertical links from values to ideological, political, legal and economic institutions are dominant in structural interaction.

The key is the social orientation of the value system (individualism / communitarism). There are principles of institutional likeness and isomorphism when the nature of institutions and organizational forms is determined by the dominant social orientations. In structural, organizational plan, market institutions are hierarchically dependent on state institutions. Values determine the nature of institutions and organizational forms acceptable within a specific socio-economic system.

Thus, the principles of subsidiarity, freedom and stratification determine the priority of the influence of liberal institutions at political and economic levels. In these circumstances, legalization at the level of economy of institutions that correspond to the redistribution economy will encounter political institutions resistance. On the opposite side, in the context of priority of values of communitarianism, egalitarianism, and order, basic political institutions will support dominance in the economic sphere of the state.

Functional complementarity is based on the principles of integrity, consistency and consistency. In cases where traditional for the appropriate type of socio-economic model of functions is insufficient, *compensatory functions characteristic* of the model of the opposite type are formed. Its carrier is either new, shadow institutions or complements existing institutions borrowed from the opposite. Changing institutional functions leads to the transformation of institutions.

In the case of renewable energy, an example is the transition from centralized to decentralized, distributed energy systems. They are developing in countries with excellent institutional models. At the initial stages, already existing institutions are taking over new functions to provide opportunities for creating distributed generation cells. However, in the future, the development and growth of its share determines the reformatting of old and the creation of new institutions. Ensuring the functional complementarity of renewable generation institutions is combined with the need for a complementary integration into the structure of the existing institutional system, restructuring of structural complementarity.

The nature and content of the activities of key, ambivalent representatives of the state and the market - officials and entrepreneurs - is being transformed. Despite the differences due to national peculiarities, the dominant mode of production, affecting the formation of bureaucracy and entrepreneurs in Western Europe (Sombart, 1998: Lachman, 2000); Asia (Luce, 2000), islamic countries (Mannam, 1991), they retain common features. Functional bureaucracy is characterized by specialization of the division of labor, hierarchical management, standardization of procedures, performance indicators and recruiting policies. Structurally, it, like entrepreneurship, is tied to the specifics of the national business culture and the dominant system, forming models of management structures and entrepreneurship. Key functional characteristics of entrepreneurial activity according to J. Schumpeter - commitment to innovation, willingness to take responsibility for economic risks (Schumpeter, 1983). In the new environment, bureaucracy becomes entrepreneurial (Osborne, 2010). It becomes a client oriented, transparent, accountable system of public service. Entrepreneurship, on the opposite side, faces the need to improve management structures, increase their dynamism, improve coordination of activities. There is a convergence of bureaucracy and entrepreneurship.

CONCLUSIONS

Economic activity is based on the distribution of the process of creating elements of the final product between many participants. The work is divided between them. Jointly-divides is a cell from which man and society have developed. This distribution is deepened in the process of economic development. Joint-separated relationships are complicated. The unification and simplification of algorithms for public interaction is provided by institutions. They are understood as established norms and organizational forms of its implementation.

In the process of development, the role and importance of complementarity, interrelationship and interdependence of institutions that ensure the coherence of social reproduction processes increases. The key role in solving this problem is played by the complementarity of market and state institutions. The markets support the interests of individual entities. The state is a defender of the interests of society as a whole.

Opposition Market / State acquires the importance of a compensatory mechanism. It maintains the balance of the private interests of particular economic entities and the interests of society as a whole.

The dialectic of relations between the state and the market is formed at the level of unity of the object of regulation (interaction of economic entities) and economic content of the institute (division of labor). The state acts from the whole to the parts. The market is from parts to the whole. The opposite of spheres of regulation (reproduction of society / movement of goods), predominant types of relations (hierarchical / horizontal) and transaction (redistribution / exchange), confrontation of stability / flexibility of the state of the system is maintained. The control of the behavior of market entities is opposed by the support of their freedom. Significant losses in the event of a relationship break are insignificant. The market and the state are the opposite complementary aspects of a single social substance. They occupy their own niches in the social reproduction system.

Institutional complementarity provides the systematic unity of structural (integration, form of existence of the institute) and functional (differentiation, function of the institute) components of formation of institutional systems. Structural complementity is laid at the level of social orientations of the value system and is based on the similarity and complementarity of institutions. Functional complementarity characterizes the functional and procedural integrity of the system. It relies on the principles of institutional integrity, coherence, and consistency.

The renewable energy sector can serve as a vivid example of the complementarity of the functions of the state and the market as structure-forming pillars for ensuring development. It allows to demonstrate the complementarity of their functions in overcoming a wide range of contradictions in the energy sphere. In particular, between the growth of opportunities to more fully use the potential of individual economic entities and the interests of supporting the sustainable development of society as a whole. A significant complication of the tasks of ensuring the coordinated interaction of market participants and balancing energy flows in the network as a result of the development of distributed generation, decentralization, and demonopolization of energy markets. Rapid improvement of renewable generation and digital technologies and increasing volatility of fossil fuel markets and exacerbation of environmental problems. The emergence of new and changing the role and place of traditional energy markets. The development of renewable generation microgrids and the need to rebuild the energy infrastructure. The growth of volatility of energy supply and demand and the expansion of the spectrum of technical, technological, software and economic tools for balancing energy flows. Introduction of dynamic pricing and increased investment risks. After all, their solution is based on preserving the balance of interests of individual subjects and society as a whole, supporting the complementarity of the market and the state.

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CHAPTER 6

GLOBAL PERSPECTIVES TO ENERGY, DEVELOPMENT, AND INEQUALITIES: TÜRKIYE’S STRATEGIC ADVANTAGE FOR THE DIGITAL AND GREEN FUTURE

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INTRODUCTION

In this day and age, specialists strongly believe that the transition of the Turkish firms towards the circular economy principles offers major strategic advantages, on the one hand, by addressing the immediate challenges and the solutions derived from them, and, on the other hand, by fostering long-term benefits that are intended to build businesses' resilience against economic shocks and financial crises (Word Bank Group, 2025a). What is more, the circular economy principles have a significant influence on the capacity of the Turkish businesses to strengthen their position in the global markets, especially in the context in which the circular economy landscape is known to be evolving rapidly in the European Union and in the other countries all around the globe (Word Bank Group, 2025b). Furthermore, it has been acknowledged that in the last years the global financial systems experienced significant disruptions, which often included the very sharp declines in the asset pricing, the worrying failures of financial institutions, and the severe shocks in foreign exchange markets (Word Bank Group, 2025c; Word Bank Group, 2024).

In continuation of the aspects highlighted in the lines above, there are numerous regions, countries, and even union of countries that offer positive, valuable, and successful models of sustainable development and resource management (Bai & Lin, 2022). In this case, for example, an extensive analysis of the European Union's shift towards a circular economy reveals the necessity to carefully focus on global perspectives related to energy, development, and inequalities (Yoshida et al., 2024). Noteworthy, for instance, the transition to circular economy in the European Union is regarded as crucial since it addresses global challenges such as climate change, resource depletion, and social inequalities (United Nations (UN), 2024).

The book chapter on "Global Perspectives to Energy, Development, and Inequalities: Türkiye's Strategic Advantage for the Digital and Green Future" centers on key elements, such as: firstly, the circular economy and the global impact; secondly, the opportunities that the country has to become a global leader, learning from the success cases already existing at an international level and applying the valuable opportunities derived from transforming the challenges into economic, technological, and environmental perspective and drivers able to foster progress as well as the implementation of the circular economy action plan; thirdly, addressing inequalities; fourthly, highlighting global collaboration and knowledge sharing, focusing on the vital role of sustainability; and, fourthly, moving beyond the Türkiye's strategic advantage for the digital and green future, while referring to other case studies that come to support the current research, such as, for instance, the specific context and challenges of the European Union and other regions.

The book chapter intends to offer answers to several key questions. Specifically, for the theme "Global Perspectives to Energy, Development, and Inequalities: Türkiye's Strategic Advantage for the Digital and Green Future" the key research questions should explore how can Türkiye leverage its position to achieve sustainable development while addressing inequalities, particularly in the context of digital and green transitions. In general terms, the questions should consider the interplay between the energy policies, the regional disparities, the social support mechanisms, and the potential for economic restructuring.

1. LITERATURE REVIEW

The nexus between renewable energy, green technology innovation, and AI offers a valuable pathway towards a more inclusive, resilient, and sustainable future. To begin with, specialists show that leveraging the capabilities of AI is paramount these days. What is more, the scope of accentuating the AI advantages and benefits in the nexus between renewable energy, green technology innovation, and AI has the profound power to optimize renewable energy systems and develop more efficient technologies. Furthermore, addressing the environmental impact of AI is crucial these days. One of the most important roles played by AI these days is to significantly reduce carbon dioxide emissions and create a more sustainable world.

Recent documents and reports indicate that there is a growing emphasis on ensuring that the progress generated by the relationship between renewable energy, green technology innovation, and AI aligns with the Sustainable Development Goals (Šebestová & Popescu, 2025b).

Besides these aspects mentioned above, Türkiye is leveraging industry and technology as drivers of progress. In addition, this nation is actively integrating digital technologies and the domains in which AI plays a significant role are manufacturing and agriculture.

Likewise, the digital technologies integration targets sustainable resource management and environmental conservation (Popescu & Verma, 2025a).

Although there are numerous benefits derived from the continuous integration of the digital technologies in manufacturing and agriculture as well as in sustainable resource management and environmental conservation, the challenges should be addressed very thoroughly as well. Hence, the challenges are encountered in the process of achieving a balance between economic growth and environmental protection (González et al., 2025a). Interestingly, further efforts are required to enhance sustainability practices across various sectors (Popescu, 2025b).

The literature carefully analyzed showed that industry and technology are accelerators. They play pivotal roles in digitalization, Industry 4.0, digital economy, and innovation. For example, in terms of digitalization, Türkiye experiences significant advancements across various sectors and these sectors are agriculture and manufacturing. In addition, the adoption of Industry 4.0 technology in Türkiye refers to AI and automation and has as aim to increase efficiency and productivity in order to generate vital transformations in agriculture and manufacturing (Popescu, 2025c).

2. MATERIALS AND METHODS

The book chapter on “Global Perspectives to Energy, Development, and Inequalities: Türkiye’s Strategic Advantage for the Digital and Green Future” employs a mixed-methods approach combining quantitative and qualitative research. Additionally, the section on materials and methods details specific data collection techniques and analytical frameworks. In particular, the focus is on examining Türkiye’s current energy landscape, while making pivotal connections with the digital infrastructure and the progress in green initiatives. Besides these, the study centers on analyzing statistical data, policy documents, and case studies. In continuation, conduction interviews is regarded as essential in offering a better and more in-depth understanding of energy, development, and inequalities in the context of Türkiye’s strategic advantage.

2.1 Quantitative Data Analysis

While referring to the quantitative data analysis, the focal point is represented by the energy data, the development indicators, the digital infrastructure, and the inequality metrics.

For the energy data Türkiye's energy production and consumption patterns are addressed, taking into consideration the following aspects: Türkiye's renewable energy resources; the implications derived from the use of fossil fuels; and, the values of the energy efficiency indicators. Hence, data was sourced from governmental agencies like the Turkish Statistical Institute (TÜIC), international organizations such as the International Energy Agency (IEA), and energy companies.

Since the development indicators' analysis is seen as vital in this current context, addressing the economic growth, the poverty rates, the education levels, and the access to healthcare was made by using sources like the World Bank, the United Nations Development Program (UNDP), and the Organization for Economic Co-operation and Development (OECD).

Moving on, centering on the digital infrastructure implicates gathering data from the Turkish Statistical Institute (TÜIC), telecommunication companies, and research institutions. The purpose is to address the internet penetration rates, the broadband access, the mobile phone usage, and the availability of specific digital technologies in different social groups and regions.

The inequality metrics are also seen as very important in this current research since measuring the income inequality, the gender inequality, and the regional disparities by using the indices such as the Gini coefficient and examining the distribution of wealth and resources is of great essence. In terms of data sources could be mentioned the Turkish Statistical Institute (TÜIC) and other relevant social research institutions.

2.2 Qualitative Research

The qualitative research centers mainly on the policy document analysis, the case studies, the interviews, and the literature review.

Concerning the policy document analysis the point of interest is represented by examining a wide range of aspects among which could be emphasized Türkiye's national energy policy, the digital development strategies, and the environmental regulations. In this regard, analyzing the legislative frameworks, the strategic plans, and the strategic documents is imperative.

When referring to the case studies, centering on specific regions and sectors within Türkiye becomes of utmost importance in order to be able to illustrate the interplay between energy, development, and inequalities. There are several aspects that are of great interest in this matter and among which could be mentioned: firstly, examining the impact of renewable energy projects on the local communities; and, secondly, highlighting the role of digital technologies in promoting economic growth and sustainable development in specific industries.

The interviews are extremely relevant for this current research. In general lines, the interviews were centered on business leaders and community representatives in the attempt to gather insights into their perspectives on the challenges and opportunities related to energy, development, and inequalities.

The literature review is seen as a major step of the qualitative research. In this matter, relevant academic research on energy transitions, digital development, and social inequalities was analyzed. Also, studies on Türkiye's specific context were gathered and thoroughly analyzed.

2.3 Analytical Frameworks

The complex analytical frameworks involve the elements stressed in the following lines: the systems thinking; the dependency theory; the resource curse theory (also known as the paradox of plenty); and, the Sustainable Development Goals (SDGs).

To begin with, applying a systems thinking approach to understand the valuable relationships between energy, development, and inequalities shows that these are not isolated issue but rather strongly linked elements which are integrated parts of a larger and more complex system.

Likewise, the dependency theory examines the way in which Türkiye's energy choices and development strategies have their roots in the country's desire to become a leader in the domain, being influenced, on the one hand, by the global power dynamics and, on the other hand, by the historical inequalities.

The resource curse theory (also known as the paradox of plenty) has as focal point the analysis of the potential negative impacts of the natural resource wealth, such as oil or gas, on the economic development, social equity, and sustainability. For instance, this situation addresses the resource-rich countries that fail to benefit fully from their natural resources.

In the end, using the Sustainable Development Goals (SDGs) as a general, inclusive, and robust framework to assess Türkiye's progress towards sustainable development relies on the analysis of the current status of the aims related to energy, poverty reduction, and inequalities.

2.4 Türkiye's Strategic Advantage

The book chapter sheds light on Türkiye's strategic advantages taking into consideration the country's strategic location at the crossroads of Europe and Asia, the immense potential of its growing digital economy, and the major capacity for reviewable energy. The country has the impressive capacity to leverage these advantages which the book chapter focuses on starting from the promotion of sustainable development, the desire to find solutions to reduce inequalities, and the need to enhance the country's importance and role in the global energy landscape. Importantly, the study could also address the challenges Türkiye faces in achieving these goals, such as the need for the significant investments in infrastructure, the dedicated programs to support human resource development, the political instability, or the regional conflicts.

Interestingly, Türkiye's key advantages implicate building the nexus between information, knowledge sharing (KS), absorptive capacity (AC), innovation, and intellectual capital (IC).

2.5 Key Research Questions

The research questions for the theme "Global Perspectives to Energy, Development, and Inequalities: Türkiye's Strategic Advantage for the Digital and Green Future" are tackle: firstly, energy and development; secondly, digital transformation and development; thirdly, inequalities and social justice; and, fourthly, the strategic advantage.

The key research questions for the energy and development are:

- How can Türkiye's energy policies be designed so that they will successfully address regional inequalities and diligently promote a just and equitable energy transition?

- What are the economic costs as well as the potential benefits of Türkiye's energy transition, and how can this situation be addressed from the cost-benefit perspective?
- How can Türkiye leverage its geographical location and existing infrastructure to become a global leader in renewable energy and green hydrogen?
- What are the challenges and the implications of Türkiye's energy development strategy for its long-term economic growth, competitiveness, and success on the marketplace?
- The key research questions for the digital transformation and development are:
- How can Türkiye's digital infrastructure and technological capabilities be harnessed to support the green transition and find solutions to social inequalities?
- What are the potential synergies between the digital and green transitions, and how can Türkiye maximize these connections for sustainable development?
- In what way can digital technologies be used to improve energy efficiency, promote successful sustainable consumption patterns, and support marginalized communities?
- What are Türkiye's challenges and strategies towards green transformation?
- The key research questions for the inequalities and social justice are:
- In what manner can Türkiye address energy poverty and ensure access to affordable and reliable energy for all the citizens?
- How can Türkiye ensure that the benefits and the advantages of the digital and green transitions are shared in an equitable manner across all social groups and all regions?
- What social support mechanisms should be used to focus on potential job displacement and other social challenges that occur from the energy transition?
- What is Türkiye's role in enhancing the partnerships for the Global Goals?
- The key research questions for the strategic advantage are:

- What are Türkiye’s unique strengths and specific weaknesses in the context of the global energy transition and how can the country benefit from its strategic advantages?
- How can Türkiye foster regional cooperation and promote the partnerships intended to advance its green and digital goals?
- What role can Türkiye play in empowering the global discourse on sustainable development, and promote a just and equitable energy transition?
- What are the structural obstacles to the energy transition in Türkiye, a country with significant socio-economic differences?

These days the analysis of the structural obstacles to the energy transition in Türkiye and in other countries with significant socio-economic differences requires a holistic in-depth approach. The research questions emphasized in the lines above provide a starting point for exploring the complex synergies between energy, development, and inequalities in Türkiye’s context. This book chapter delves into specific policy areas, highlights technological advancements, and tackles social dimensions to inform evidence-based decision-making and promote a sustainable and equitable future for all citizens and, in this particular case, in Türkiye. Likewise, the book chapter addresses numerous success examples on how the instruments of the circular economy and the circular economy principles can revive the Sustainable Development Goals (SDGs). Significantly, the study delves into the challenges of the European Union’s road to a circular economy, while targeting the key steps and the major challenges.

3. RESULTS AND FINDINGS

The book chapter is extremely valuable in shedding a new light on the international perspectives on energy, development, and inequalities making a bold analysis of the European Union’s challenges and the road to the circular economy. In addition, offers a model of sustainable development and resource management, focusing on the case of Türkiye. There are several key elements that are being brought to the attention: the circular economy and the global impact; the European Union role a leader; Türkiye’s potential to address in a successful manner the international challenges on energy, development, and inequalities; addressing inequalities; global collaboration; and, beyond the European Union, the international perspectives (Di Foggia et al., 2024).

In the lines below the focus will be on the circular economy and the global impact. The circular economy is seen as extremely valuable for the planet, emphasizing resource efficiency and promoting waste reduction (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2022). What is more, the circular economy focuses on the regeneration of the natural systems and provides a framework for tackling global issues. Furthermore, it becomes essential to point out that by analyzing the European Union approach a better understanding can be shown on how the European Union model can be applied and adapted when referring to the regions' and countries' capacity to promote sustainable development and address the reduction of inequalities.

While pointing out the European Union role a leader it needs to be stressed that the countries have set very ambitious goals to become global leaders in the circular economy (Popescu & Verma, 2025b). It noteworthy that its initiatives, policies, and strategies that embrace sensible subjects, such as waste management, product design, and resource efficiency have the potential to serve as blueprint for other nations, offering valuable insights on how to successfully develop frameworks for a better and more inclusive future for all citizens.

In this day and age, Türkiye's potential to address in a successful manner the international challenges on energy, development, and inequalities becomes paramount. The strategic location and the continuously growing energy sector reflect Türkiye's potential to address international energy, development, and inequality challenges (Duháček Šebestová & Popescu, 2025a). Notwithstanding, the government and the policymakers realize that it requires the overwhelming challenges that raised over the years in terms of energy diversification, infrastructure development, and social inclusion (Popescu, 2025a).

Moving on to the next focal point, assessing inequalities is extremely important. Hence, specialists stated on numerous occasions that the transition to a circular economy can have both positive and negative implications on communities and regions. By analyzing the countries experience, such as, for example, the case of Türkiye or the situation of the European Union's regions and countries, several crucial aspects can be identified: the potential social and economic inequalities; the strategies intended to arise and develop partnerships capable to mitigate the potential social and economic inequalities; and, the shift to the circular economy (Beslin Pajila et al., 2025). An important idea is that the shift to the circular economy can have a powerful impact in the employment sector, requiring retaining and social safety nets.

Likewise, global collaboration becomes pivotal since the European Union's circular economy efforts point out the importance of international collaboration and knowledge sharing (Chawla et al., 2025). Hence, very importantly, the intention is to achieve a global transition towards sustainability. Moreover, ensuring a just and equitable transition is seen as essential when having in mind aspects such as policy coordination, financial mechanisms, and trade reform.

All in all, beyond Türkiye and beyond the European Union there are other examples that can be offered as valuable case studies, since other regions have specific context and different challenges, but the importance of the circular economy characteristics and principles are crucial, while the energy challenges are still vital. The comprehensive analysis that would go beyond Türkiye and beyond the European Union should consider, on the one hand, the unique circumstances of each region and, on the other hand, the tailored solutions that are designed for the specific traits of each region.

In the lines above the scenario described is the one in which the positive aspects specific to the relationship renewable energy, green technology innovation, and artificial intelligence (AI) are brought to light.

There is another scenario that can be introduced in this case and this time this new scenario is indicative of a financial crisis. In this scenario the situation could be as follows: sharp declines in asset prices, failures of financial institutions, and foreign exchange market shocks will influence the nexus between renewable energy, green technology innovation, and artificial intelligence (AI). What is more, all these disruptions are known to lead often to broader economic instability, generating economic and financial instability, impacting households, businesses, and governments. The sharp declines in asset prices tackle the situations in which there is a rapid decrease in the values of certain assets such as: investments, stocks, and real estate.

CONCLUSION

Firstly, renewable energy, green technology innovation, and artificial intelligence (AI) are interconnected, on the one hand, in the effort to reduce carbon dioxide emissions and, on the other hand, to achieve sustainability. It needs to be taken into account that green technology innovation enables the AI to improve the efficiency of renewable energy systems the focal point being to create and support more sustainable and resilient industrial processes. Additionally, a significant concern is shown to the process of optimizing energy grids. It is believed that AI can make a significant contribution to emissions through energy consumption in data centers, hence leading to the fact that AI represents a valuable tool for de-carbonization especially when it is applied to optimize energy usage and to promote renewable energy adoption.

Secondly, there are very powerful relationships built between the green human capital, the renewable energy consumption, and the importance of ensuring the high quality of the air and the well-being as well as the health of the citizens. The general outcome supported in this scenario is significantly reducing the carbon dioxide emissions.

This section which is dedicated to the conclusions tackles aspects related to the practical implications, the limitations, and the future lines of research.

There are several practical implications that are taken into account in the lines below and which are as follows: firstly, renewable energy and green technology innovation; secondly, AI and renewable energy; thirdly, AI and carbon dioxide emissions; and, fourthly, the interplay and synergies.

To begin with, there is a vital nexus between renewable energy and green technology innovation. Renewable energy sources, like solar, wind, and hydropower, play a key role in reducing the reliance on fossil fuels and mitigating climate change. What is more, innovation's impact is of utmost importance. In this context, green technology innovation focuses, on the one hand, on developing more efficient and cost-effective renewable energy technologies and, on the other hand, on discovering and implementing solutions able to minimize the environmental impact of various sectors while centering on the technologies that are used in the process. In this given case there are some examples that prove to be noteworthy and which make direct reference to the green technology innovation, namely: the advancements in solar panel efficiency; the changes that occurred in the wind turbine design; and, the most modern energy storage solutions (European Policy Center (EPC), 2024).

In continuation, AI and renewable energy are strongly interrelated (Jain et al., 2024). The role of AI in energy optimization is seen as pivotal. It needs to be stressed that AI algorithms are designed so that they successfully analyze vast amounts of data so that the optimization of the energy production is accomplished based on the use of renewable sources, the prediction of the energy demand, and the highly efficient management of the energy distribution (González et al., 2025b). What is more, a specific attention is paid to smart grids. Specialists show that AI-powered smart grids can seamlessly integrate renewable energy sources and, in the same time, can flawlessly balance supply and demand in real time (Geng et al., 2024). In this way, the grid stability is obtained. An important part of this process is represented by predictive maintenance. Hence, AI can predict potential failures in renewable energy infrastructure, such as, for example, solar farms or wind turbines (Ordóñez de Pablos et al., 2025). This is known for allowing proactive maintenance and minimizing the downtime.

Notwithstanding, the AI and the carbon dioxide emissions have powerful relationships. The potential for de-carbonization should be brought to light in this context. The following book chapter has shown that AI can play a significant role in reducing carbon emissions by optimizing industrial processes. Additionally, the current research emphasized that AI is centered on improving energy efficiency in buildings as well as becoming responsible for enabling the transition to electric vehicles. There are numerous challenges when discussion the nexus between the AI and the carbon dioxide emissions. One noteworthy challenge is that AI development and deployment also requires significant energy consumption. A key example in this case is represented by the data centers and the role played by AI in these data centers. A new concept started to become more and more important in the last years, namely “Green AI” (European Union External Action (EUEA), 2024). The concept of “Green AI” has major implications these days and focuses on developing AI instruments, technologies, and techniques which are intended to minimize the environmental impact.

Some of the examples that can be offered in this case are the energy-efficient algorithms and the energy-efficient hardware (Guo et al., 2024).

In the end, the interplay and synergies are very important when centering on the AI-driven green technology, the renewable energy integration, and the sustainable industrial processes (Organization for Economic Cooperation and Development (OECD), 2024). Nowadays, when addressing the AI-driven green technology it should be mentioned that AI is becoming a key part of the green technology innovation. This has as ultimate outcome to enable the development of more efficient and sustainable solutions. Moving on, the renewable energy integration centers on the idea that the AI facilitates the renewable energy integration sources into the already existing energy systems, which makes these systems more accessible and more reliable (Özgün, 2025). The ongoing importance of the sustainable industrial processes has as focal point that AI can optimize industrial processes. The ultimate goal in this case is to reduce energy consumption and to minimize waste. Likewise, by reducing energy consumption and by minimizing waste a significant contribution is made to a more circular and sustainable economy.

There are various recommendations that require a keen interest. First of all, strengthen industrial policy: incentivizing sustainable practices and supporting sustainable practices represent a must these days since these have the power to support further development of industrial policies. Second of all, promote digitalization for sustainability: enhancing environmental sustainability and addressing resource management are essential about levering digital technologies. Third of all, enhance stakeholder engagement: achieving sustainable development can be ensured with the involvement of all stakeholders, including the private sector, the civil society, and academia.

These precious recommendations display the implications of prioritizing sustainable development alongside technological advancement. In this way, Türkiye can ensure that the progress that is done is inclusive, shows that is has the vital components of environmental responsibility, and is beneficial to all citizens.

There are several limitations of this book chapter. The accent is placed on sustainable development but although the emphasis is placed on sustainable development the areas specific to this topic should be even more analyzed and detailed. In the case of environmental sustainability in Türkiye it would be extremely interesting to address the “zero waste” practices, the sustainable water management benefits, and the energy efficiency continuous challenges. Also, climate action in Türkiye is of great interest nowadays, which means that a particular accent ought to be placed on reducing deforestation, focusing on afforestation, and using the most modern advancements in technology to combat forest fires.

One future line of research could be pursuing the Sustainable Development Goals (SDGs) while analyzing the case of Türkiye over the last years, while addressing industry and technology as accelerators of progress. Another major line of research is represented by the benefits and the challenges of digitalization to achieve the Sustainable Development Goals (SDGs). Also, of great interest would be to adapt some characteristics of the Global Goals to the current situation of tourism in Türkiye.

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CHAPTER 7

ENERGY SECURITY IN THE AGE OF DECARBONIZATION

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INTRODUCTION

Energy security, traditionally defined as the uninterrupted availability of energy sources at an affordable price, is undergoing a profound transformation in the context of global decarbonization efforts. As nations strive to mitigate climate change by reducing greenhouse gas emissions, the integration of renewable energy sources, enhancement of energy efficiency, and adoption of innovative technologies are reshaping the landscape of energy security. This chapter explores the evolving nexus between energy security and decarbonization, examining the challenges and opportunities that arise in this transition (IEA, 2021; Sovacool and Ryan, 2020; Cherp and Jewell, 2014; UNFCC, 2015; IPCC, 2022).

This transformation also necessitates a broader and more dynamic understanding of energy security—one that incorporates environmental sustainability, technological resilience, and social equity. While traditional energy systems prioritized stability through centralized fossil fuel infrastructure, modern decarbonized systems rely increasingly on variable renewable sources like wind and solar, which introduce new concerns related to intermittency, storage, and grid stability. Moreover, the transition poses geopolitical implications, as the global shift toward clean energy technologies redistributes strategic importance from oil and gas resources to critical minerals such as lithium, cobalt, and rare earth elements. Ensuring secure, ethical, and diversified supply chains for these materials becomes essential in a low-carbon future, highlighting the need for integrated policy approaches that balance security, sustainability, and justice (Bazilian et al., 2018).

Historically, energy security focused on the reliability of fossil fuel supplies, geopolitical stability, and the resilience of energy infrastructure (Yergin, 2006; Chester, 2010). Key concerns included the stability of oil-producing regions, the security of supply chains, and the affordability of energy prices (IEA, 2014; Kruyt et al., 2009).

However, the traditional fossil fuel-centric model of energy security is increasingly inadequate in addressing the multifaceted risks of the 21st century. Climate-induced disruptions such as extreme weather events, heatwaves, floods, and wildfires, now pose significant threats to the reliability of energy infrastructure, particularly centralized fossil fuel systems that lack flexibility and redundancy (Sovacool, 2020).The vulnerability of power grids to climate change impacts has prompted a reevaluation of system resilience and adaptive capacity. Furthermore, continued reliance on fossil fuels exposes economies to the volatility of global energy markets, which are often subject to price shocks driven by geopolitical tensions, trade disputes, and supply chain disruptions—as witnessed during the Russia-Ukraine conflict and the COVID-19 pandemic. As global priorities increasingly align with climate goals, energy security is being reconceptualized to include not only availability and affordability but also sustainability, equity, and technological resilience (Cherp et al., 2014; IPCC, 2022). This includes diversifying energy portfolios through renewable integration, enhancing grid flexibility with smart technologies, and building decentralized, community-based energy systems that are more adaptive to local needs and less vulnerable to centralized failure (IRENA, 2021). The modern understanding of energy security thus reflects a broader paradigm shift, where secure energy systems are not only reliable and cost-effective, but also low-carbon, inclusive, and robust in the face of both environmental and geopolitical uncertainty.

1. DECARBONIZATION AND NEW DIMENSIONS

The shift towards decarbonization introduces new dimensions to energy security, fundamentally reshaping how nations assess and manage risks in the energy sector. While traditional concerns focused on securing fossil fuel supplies and maintaining infrastructure resilience, decarbonization adds layers of complexity related to the variability of renewable energy sources, the need for advanced storage technologies, and the growing dependence on critical minerals essential for clean energy systems (IEA, 2021). Solar and wind power, though abundant and low carbon, are inherently intermittent, requiring investments in grid modernization, flexible demand systems, and backup capacities to ensure reliability.

Moreover, the global energy transition shifts strategic focus from oil and gas to minerals such as lithium, cobalt, nickel, and rare earth elements, many of which are geographically concentrated in politically or environmentally sensitive regions (World Bank, 2020). This introduces new supply chain vulnerabilities and geopolitical dynamics, necessitating comprehensive strategies for resource diversification, ethical sourcing, and international cooperation. At the same time, decarbonization brings opportunities to enhance energy sovereignty through local renewable production, reduce exposure to fossil fuel price volatility, and foster innovation in clean technologies. Ultimately, the intersection of decarbonization and energy security calls for integrated policies that address climate goals while ensuring system resilience, economic stability, and social inclusiveness (Bazilian et al., 2011; Cherp et al., 2018; IPCC, 2022).

As countries advance their decarbonization agendas, energy security is being redefined through a broader and more integrated lens that encompasses technological, economic, and infrastructural dimensions. Rather than relying on a narrow focus on fossil fuel availability, contemporary strategies increasingly emphasize the need for diversified energy systems, resilient power infrastructure, and sustainable economic development. These elements are not only essential for achieving climate targets but also for enhancing national autonomy, minimizing supply disruptions, and fostering long-term economic stability. The transition to a low-carbon energy system offers a unique opportunity to strengthen energy security through multiple, interrelated pathways, including supply diversification, grid reliability, and economic resilience.

Below the supply diversification, grid reliability, and economic resilience definitions are presented.

- Supply Diversification: Transitioning from fossil fuels to renewable sources like solar, wind, and hydropower reduces dependence on imported fuels.
- Grid Reliability: Integrating variable renewable energy sources necessitates advancements in grid infrastructure and energy storage solutions.
- Economic Resilience: Investing in clean energy technologies can stimulate economic growth and reduce exposure to volatile fossil fuel markets.

As the global energy landscape evolves, countries are increasingly shifting from fossil fuels to renewable energy sources. This transition, while essential for achieving climate goals, also introduces new challenges related to resource availability and trade. Figure 1 illustrates regional shifts in energy-security-related trade risks as economies transition to renewable sources. The figure highlights evolving dependencies on materials vital for clean energy (solar, wind, batteries, etc.). It also shows how supply dynamics change under net-zero pathways, impacting grid reliability and economic resilience.

Table 1 shows the dimensions and illustrated insights derived from the analysis of energy security in the context of the clean energy transition. It breaks down key factors such as resource availability, trade dependencies, geopolitical exposure, and supply chain resilience. The table also provides regional comparisons, highlighting where vulnerabilities or strengths lie across different economies. These insights are critical for policymakers and industry leaders as they plan for a secure and stable transition to net-zero energy systems.

Table 1: Dimension – illustration insight

Dimension	Illustrated Insights
Supply Diversification	Figure 1 shows how decreasing fossil fuel reliance shifts import risks toward clean-tech materials, underscoring the need for diverse renewable supply chains.
Grid Reliability	Integrating renewables alters import patterns, signaling evolving infrastructure needs for system stability.
Economic Resilience	Transition-induced trade shifts reflect economic adjustments, new dependencies and investment avenues in clean energy value chains.

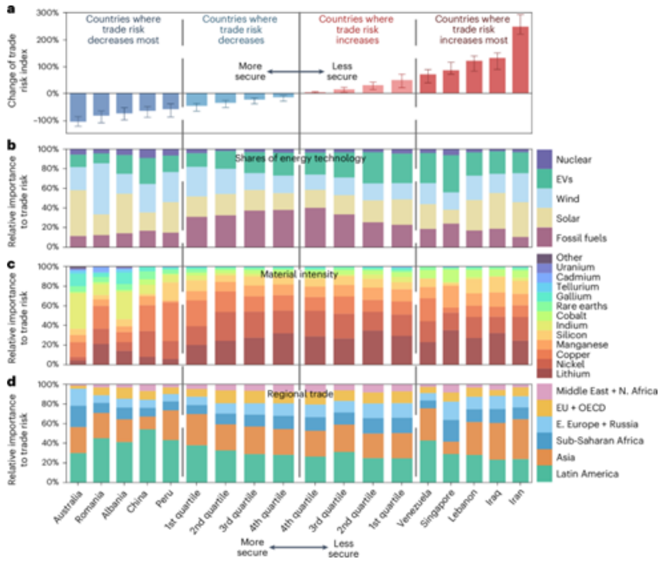

Figure 1: Shift in energy security (Cheng, et al., 2025)

2. CHALLENGES IN ACHIEVING ENERGY SECURITY AMID DECARBONIZATION

Achieving energy security amid decarbonization presents a complex set of challenges, as nations and industries work to transition away from fossil fuels while ensuring reliable, affordable, and accessible energy. Renewable energy sources such as wind and solar, while essential to reducing emissions, are inherently variable and require robust grid infrastructure, energy storage solutions, and smart technologies to maintain stability. Additionally, the shift places pressure on existing supply chains for critical minerals needed for clean energy technologies, raising concerns about geopolitical dependencies. Balancing the pace of decarbonization with the need for uninterrupted energy supply demands careful policy planning, substantial investment, and cross sector collaboration to avoid shortfalls and ensure a just and resilient energy transition.

Intermittency and Reliability

Renewable energy sources such as solar and wind are inherently intermittent, as their output depends on weather and time-of-day conditions. This variability can lead to fluctuations in power supply, making it challenging to maintain grid stability and meet constant demand (IEA, 2023). As the share of renewables in the energy mix increases, addressing intermittency becomes critical for ensuring a secure and reliable electricity system.

To manage this challenge, countries are investing in advanced energy storage technologies, including lithium-ion batteries, pumped hydro storage, and emerging solutions like green hydrogen. These systems store excess energy during periods of high generation and release it when supply is low, helping to balance the grid and reduce curtailment (IRENA, 2022).

In addition to storage, flexible grid management strategies—such as demand-side response, real-time data monitoring, and smart grid technologies are essential. These enable utilities to dynamically adjust electricity flow, integrate distributed energy resources, and forecast generation patterns with greater accuracy (World Bank, 2020).

Diversifying the energy mix, expanding regional interconnections, and enhancing forecasting tools also contribute to grid resilience. Ultimately, a combination of technological innovation and regulatory support is needed to ensure that renewable energy systems remain both sustainable and dependable.

Infrastructure Overhaul

Decarbonization depends on coherent policies and regulations that drive investment in clean energy, support energy efficiency, and ensure fair access to energy. These frameworks reduce market uncertainty and help scale low-carbon technologies through tools like carbon pricing, tax incentives, and renewable energy targets (IEA, 2023, Afaq, et al.2024).

Equity and inclusiveness are also critical. Policies must address energy poverty, ensure a fair distribution of benefits, and support communities affected by the transition away from fossil fuels (UNFCCC, 2022).

Effective coordination across government agencies, industry, and civil society is key to avoiding policy gaps and ensuring smooth implementation. Strong institutions and clear regulations help build investor confidence and enable innovation (IRENA, 2022).

As shown in Figure 2, robust governance is essential. Table 2 summarizes major energy challenges during decarbonization, many of which stem from weak or fragmented policy frameworks.

Policy and Regulatory Frameworks

Effective decarbonization requires coherent policies and regulations that incentivize investment in clean energy, promote energy efficiency, and ensure equitable access to energy. This necessitates coordinated efforts across governments, industries, and communities (see Figure 2).

Table 2 summarizes the challenges to energy during decarbonization.

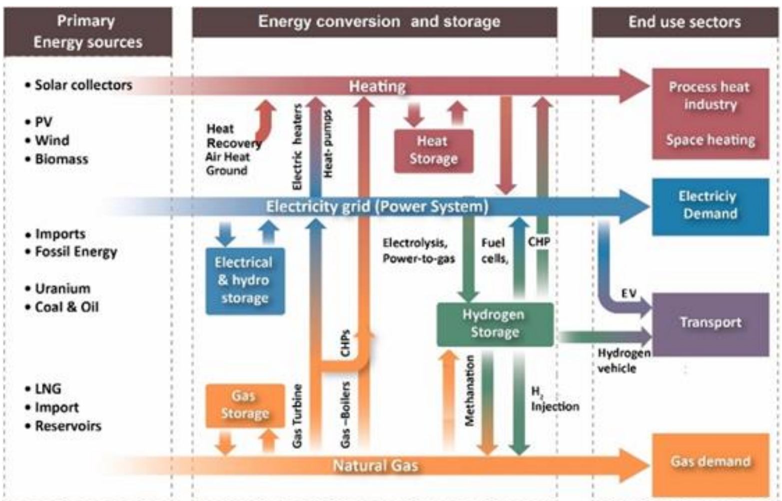

Figure 2: Energy framework

Table 1: Key Challenges to Energy Security During Decarbonization

Challenge	Description	Potential Solutions
Intermittency & Reliability	Variability in solar and wind energy output affects grid stability.	Energy storage systems, demand response, smart grids
Infrastructure Overhaul	Outdated infrastructure not suited for decentralized renewables.	Upgrading transmission networks, smart grid tech
Policy & Regulation	Inconsistent or unclear frameworks can hinder clean energy adoption.	Coherent policies, investment incentives, coordination

3. OPPORTUNITIES RESENTED BY DECARBONIZATION

Decarbonization presents significant opportunities for innovation, economic growth, and long-term sustainability across industries. As governments and consumers increasingly prioritize low-carbon solutions, businesses that invest in clean technologies, renewable energy, and energy-efficient processes can gain a competitive edge and access new markets. Decarbonization also drives job creation in emerging sectors such as green infrastructure, electric mobility, and carbon capture. Additionally, it offers organizations the chance to strengthen their Environmental, Social, and Governance (ESG) performance, enhance brand reputation, and build resilience against regulatory and climate-related risks. Embracing decarbonization is not just an environmental imperative it is a strategic advantage in the transition to a net zero future.

Enhanced Energy Access

Distributed renewable energy systems such as solar home systems, mini-grids, and micro-hydro offer practical solutions for providing reliable power to remote and underserved areas. These systems are often more affordable and faster to deploy than centralized grid extensions, especially in rural or hard-to-reach regions (IEA, 2022).

Improved energy access supports essential services such as healthcare, education, and water supply, while also enabling small businesses and productive uses like agricultural processing. This contributes to local development and poverty reduction, particularly when systems are designed with community input and tailored to local needs (UN DESA, 2021).

In sub-Saharan Africa and South Asia, decentralized renewables have become a key driver of electrification, accounting for most new connections in some areas (IRENA, 2022). Advances in digital tools like pay-as-you-go models and remote monitoring are enhancing affordability, reliability, and user engagement.

Thus, distributed renewables are not only a solution for energy access, but a foundation for inclusive and resilient development.

Economic Diversification

Investments in renewable energy technologies can create new industries and job opportunities, contributing to economic diversification and resilience. As countries seek to reduce their dependence on fossil fuels, particularly oil and gas, renewable energy development presents a strategic opportunity to broaden the economic base and stimulate innovation driven growth.

The renewable energy sector encompasses a wide range of technologies, including solar Photovoltaics (PV), wind, green hydrogen, biomass, and energy storage, each supporting diverse value chains that require skilled labor, engineering expertise, manufacturing capabilities, and supporting services (IRENA, 2023). This enables the emergence of new sectors and Small and Medium-sized Enterprises (SMEs), particularly in construction, maintenance, smart grid technologies, and energy efficiency services.

In regions historically dependent on extractive industries, such as many oil-exporting economies, renewables offer a pathway to reduce vulnerability to oil price volatility and enhance economic stability. For example, solar and wind projects can create more stable, long-term employment opportunities compared to the cyclical nature of fossil fuel extraction (UNDP, 2022). Additionally, integrating local content requirements into renewable energy procurement strategies can foster domestic manufacturing and skill development.

Beyond job creation, renewable energy investment can attract Foreign Direct Investment (FDI), increase energy exports (e.g., through green hydrogen), and improve trade balances by reducing fossil fuel imports. It also opens pathways for cross-sector innovation, such as clean technology development, battery manufacturing, and digital energy platforms that support the broader digital economy (World Bank, 2020).

Moreover, by embedding renewables within national development strategies, countries can align economic diversification with climate goals, creating a mutually reinforcing cycle of low carbon growth and sustainable development. As such, renewable energy is not just an environmental imperative but also a pillar of forward-looking industrial policy.

Environmental and Health Benefits

Reducing reliance on fossil fuels plays a critical role in mitigating air pollution and lowering greenhouse gas emissions, both of which have significant positive impacts on public health and environmental sustainability. The combustion of fossil fuels releases pollutants such as particulate matter (PM2.5), Nitrogen Oxides (NO2), Sulfur Dioxide (SO2), and Volatile Organic Compounds (VOCs), which contribute to respiratory and cardiovascular diseases, premature deaths, and other health issues (WHO, 2018). Transitioning to cleaner energy sources significantly reduces these harmful emissions, improving air quality and thereby decreasing the incidence of asthma, lung cancer, heart disease, and stroke (Landrigan et al., 2018).

Moreover, reducing greenhouse gas emissions is essential for combating climate change, which itself poses direct and indirect health risks including heat related illnesses, vector-borne diseases, food and water insecurity (Ebi et al., 2021). By decarbonizing energy systems, countries contribute to global climate stabilization, protecting ecosystems and biodiversity, which in turn supports human wellbeing (IPCC, 2022, Afaq, et al. 2025).

Environmental benefits also extend to reduced acid rain, improved soil and water quality, and preservation of natural habitats, which are often degraded by fossil fuel extraction and combustion (UNEP, 2020). These benefits enhance ecosystem services such as clean water provision, pollination, and carbon sequestration.

Table2 summarizes the wide-ranging opportunities presented by decarbonization, illustrating how integrated efforts to reduce fossil fuel dependency translate into measurable gains for both environmental integrity and public health outcomes.

Table 2: Opportunities presented by decarbonization

Opportunity	Description
Enhanced Energy Access	Distributed renewable energy systems can provide reliable electricity to remote and underserved regions, fostering local development and energy equity.
Economic Diversification	Renewable energy investments can generate employment, stimulate innovation, and support the creation of new industries, enhancing economic resilience.
Environmental and Health Benefits	Transitioning away from fossil fuels reduces greenhouse gas emissions and air pollutants, contributing to better health and environmental sustainability.

4. CASE STUDIES

Oman is making significant strides in renewable energy development as part of its broader strategy to diversify the national energy portfolio and reduce dependency on fossil fuels. Key projects such as the Miraah Solar Plant, the world's largest solar thermal project integrated with enhanced oil recovery, and the Dhofar Wind Power Project highlight the country's commitment to leveraging its abundant solar and wind resources (Al-Wahaibi and Al Busaidi, K. A., 2023; PDO, 2021).

The Miraah project utilizes Concentrated Solar Power (CSP) technology to generate steam, which is then used in oil extraction, reducing the carbon footprint of traditional hydrocarbon production. Meanwhile, the Dhofar Wind Power Project taps into Oman's coastal wind corridors, providing clean electricity to the grid and enhancing energy security in the southern regions (Madsar, 2022). These flagship initiatives demonstrate Oman's innovative approach to integrating renewables with existing energy infrastructure.

Aligned with Oman's Vision 2040, the country has set ambitious targets to increase renewable energy's share to 50% of its energy mix by 2040, supporting climate action and sustainable development goals (OPWP, 2023). This objective is supported by policy frameworks encouraging public-private partnerships, capacity building, and research and development in clean energy technologies.

Beyond large-scale projects, Oman is also exploring decentralized and off-grid renewable solutions to improve rural electrification and reduce reliance on diesel generators. The government's strategy includes fostering regulatory reforms that simplify permitting processes and provide financial incentives for renewable investments.

Table 2 summarizes some of the key energy projects currently underway in Oman, highlighting their capacity, technology type, and expected contribution to the national grid. Collectively, these efforts position Oman as a regional leader in the Middle East's renewable energy transition.

Table 2: Key Renewable Energy Projects in Oman

Project Name	Technology	Capacity	Purpose
Miraah Solar Plant	Concentrated Solar Power (CSP)	1,021 MW (thermal)	Used for steam generation in enhanced oil recovery (EOR)
Dhofar Wind Power Project	Onshore Wind	50 MW	The first large-scale wind farm in the GCC; supports local grid.
Ibri II Solar Project	Photovoltaic (PV)	500 MW	Supplies clean electricity to the grid; supports national energy goals.

5. STRATEGIC PATHWAYS FORWARD

Strategic pathways forward involve identifying clear, actionable steps that align with an organization's long-term vision while adapting to evolving market conditions and emerging challenges. This process requires a comprehensive analysis of internal capabilities, external opportunities, and potential risks to ensure decisions are both informed and forward thinking. Key elements include setting measurable goals, fostering innovation, investing in talent and technology, and maintaining agility to pivot when necessary. Ultimately, a successful strategic pathway should position the organization for sustainable growth, resilience, and competitive advantage in a rapidly changing environment.

5.1 Integrated Energy Planning

Developing integrated energy plans that consider the full spectrum of energy sources, infrastructure needs, and policy frameworks is essential for achieving sustainable energy security (see Table 3). Integrated planning enables the coordination of diverse energy sectors—electricity, heating and cooling, transport, and industry—into a cohesive strategy that addresses both current demand and future resilience (IEA, 2021).

Such planning must align operational priorities with long-term decarbonization goals, ensuring that infrastructure investments are both efficient and compatible with net-zero pathways (IRENA, 2022).

This involves comprehensive scenario modeling that takes into account renewable energy integration, storage capabilities, grid flexibility, and evolving consumption patterns (World Bank, 2020). It also requires the harmonization of regulatory and policy frameworks to support innovation, attract investment, and promote equitable energy access (UN ESCAP, 2023).

Stakeholder collaboration is a foundational element of successful integrated energy planning. Governments, utilities, regulators, private sector actors, and community organizations must work together to develop context-specific plans that reflect regional characteristics and social priorities (REN21, 2023). Local engagement not only enhances legitimacy but also helps identify feasible solutions based on local resources and capabilities.

Moreover, digital tools such as Geographic Information Systems (GIS), big data analytics, and integrated energy system models enhance the planning process by enabling real-time data analysis, predictive scenario testing, and performance tracking (IEA, 2023). These tools are especially important in navigating uncertainties related to climate change, geopolitical disruptions, and market volatility.

Ultimately, integrated energy planning is a critical enabler of sustainable energy transitions. It supports the deployment of clean energy technologies, improves system reliability, and strengthens energy security in a rapidly changing global environment.

5.2 Investment in Research and Development

Continued investment in Research and Development (R&D) is crucial to advance energy storage technologies, improve grid management systems, and reduce the costs of renewable energy technologies. Strategic R&D funding not only fosters innovation but also accelerates the deployment of sustainable energy solutions on a scale.

In the realm of energy storage, breakthroughs in battery chemistry, such as solid-state batteries or next-generation lithium-sulfur technologies, hold the potential to drastically enhance storage capacity, safety, and lifespan. These advancements are vital for addressing the intermittency of renewable energy sources like solar and wind. Equally important is R&D focused on alternative storage systems, including pumped hydro, hydrogen storage, and thermal energy storage, which can provide scalable and long-duration solutions.

Grid management systems also require continuous innovation. As the penetration of Distributed Energy Resources (DERs) increases, smart grid technologies must evolve to ensure reliable and resilient operation. Investments in artificial intelligence, real-time data analytics, and advanced forecasting tools can enable dynamic grid balancing, better demand-side management, and faster response to outages or fluctuations in supply and demand.

Moreover, reducing the costs of renewable energy technologies through R&D is key to expanding their adoption globally. This includes improving the efficiency of photovoltaic cells, optimizing wind turbine designs, and advancing manufacturing processes to lower production costs. Research into materials science, automation, and circular economy principles can further enhance the sustainability and affordability of clean energy systems.

Public-private partnerships, international collaboration, and targeted government incentives can amplify the impact of R&D initiatives. By prioritizing innovation and supporting a robust pipeline of research activities, stakeholders can accelerate the transition to a low carbon energy future, stimulate economic growth, and create high-quality jobs in the green technology sector.

5.3 International Collaboration

Global cooperation is vital to share knowledge, harmonize standards, and mobilize financing for clean energy projects, particularly in developing countries. As the energy transition accelerates, no single country can tackle the multifaceted challenges of decarbonization and energy security in isolation. International collaboration enables the transfer of best practices, facilitates the development of interoperable technologies, and ensures that all regions, especially those most vulnerable to climate impacts can access the technical and financial resources needed for sustainable development (IEA, 2021).

Multilateral institutions such as the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), and the United Nations Framework Convention on Climate Change (UNFCCC) play crucial roles in fostering dialogue, setting global benchmarks, and supporting capacity-building efforts (IRENA, 2023). Joint initiatives like Mission Innovation and the Clean Energy Ministerial have been instrumental in advancing public-private partnerships, promoting research collaboration, and deploying large-scale clean energy projects across borders (Clean Energy Ministerial, 2022).

Furthermore, coordinated policy frameworks and international agreements, most notably the Paris Agreement, create a shared vision and accountability mechanisms that guide national actions toward global climate goals. They also support the establishment of carbon pricing, climate finance mechanisms, and green technology transfer platforms, which are essential to achieving equitable decarbonization (UNFCCC, 2021).

International financial institutions, including the World Bank, the Green Climate Fund, and various regional development banks, are pivotal in mobilizing capital for renewable infrastructure and energy access programs in low-income countries. Their involvement not only reduces investment risks but also attracts private capital by improving project bankability and ensuring regulatory stability (World Bank, 2022).

Figure 3 provides global data illustrating disparities in clean energy investment across regions, highlighting the persistent gap between high-income and developing economies. This underscores the urgent need for enhanced international support, especially in the form of concessional financing, technical cooperation, and investment in local capacity building.

Ultimately, international collaboration strengthens global energy security, accelerates innovation, and ensures that the benefits of the clean energy transition are widely and fairly and distributed. Without such cooperation, the global community risks fragmented progress, increased geopolitical tensions, and failure to meet critical climate targets (WEF, 2022)

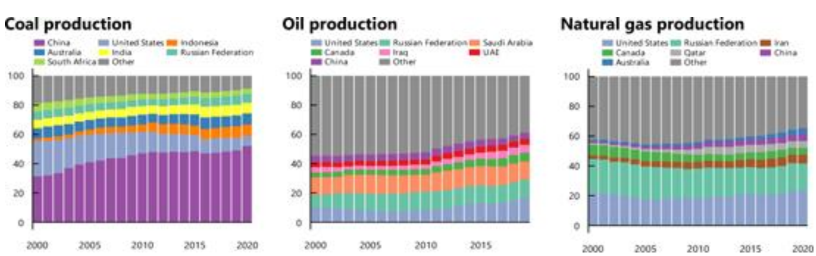

Figure 3: Some global data

Table 3: Strategic pathway

Strategic Pathway	Key Objectives	Core Measures	Energy Security Impact
Efficiency & Demand Management	Reduce energy intensity	Building retrofit, transport modal shift, industry process optimization	Lower fuel dependency, enhanced supply resilience
Electrification + Renewables	Shift end-use to clean electricity	Grid expansion, heat pumps, EVs, renewables deployment	Diversifies supply; reduces import reliance
Low-Carbon Fuels & CCUS	Decarbonize hard-to-electrify sectors	Hydrogen (blue/green), CCS in steel/chemicals	Improves domestic supply; mitigates import risk
Diversification & Minerals	Ensure critical metal supply & storage	Scaling battery and hydrogen storage, relying on diversified mineral sourcing	Secures key transition inputs
Resilience Planning	Manage disruptions & slow-burn threats	Policy buffers, strategic stocks, grid resilience frameworks	Enhances robustness to shocks

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CONCLUSION

The intersection of energy security and decarbonization presents both challenges and opportunities. By embracing innovative technologies, fostering collaborative efforts, and implementing forward thinking policies, nations can navigate the complexities of this transition and build a resilient, sustainable future of energy. This dual pursuit not only addresses the urgent need to reduce greenhouse gas emissions but also strengthens the reliability and independence of national energy systems. Achieving this balance requires a coordinated approach, where governments, industries, and communities work together to accelerate clean energy deployment, invest in grid modernization, and ensure equitable access to resources. Moreover, strategic planning and international cooperation can mitigate risks associated with supply chain disruptions and geopolitical tensions. Ultimately, the successful integration of energy security and decarbonization goals will define the global energy landscape for decades to come, shaping a future that is both environmentally responsible and economically robust.

Building on this foundation it is essential to recognize the role of technological innovation in bridging the gap between energy security and decarburization. Advancements in energy storage, smart grid systems, hydrogen technologies, and CCS are critical enablers that can enhance system flexibility and reliability while reducing emissions. These technologies not only support the integration of variable renewable energy sources, such as solar and wind, but also provide alternative pathways for hard-to-decarbonize sectors like heavy industry and long-haul transportation.

Equally important is the need to reform market structures and regulatory frameworks to encourage investment in sustainable energy infrastructure. Clear policy signals, stable incentives, and transparent regulatory environments can attract private sector participation and unlock capital for clean energy projects. In particular, aligning financial flows with climate goals—through green bonds, climate risk disclosure, and sustainable finance regulations—can catalyze large-scale transitions without compromising economic competitiveness.

Social inclusion must also remain at the heart of this transformation. As energy systems evolve, policymakers must ensure that all populations are inclusive, including supporting workforce due to transitions from fossil fuel industries to green jobs, promoting energy affordability, and engaging local communities in decision-making processes. A just and inclusive transition will not only strengthen public support but also enhance the resilience and legitimacy of energy reforms.

In summary, the journey toward a secure and decarbonized energy future is multifaceted and dynamic. It demands integrated solutions that transcend traditional boundaries between sectors, nations, and societal groups. With sustained commitment, informed leadership, and global solidarity, the world can rise to this challenge and seize the immense opportunities of a low carbon energy era.

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CHAPTER 8

GREEN ENERGY POLICIES IN ROMANIA – ECOLOGICAL EDUCATION

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INTRODUCTION

In the context of the global climate crisis and the need to reduce greenhouse gas emissions, Romania is aligning itself with European strategies regarding the transition to green energy sources. These policies aim at a sustainable future, and the key to their success is not only technological implementation, but also the environmental education of citizens. An informed society is a society capable of sustaining and accelerating the changes necessary to protect the environment, (Wang et al., 2025).

Romania's energy potential is undeniable due to the diversified resources available to our country. At the same time, the investments in recent years in the production of energy from renewable sources, the start of the exploitation of gas in the Black Sea, as well as the plans to expand the nuclear energy production capacity strengthen Romania's position as an important player in the region.

Currently, electricity production in our country is mainly based on hydropower resources (about a third), nuclear energy (20%), gas, coal and wind energy (about 15% each). Therefore, a diversified energy mix compatible with the climate objectives assumed at European level.

Investments in recent years in renewable electricity generation capacities demonstrate Romania's commitment to sustainability goals and are expected to continue. Our country currently has a renewable energy production capacity installed in the national energy system of 11.8 GW, of which 6.4 GW (55%) in hydroelectric capacities, 3.1 GW (26%) in wind capacities and 2.1 GW (18%) in solar capacities. The intensification of investments in storage capacities is also noteworthy. The electricity storage capacity installed in the national energy system is currently 138 MW, with a need of 2 GW by 2030, according to official estimates.

Romania's plans to continue investments in nuclear energy through strategic projects estimated at over 12 billion euros by 2030, including the refurbishment of unit 1 of the Cernavoda plant and the commissioning of units 3 and 4, also have an important role in supporting our country's objectives of ensuring energy security at national level, but also regionally. The two new reactors will add up to an additional nuclear capacity installed in the national energy system of 1.4 GW. At the same time, Romania is the leader in natural gas production at regional level, currently having the lowest degree of dependence on imports, around 5%, compared to the European Union average of about 89%. Romania became the largest natural gas producer in the European Union for the first time in the second quarter of 2024 (2.3 billion cubic meters), followed by the Netherlands (2.2 billion cubic meters) and Germany (0.9 billion cubic meters). The start of the development phase of the Domino and Pelican Sud commercial natural gas fields, within the Neptun Deep project, an estimated investment of four billion euros, will ensure an estimated volume of natural gas of 100 billion cubic meters. This project will strengthen Romania's position as the largest natural gas producer in the European Union and will contribute to energy security and independence at national and regional level, (E.ON Romania, 2021).

1. ENVIRONMENTAL EDUCATION – THE FOUNDATION FOR THE TRANSITION TO A GREEN ECONOMY

In the current context of the energy transition and the intensification of global efforts to combat climate change, environmental education becomes an essential pillar for building a conscious, responsible society capable of supporting sustainable development policies. In Romania, the importance of environmental education is increasingly recognized in national green energy strategies, but its application often remains fragmented and insufficiently integrated into public policies, ((Bucuroiu) et al., 2024). Figure 1 shows the role of environmental education in supporting the sustainable energy transition.

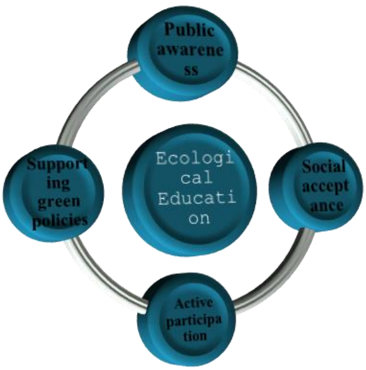

Figure 1. The role of environmental education in supporting sustainable energy transition

Environmental education is not limited to transmitting information about environmental issues, but aims to form attitudes, values and behaviors aimed at protecting natural resources, reducing conventional energy consumption and promoting sustainable alternatives. It must start from pre-university education and continue through vocational training programs and awareness campaigns aimed at adults, consumers, decision-makers and economic operators, (Canuta (Bucuroiu) & Ioana, 2024).

In particular, in the context of the development of renewable energy policies, environmental education plays a strategic role in facilitating the social acceptance of green projects – such as photovoltaic parks, wind farms or new energy storage technologies, (Ioana et al., 2021). Properly informing the population contributes to combating disinformation, reducing local opposition to investments in green infrastructure and actively involving citizens, including through their role as prosumers or members of energy communities.

In addition, an environmentally educated society is better prepared to adopt responsible consumption practices, understand the impact of carbon emissions and support ambitious public policies for decarbonization, (Hryhorash et al., 2020). Therefore, the integration of environmental education into the national energy transition strategy should not be seen as a secondary element, but as a necessary condition for the long-term success of the structural transformation process of the economy, (Ioana et al., 2021).

In Romania, initiatives in the field exist, but they are dispersed and often lacking continuity. A systemic approach is needed, which includes environmental education in the national curricula in an applied way, but also in energy, environmental and regional development strategies. Only by cultivating an authentic organic culture, supported by coherent policies and adequate resources, can Romania strengthen its transition to a green, resilient and inclusive economy.

2. THE STRUCTURE AND DYNAMICS OF ELECTRICITY PRODUCTION IN ROMANIA: AN ANALYSIS OF THE ENERGY MIX

In the last two decades, Romania's energy mix has undergone significant transformations, as a result of the modernization processes of the electricity system and the alignment with European decarbonization policies. From an almost total dependence on conventional sources – coal and hydrocarbons – Romania has gradually moved to diversify its production portfolio, including renewable sources such as wind, solar and biomass. The current structure reflects this balance in transition.

Renewables have come to generate more than 50% of the electricity produced at a representative time, with hydropower still dominating, followed by solar and wind power. However, conventional sources (coal, natural gas) continue to provide significant base capacity, being used in particular to cover peak loads or in weather conditions unfavorable to renewable production. Nuclear energy, with a relatively constant contribution of around 10–15%, plays a stabilizing role, providing predictable output and low emissions.

This dynamic is influenced by economic, political and technological factors. On the one hand, the phased closure of coal-fired capacities, for environmental and economic efficiency reasons, led to an increase in the share of renewables. On the other hand, the lack of energy storage solutions and the limitations of grid infrastructure put pressure on the efficient integration of intermittent generation.

Therefore, the current structure of energy production not only reflects a technical reality, but also an ongoing transition process. This shift requires constant investment in the development of new capacities, digitalization, increased flexibility and, crucially, in storage systems that ensure the balance between production and consumption in a decarbonized and secure energy system. Romania benefits from an important potential in the field of renewable energy, due to the diversity of geographical characteristics and the favorable climate.

Solar Energy

In the context of growing concerns about climate change and environmental protection, solar energy is emerging as a viable and environmentally friendly solution to cover our energy needs. Being a renewable source, it offers numerous advantages from the perspective of sustainability and reduction of environmental impact.

Considered one of the cleanest and most abundant forms of green energy, solar energy can be harnessed by capturing solar radiation and converting it into electricity or heat, without greenhouse gas emissions or air pollutants.

Current technologies, such as photovoltaic panels and solar thermal panels, are becoming more and more efficient and accessible, facilitating the widespread use of this resource. Every day, the Earth receives an enormous amount of solar radiation, and solar technology allows us to convert it into a useful and sustainable form of energy.

The figure below symbolizes the global transition to sustainable energy sources, through the use of solar and wind energy, as essential pillars of sustainable development.

Figure 2. Symbol of the transition to clean energy: the harmony between nature and technology (Soleos Solar Energy, 2024)

Solar energy is an innovative solution for meeting our energy needs, protecting the environment and combating climate change. As a renewable energy source, solar energy has multiple benefits, including reducing greenhouse gas emissions, using an inexhaustible resource, increasing technological efficiency, flexibility and accessibility in various geographical areas, as well as creating jobs in the green industry. It is essential that we continue to invest in solar technology and promote its adoption in an effort to build a future that is more beneficial for us, but also for future generations, (Pourasl et al., 2023).

Aeolian Energy

Aeolian energy offers a sustainable and efficient way to meet modern energy demands. It harnesses the natural movement of air to generate electricity, using turbines that transform wind's kinetic energy into power. This clean and renewable resource has significant potential, especially in areas where wind conditions are favorable year-round.

As a green energy source, wind power plays a key role in reducing environmental impact and promoting a more sustainable future. Wind is an unlimited natural asset, unlike fossil fuels, and the process of converting wind into electricity involves no greenhouse gas emissions.

Over recent decades, wind technology has progressed considerably, leading to more reliable and cost-effective energy systems. Aeolian turbines are built to endure various weather conditions and can operate efficiently over long periods—typically 20 to 25 years—with relatively low maintenance costs.

Aeolian farms can also be integrated into agricultural or rural landscapes, enabling a dual use of land. Local communities often benefit economically, as landowners can lease space for turbines while continuing agricultural activities, (Gheorghe, 2009).

Hydropower

Hydropower is one of the oldest and most widely implemented renewable energy sources. It captures the energy of flowing water—such as rivers or waterfalls—to generate electricity, offering a clean alternative to conventional power generation and contributing to climate change mitigation.
Hydroelectric energy is especially effective in regions rich in water resources. Beyond generating electricity, it also serves purposes like irrigation and flood control. One of its major environmental benefits is the absence of carbon emissions during operation, unlike fossil fuel-based power plants.

Moreover, hydropower systems are highly flexible. Since the flow of water can be regulated, these plants can be activated or shut down swiftly, responding efficiently to fluctuations in electricity demand. This makes hydropower an excellent companion to variable renewable sources like wind and solar, helping to stabilize the energy grid and even support energy storage solutions, (Killingtveit, 2020).

Biomass Energy

As the most widespread renewable resource on the planet, biomass comprises all organic matter resulting from the metabolic processes of living organisms. Throughout human history, biomass has been one of the first sources of energy used. The use of energy from biomass helps reduce dependence on fossil fuels and capitalizes on organic waste, turning it into a useful and renewable resource. In the figure 3 is presented the cycle of biomass energy.

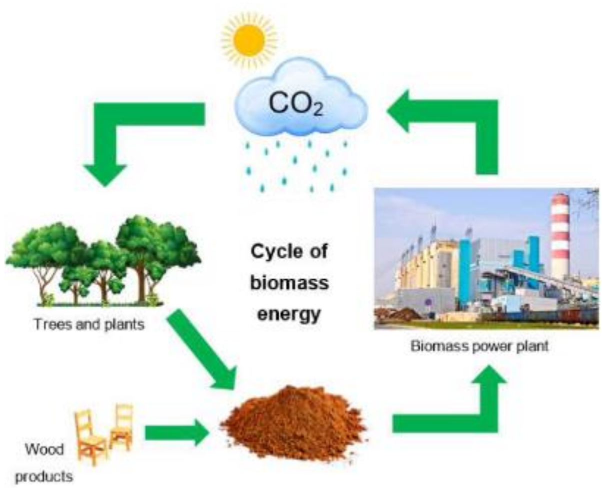

Figure 3. Cycle of biomass energy (Kalak, 2023)

Biomass is composed of all biodegradable materials from agriculture, waste and residues, including plant and animal substances. The energy of biomass is obtained by burning these organic matter. The combustion process releases heat, which can be used to heat buildings or produce electricity.

There are numerous advantages to using biomass as an energy source. One of the main advantages of biomass is its renewable nature—it can be replenished through natural cycles of plant growth and decomposition. While biomass combustion does release carbon dioxide, this is balanced by the CO_2 absorbed by plants during their life cycle, making it a carbon-neutral process under sustainable management.

Biomass can be utilized in several ways. It can be burned directly to produce heat for heating systems or hot water, or used to generate electricity through combustion, gasification, or fermentation. However, it's crucial that biomass is sourced responsibly—avoiding materials from illegal deforestation or vulnerable ecosystems—and that conversion technologies are efficient and minimize emissions.

Given the availability of biomass resources at a national level, there is strong potential for a strategic approach that aligns renewable energy investments with infrastructure development, local energy needs, and decarbonization goals, (Mignogna et al., 2024).

The availability of these resources at national level opens up the opportunity for an integrated strategy, in which investments in renewable energy are correlated with infrastructure development, local consumption needs and decarbonization objectives.

Romania's renewable potential represents not only a competitive advantage, but also an essential basis for ensuring energy security, reducing greenhouse gas emissions and attracting investments in sustainable technologies.

At the national level, the presence of all the main types of renewable sources – solar, wind, hydro and biomass – is noteworthy, which provides solid premises for the diversification and sustainable transition of the energy system. Solar energy benefits from a sufficiently high average annual degree of irradiation to support the development of photovoltaic systems, both in centralized regime and on a small scale, of the prosumer type.

Also, aeolian resources are significant, especially at higher altitudes or in open areas, allowing efficient energy production through modern turbines.

The hydropower potential, resulting from the dense hydrographic network and the mountainous relief, already contributes to the production of a significant proportion of renewable electricity.

Biomass, supported by extensive agricultural and forestry activities, is a valuable resource, especially in the context of the circular economy and the recovery of organic waste, (E. ON România, 2021).

The current structure of electricity production in Romania reflects a slow but steady transition towards a more diversified and sustainable energy mix. Figure 4 shows the structure of electricity production in Romania on 16/06/2025, at 16:22, (Transelectrica, n.d.).

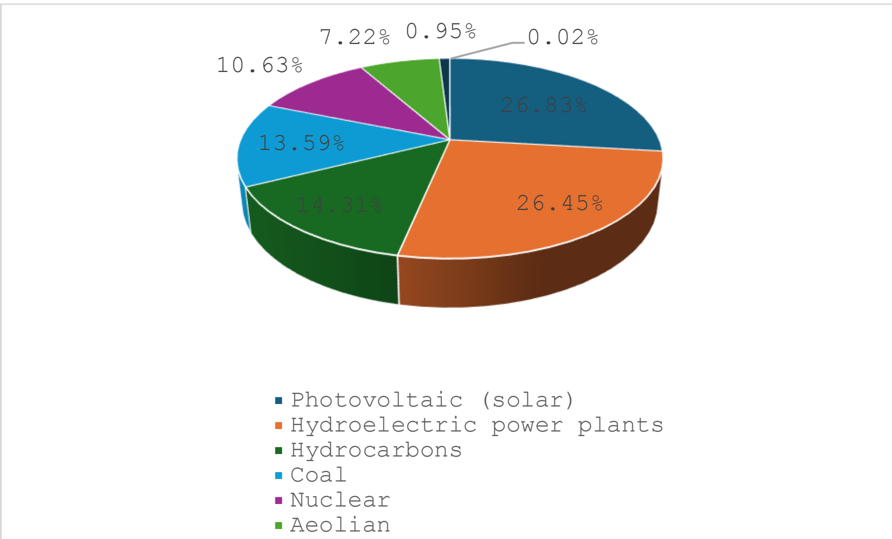

Figure 4. Structure of electricity production in Romania as of 16/06/2025

At the analyzed reference point, renewable resources (solar, hydro, wind and biomass) accumulate a significant percentage of the energy produced – approximately 61.45% of the total active power. Of these, photovoltaic energy occupies the largest share (26.83%), followed by hydro (26.45%).

In parallel, conventional sources, such as hydrocarbons (14.31%) and coal (13.59%), continue to play an important role in ensuring energy balance, especially during periods of low renewable production. Nuclear energy, provided by the Cernavoda power plant, accounted for 10.63% of active production, contributing to the stability of the system through a constant and non-intermittent contribution. Also noteworthy is the low contribution of biomass (0.95%), but also the extremely low storage capacities (0.02%), which highlights one of the main challenges of the energy transition in Romania – the lack of infrastructure to balance intermittent production from renewable sources.

Therefore, the data indicate that, although Romania has a relatively balanced energy mix, it is necessary to accelerate investments in storage capacities, smart grids and digitalization in order to fully capitalize on renewable energy potential and reduce dependence on conventional polluting sources.

3. GREEN ENERGY POLICIES IN ROMANIA: A NECESSARY CHANGE CHALLENGES AND PERSPECTIVES

In the current context of climate change and European commitments to reduce carbon emissions, green energy policies in Romania are becoming more than an option – they are a necessity. The transition to clean energy sources is essential not only for protecting the environment, but also for modernising the national economy and strengthening energy independence. Romania benefits from a considerable natural potential for the development of renewable energy. The sunny areas in the south, the favorable air currents in the coastal region, the hydrographic networks in the mountainous area and the agricultural areas for biomass offer real opportunities for the diversification of energy sources. However, the adoption of coherent and effective policies remains a major challenge.

One of the central difficulties is the lack of a unitary and consistent long-term strategy. Although support programs have been launched – such as the one for the installation of photovoltaic panels through “Green House” – they have been marked by delays, bureaucracy and reduced accessibility for a large part of the population. Moreover, legislative fluctuations and a lack of predictability have discouraged private investment, especially in wind and solar.

On the other hand, integrating green energy into existing grids requires significant investments in infrastructure. The distribution networks in many areas of the country are obsolete and do not allow the takeover of a large volume of energy produced from alternative sources. This slows down the pace of development and limits the benefits for local communities.

Another important dimension is public education and awareness. For green energy policies to be successful, citizens, local communities and public administrations need to be involved. Prosumer projects – in which consumers also become energy producers – must be stimulated through clear regulations and financial incentives.

Romania's energy transition to green sources is no longer just a strategic option, but an imperative necessity, driven by both international commitments to reduce carbon emissions and the European Union's increasingly stringent requirements in the field of climate and energy. In this context, public policies in Romania have begun to outline a legislative and institutional framework that is increasingly favorable to the promotion of renewable energies, the digitization of energy networks and energy efficiency.

According to (Ministry of Energy, 2023), Romania has assumed, through the National Integrated Energy and Climate Change Plan (PNIESC) 2021–2030, the objective of reaching a share of at least 30.7% of energy from renewable sources in the gross final energy consumption. In parallel, Romania's Energy Strategy provides for the gradual replacement of coal-based capacities, the expansion of wind and photovoltaic capacities, as well as investments in civil nuclear energy and storage technologies. These strategic documents are central pillars of the national policy in the field. Also, Romania has the obligation, as an EU member state, to achieve clear objectives regarding the share of renewable sources in the national energy mix.

However, the implementation of these policies faces a number of major challenges. These include excessive bureaucracy in the permitting process for renewable projects, the reduced capacity of distribution networks to integrate intermittent production and, last but not least, the lack of functional energy storage infrastructure, as we have previously presented. In addition, fluctuations in the energy market and the lack of clear support mechanisms for prosumers and energy communities limit market dynamism.

In the medium and long term, however, the prospects are encouraging. Access to European funds through programs such as REPowerEU, the Modernization Fund and the PNRR (National Recovery and Resilience Plan) offers concrete opportunities to accelerate the energy transition. Increasing investor interest in the renewable sector, the development of new technologies and the active involvement of civil society in climate action can also help strengthen a decarbonized and resilient economy.

Therefore, Romania's green energy policies are at the intersection of the pressure of external obligations, domestic modernization needs, and a window of economic opportunity. Turning this potential into a just and effective transition depends on political will, administrative capacity and a coherent and long-term vision.

4. INVESTMENTS IN ENERGY, A CHAIN EFFECT IN THE ECONOMY

Investments in the energy sector play an essential role in the economic dynamics of any country, (Ioana et al., 2019). They do not only mean the development of the infrastructure necessary for the production and distribution of energy, but they generate a knock-on effect throughout the economy, (Sun & Zhang, (2025). Whether we are talking about renewable energy, the modernization of distribution networks or the development of storage capacities, each investment brings with it new economic and social opportunities. Figure 5 shows the investments in energy projects and, implicitly, the way in which they contribute to job creation, because the human resources are put in the foreground.

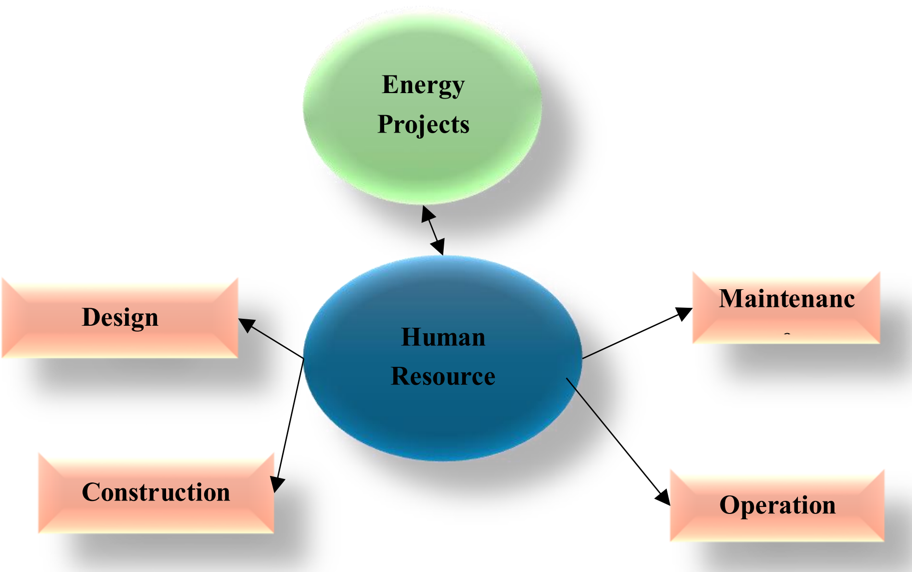

Figure 5. The effects of investing in energy projects

The first direct effect of these investments is job creation. Energy projects involve a wide range of activities: design, construction, operation and maintenance, all of which require skilled human resources. In the long term, this translates into increasing household incomes and stimulating domestic consumption. In addition, investments in energy help attract private capital and increase confidence in the national economy. Local companies benefit from orders and related contracts, from suppliers of construction materials to logistics or consulting services. Thus, the value chain extends beyond the energy field and influences complementary industries. On the other hand, a modern and efficient energy infrastructure reduces production costs for companies, thus increasing their competitiveness in domestic and foreign markets. Investments in sustainable energy sources, such as solar or wind, reduce dependence on imports and contribute to long-term economic stability.

Last but not least, through the transition to green energy sources, new markets and areas of research, innovation and education are opening up, which favors sustainable development and the adaptation of the economy to global climate challenges.

Beyond the positive impact on the energy market, these investments also contribute to the growth the country's gross domestic product, but also to economic stability and increased competitiveness of the Romanian economy at international level. Romania thus has the potential to become a leader European Union, with an important role to play in ensuring the security and energy independence, as well as in increasing economic competitiveness in the area. More given its geographical positioning, the Romanian state could consider carrying out investments in the energy sector in the region.

To achieve this goal, however, substantial investment in infrastructure is needed including through the deployment of digital technologies in energy networks and other segments of the production chain, in order to optimize the balance between production and consumption of energy. Modernization, strengthening and expansion of the national infrastructure, along with the growth of interconnection capacities with regional markets, are essential to facilitate the transition to renewable energy sources and energy security, in parallel with capacity development storage.

In addition, in order to maximize the national energy potential, a legislative framework is needed predictably, including in terms of taxation, given that the projects developed in this extend over long periods of time, and regulatory stability is essential for success.

CONCLUSIONS

Energy investments are not only necessary to ensure energy security, but are a catalyst for economic growth, innovation and social development. They set in motion a complex mechanism, the benefits of which are felt in multiple sectors of society.

Romania's green energy policies reflect a slow but inevitable transition to a sustainable energy system, in line with European directives and international climate commitments. Although the legislative and public policy framework has developed gradually over the past two decades, the concrete implementation of these measures still faces major difficulties – from administrative rigidities and outdated infrastructure, to the poor integration of renewables into existing energy networks.

Despite the challenges, Romania holds significant untapped potential in the renewable energy sector. This advantage is rooted both in its favorable geographic and climatic conditions—such as access to solar, wind, and hydropower resources—and in the financial support available through various European funding programs. By leveraging these assets through a clear long-term strategy, focused investments, and meaningful institutional reforms, Romania has the opportunity to speed up its energy transition and establish itself as an influential player in the regional green energy market.

In this regard, energy policy should not be viewed in isolation, but rather integrated into a broader national vision for sustainable development. Such an approach would bring long-lasting benefits, including enhanced energy security, economic growth, and an improved standard of living.

With thoughtful planning and a stable, investor-friendly environment, Romania has a realistic opportunity to become a leader in clean energy.

To conclude, adopting strong and forward-thinking renewable energy policies is both essential and advantageous. Although obstacles remain, ranging from legislative gaps to outdated infrastructure, the country possesses the necessary resources and mechanisms to make this shift a success.

With committed political leadership, strategically placed investments, and active collaboration between government bodies, private stakeholders, and civil society, Romania can position itself as a model for sustainable energy.

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CHAPTER 9

THE POLITICAL ECONOMY OF ENERGY IN THE MIDDLE EAST: CONTEMPORARY CHALLENGES AND POLICY RESPONSES

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INTRODUCTION

Energy subsidies represent one of the most pervasive—and contentious—fiscal policy tools in the Middle East. Originally designed to protect low-income households and support domestic industrial development, these subsidies have proven politically, economically, and socially challenging to reform. In a region with limited functioning social welfare systems, subsidized energy prices have long served as a critical, albeit costly and inefficient, social safety net. For oil and gas-producing states, low domestic energy prices have historically formed a central component of an implicit social contract: in exchange for the state's extraction of hydrocarbon wealth, citizens received a share of resource rents via direct transfers, free public services (such as health and education), and access to inexpensive energy. The transition from hydrocarbon-based energy systems to renewable energy, particularly in the Gulf, presents both significant challenges and new opportunities, as discussed by El-Katiri (2023). Since the onset of the Arab Spring in late 2010, calls for socio-economic justice have become central to the region's political discourse. Within this context, energy subsidies are seen not only as economic entitlements but also as social rights—despite the considerable strain they place on government budgets, especially in lower middle-income countries. While wealthier hydrocarbon exporters in the region face less immediate fiscal pressure, the rationalization of domestic energy consumption is increasingly vital. Continued reliance on resource revenues links domestic consumption patterns directly to long-term fiscal—and thereby political—stability. Moreover, sustained declines in global oil prices have heightened the urgency to reform subsidy systems and reallocate public spending. Though energy subsidy reform is not a cure-all, it can yield significant socio-economic benefits.

These include enhanced fiscal sustainability, increased capacity to invest in critical sectors like education, health, and social protection, and more equitable allocation of scarce resources—objectives that are integral to promoting long-term political stability. The fiscal dimensions of a green recovery strategy in the Middle East and North Africa are explored further in IMF (2022). For middle-income economies, energy subsidy reform—if paired with effective mitigation measures—can become a powerful instrument for addressing the socio-economic grievances that have fueled political unrest.

Meanwhile, net oil importers stand to benefit from declining global prices, which reduce energy import costs and ease fiscal burdens, thereby opening a window of opportunity for energy pricing reforms. This chapter examines potential pathways for reforming energy subsidies in the Middle East. Despite the well-documented political challenges, recent reform efforts in several countries indicate that success is possible—provided key enabling conditions are in place. The rest of the chapter is organized as follows: Section 2 provides an overview of the background and scope of energy subsidies in the region; Section 3 examines selected country experiences with reform; and Section 4 concludes with key findings and implications.

1. ENERGY SUBSIDIES AND THE POLITICAL ECONOMY OF THE MIDDLE EAST REGIONS

Energy subsidies play a central role in shaping the political economy of the Middle East, where governments have long used them as a tool for social stability, wealth redistribution, and political legitimacy. In many oil- and gas-rich states, especially rentier economies, subsidies help maintain the social contract by offering citizens access to cheap energy in exchange for political acquiescence. While this has ensured short-term stability, it has also encouraged inefficient energy consumption, discouraged private sector investment, strained public finances, and contributed to environmental degradation. Moreover, subsidies often disproportionately benefit wealthier households and energy-intensive industries rather than vulnerable populations. Efforts to reform energy subsidies face significant political resistance, as reducing them can trigger public unrest and erode regime legitimacy. As a result, subsidy reform must be carefully sequenced and accompanied by compensatory social measures, such as targeted cash transfers or gradual price adjustments. Understanding the interplay between subsidies, governance structures, and fiscal sustainability is crucial for designing effective policy interventions that promote economic diversification and long-term resilience in the region.

1.1 Issues in Measuring Energy Subsidies

There is no universally accepted definition of what constitutes a subsidy, and measuring energy subsidies remains a complex and contested issue. This lack of consensus is evident in the continued inability of major international organizations—such as the World Bank, UNDP, and OPEC—to agree on common terminology or accounting standards. A widely cited definition by de Moor and Calamai describes a subsidy as "any measure that keeps prices for consumers below the market level, keeps prices for producers above the market level, or reduces costs for consumers and producers by providing direct or indirect support." Under this broad definition, a wide range of government interventions could be considered subsidies. These may take the form of explicit, or on-budget, subsidies—such as direct financial transfers to producers or consumers—which are clearly recorded in the national budget. For example, a government may require a public utility to sell energy at a price below the cost of production, and then cover the resulting financial shortfall through budgetary transfers. Subsidies can also be cross-financed between different consumer groups. Cross-subsidies occur when one group—often households—receives energy at below-cost tariffs, while the resulting revenue gap is offset by charging higher-than-cost tariffs to other groups, such as industrial or commercial users. Countries like Lebanon, Yemen, Egypt, Libya, and Syria exemplify this practice, where industrial users often face significantly higher electricity prices than residential consumers, implying a degree of cross-subsidization. In contrast, implicit subsidies are less transparent and harder to quantify.

These typically arise in oil- and gas-producing countries with vertically integrated, state-owned energy companies. For instance, a national oil company might be instructed to sell petroleum products domestically at prices below international market rates, but above domestic production costs. In such cases, there is no explicit financial loss to the company, and hence no corresponding budgetary transfer. However, the opportunity cost—the revenue foregone by not selling the energy products at higher international prices—still represents a substantial economic cost. This implicit subsidy amounts to an indirect transfer from the state to domestic consumers, though it remains invisible in official fiscal accounts. If this forgone revenue were captured, it could be allocated toward a range of more productive uses: reducing fiscal deficits and public debt; increasing investment in infrastructure, education, or healthcare; offering direct cash transfers to citizens; or lowering taxes. Implicit subsidies also influence economic behavior by distorting domestic price signals—encouraging energy-intensive industrial strategies and artificially reducing the marginal cost of energy for consumers, much like explicit subsidies do. Using the price-gap approach—which calculates the difference between the subsidized domestic price and a benchmark market price (typically based on the supply cost, including transportation and distribution)—the IMF estimated that pre-tax energy subsidies in the Middle East reached USD 237 billion in 2011. This represented 48% of global energy subsidies, 8.6% of regional GDP, and 22% of government revenue. For updated figures and assessments of energy subsidy reforms and their implications for fiscal sustainability, see Sdralevich, Sab, Zouhar, and Albertin (2021) and the World Bank's MENA Economic Update (2023).

However, these figures should be interpreted with caution due to the limitations of the price-gap method. Several region-specific factors—such as joint production of crude oil, natural gas, and NGLs; spare production capacity (especially in Saudi Arabia); and the ability of major producers to influence global oil prices—can complicate the assessment of opportunity costs. Many oil and gas producers challenge the use of international market prices as the benchmark for domestic pricing. They argue that as long as domestic energy prices exceed production costs, no subsidy exists.

This view aligns with the World Trade Organization (WTO) definition of subsidies as a financial contribution by a government or public body that confers a benefit. According to this definition, if no financial loss or transfer occurs and no benefit is clearly conferred to domestic producers or consumers, then it may be difficult to justify classifying such pricing practices as subsidies.

1.2 Financial Pressures and Political Constraints

Fiscal Pressures and Political Constraints Throughout the 2000sIt became increasingly evident that energy subsidies impose a substantial fiscal burden across the Middle East. As global oil and natural gas prices surged, many countries in the region—especially net energy importers—faced growing fiscal pressure due to rising domestic energy demand. This dual trend resulted in rapid and unsustainable increases in government expenditures on energy subsidies in countries such as Morocco, Egypt, Jordan, Syria, and Lebanon. In Egypt, energy subsidy expenditures reached EGP 143.7 billion (approximately USD 21 billion) in the fiscal year 2013/14, accounting for 19.5% of total government spending. For updated information on Egypt's subsidy reform trajectory and fiscal outlook, see MEES (2014a) and more recent IMF or World Bank publications. Similarly, in Morocco, energy subsidies peaked in 2012 at levels described by the IMF as being “almost the size of the overall fiscal deficit, as much as spending on investment, and more than the spending on health and education combined.” Following an initial round of subsidy reductions and energy price adjustments, Morocco succeeded in halving its subsidy expenditure to approximately USD 4.1 billion—still around 10% of government spending in 2013 (Verme, El-Massnaoui, & Araar, 2014). Yemen also faced a severe subsidy burden, with its 2013/14 energy subsidy bill estimated at USD 3.5 billion—one-third of total government expenditure and exceeding the country’s budgeted fiscal deficit of USD 3.2 billion. While the drop in global oil prices since 2014 offered temporary relief for many oil-importing countries, this reprieve is likely to be short-lived, given the high volatility and unpredictability of international commodity markets. In both oil-importing and oil-producing states, current energy pricing frameworks have long-term consequences for domestic production and fiscal sustainability. In several countries—including partial importers like Egypt—low domestic energy prices disincentivize investment in exploration and upstream development, especially by independent oil and gas firms. These price distortions are particularly detrimental to natural gas development, where fiscal terms offered to investors are often unattractive. As a result, despite the Middle East’s substantial natural gas reserves, development has lagged behind potential for decades.

This underinvestment reflects not only poor pricing incentives but also governments’ unwillingness—or fiscal inability—to offer more favorable terms to investors. This dynamic threatens to undermine the region’s long-term production capacity at a time when new extraction projects are becoming increasingly expensive. The structural dependence of Middle Eastern economies on oil and natural gas—a pair of highly tradable commodities with volatile global prices—further amplifies their fiscal vulnerability. Energy subsidies intensify this instability by acting as pro-cyclical fiscal instruments: government spending on subsidies tends to expand during periods of economic growth and high energy demand, and contract during downturns, thereby reinforcing economic volatility. Moreover, many Middle Eastern economies exhibit a strong positive correlation between GDP growth and global oil prices.

This relationship exacerbates the cyclical nature of fiscal policy, especially in countries with weak institutional mechanisms for counter-cyclical stabilization. Several empirical studies have shown that pro-cyclical public spending, especially when linked to commodity cycles, can contribute to long-term fiscal imbalances and political instability in developing economies. In sum, while energy subsidies are often politically popular and socially justified as tools for protecting vulnerable populations, they impose substantial and growing fiscal costs. They also discourage private investment in domestic energy production, reinforce economic volatility, and reduce the policy space available to governments seeking to respond to external shocks. These challenges underscore the importance of carefully designed reform strategies that account for both economic and political constraints.

1.3 Inequities in Subsidy Distribution and Political Implications Although

Energy subsidies in developing countries are often justified on the grounds of promoting social welfare and ensuring equitable access to energy, in practice they tend to be regressive and highly inefficient. Rather than primarily benefiting the poor, subsidies disproportionately favor energy-intensive industries and middle- to high-income households—particularly in urban areas where car ownership and energy consumption are higher. Petroleum product subsidies, in particular, tend to accrue to the urban middle class, providing the most significant benefits to those who can afford private vehicles and higher electricity consumption. A recent study by the International Monetary Fund (IMF) revealed stark inequalities in the distribution of diesel subsidies across several Middle Eastern countries. In Egypt, Jordan, Mauritania, Morocco, and Yemen, the poorest 20% of the population received only 1–7% of total diesel subsidies, whereas the richest 20% captured 42–77%. In Egypt specifically, the poorest 40% of the population received just 3% of gasoline subsidies, 7% of natural gas subsidies, and 10% of diesel subsidies. For further insights on the latest equity impacts of subsidy reforms, see Sdralevich, Sab, Zouhar, & Albertin (2021). The misallocation of subsidies away from those most in need reflects a significant opportunity cost. Resources currently directed toward energy subsidies could be reallocated to sectors with broader social and economic returns—such as public health, education, infrastructure, or targeted tax relief for small and medium-sized enterprises (SMEs). Furthermore, a more effective approach would involve developing comprehensive social safety nets and direct transfer programs to support vulnerable households without distorting energy markets or consumption patterns.

The scale of subsidy expenditure relative to other key public spending items highlights the gravity of the issue. In Egypt (2008), government spending on energy subsidies was equivalent to the combined national spending on health and education. Similarly, fuel subsidies in Jordan prior to the 2008 reforms exceeded spending on both education and health. Yemen's 2008 fuel subsidy budget accounted for over 34% of total government expenditure, more than 1.5 times the combined expenditure on education and health. Subsidies also distort the structure and quality of energy provision. Investment disincentives are particularly apparent in electricity and fuel sectors. In several Middle Eastern countries, caps on government compensation to producers and flat payment structures often fail to cover the losses incurred by domestic oil and gas producers, refineries, importers, and electricity companies. This erodes profitability and limits the capacity of these firms to upgrade infrastructure, adopt cleaner technologies, or expand service coverage. The consequences are especially visible in the region's electricity sectors, where prolonged underinvestment has led to unreliable service, frequent power outages, and long connection delays—issues that disproportionately affect middle-income households and small businesses. In parts of the Levant and Gulf Cooperation Council (GCC) countries, electricity supply is further hampered by a culture of non-payment of utility bills, exacerbating financial deficits among state utilities. Recurring blackouts—observed in recent years in Iraq, Egypt, Lebanon, and even in some GCC states like Kuwait and Bahrain—highlight the systemic challenges caused by distorted pricing and underfunded infrastructure.

These outages result in lost business productivity, increased reliance on backup generation, and growing economic inefficiencies. In the poorest and most remote areas, the consequences are even more severe. Electrification gaps persist in countries like Yemen and rural Morocco. In Yemen, just over half the population has access to electricity, and service quality is uneven and unreliable. The national utility, chronically underfunded, lacks the capital needed to extend the grid or enhance generation capacity. Even among households with access—concentrated in the wealthier northern regions—nearly 70% are on lifeline tariffs meant for low-income users. This reflects the highly regressive impact of subsidies, as they fail to improve access in truly underserved regions while subsidizing consumption among wealthier groups. Another significant consequence of subsidy disparities is fuel smuggling, driven by stark cross-border price differentials across the region.

Smuggling is rampant along the borders of Syria, Jordan, and Lebanon, between Egypt and the Palestinian territories, and particularly around Iran, which maintained some of the lowest fuel prices globally until 2010. The problem is increasingly shared by the wealthier Gulf states, which have also become targets for illicit cross-border fuel trade. Smuggling not only undermines domestic economies and diverts fuel supplies, but also exacerbates shortages in countries that already face supply challenges due to poor pricing and fiscal inefficiencies. In summary, while energy subsidies are politically attractive and often positioned as a social benefit, their distributional effects reveal systemic inequities, inefficient resource allocation, and significant negative externalities.

By reinforcing wealth disparities, undermining investment, distorting energy markets, and weakening infrastructure, the current subsidy systems across the Middle East often contradict their stated goal of fostering social welfare.

1.4 Energy Subsidies And Domestic Energy Consumption

While many of the Middle East's major oil and gas exporters currently benefit from high foreign reserves and hydrocarbon revenues that cushion short-term fiscal pressures, these states face significant long-term challenges linked to their domestic energy pricing policies. These policies, which have historically ensured some of the lowest global prices for fuel, natural gas, and electricity, are rooted in the region's political economy—particularly the citizen–state relationship, in which the abundance of national hydrocarbon resources is perceived as a guaranteed entitlement. The provision of heavily subsidized energy has not only underpinned economic development—notably the expansion into energy-intensive industries during the 1960s and 1970s—but also formed a central pillar of the social contract, reinforced by generous welfare systems.

This model has contributed to political stability in many rentier states. However, it has also driven rapid growth in domestic energy consumption, surpassing trends attributable to economic and demographic growth alone. Over the past three decades, regional energy consumption has quadrupled, positioning the Middle East as one of the fastest growing energy markets globally. Projections suggest the region could become the second most significant contributor to global energy demand growth after Asia by 2040. Saudi Arabia exemplifies this trend. It ranks as the twelfth largest energy consumer in the world and sixth in oil and gas consumption, with domestic oil consumption more than doubling in the past decade. Other Gulf states display similar patterns, albeit with smaller populations and some of the highest per capita energy consumption levels globally. These patterns of consumption pose fiscal sustainability risks, particularly because most of these states do not levy taxes on citizens, instead financing their public expenditures almost exclusively through oil and gas export revenues. This dependence ranges from around 60% of total government revenue in Qatar to over 90% in countries like Libya, Iraq, Kuwait, and Saudi Arabia.

The sustainability of this model is increasingly in question. Generous welfare transfers and subsidized energy prices helped shield Gulf monarchies from the Arab Spring, but this strategy hinges on the continued ability to export substantial volumes of hydrocarbons. Under a business-as-usual scenario, where domestic consumption rises unchecked and economic diversification remains limited, several states risk a diminishing export capacity, leading to a shrinking fiscal base and potentially destabilizing political consequences. The recent decline in oil prices has added urgency to the need for subsidy reform and fiscal adjustment. Low energy prices have also generated a series of unintended macroeconomic consequences. Chief among them is the region's rising energy intensity, which contrasts sharply with global trends toward greater efficiency. Middle Eastern economies now require more energy per unit of economic output than almost any other region. This inefficiency is partly due to a structural bias in favor of energy-intensive industries, crowding out investment in diversified sectors.

Additionally, systemic inefficiencies in energy use further inflate consumption. A recent ABB study on energy efficiency in power generation found that countries like the UAE, Libya, and Saudi Arabia are among the least efficient globally in terms of energy use for electricity production. Energy-importing countries in the region, including Jordan, Lebanon, and Morocco, also fare poorly, underperforming even relative to their counterparts in Latin America. The transport sector offers another illustration of inefficiency: average fuel consumption per vehicle across the Middle East is more than twice the average in countries without fuel subsidies. Low domestic prices for oil and natural gas have also discouraged diversification of the energy mix. Unlike countries in Europe or North America, which have invested in renewables and nuclear power for energy security reasons, many Middle Eastern states have seen little incentive to shift away from fossil fuels. As a result, the region remains 95% dependent on oil and gas for its domestic energy needs—the highest such dependency globally. This lack of diversification makes energy-importing countries especially vulnerable to global commodity price fluctuations.

The absence of domestic alternatives has left these economies exposed to energy insecurity, especially in times of crisis. Recent analysis from Kuwait suggests that realigning domestic prices to market levels could yield significant fiscal benefits for both current and future generations. Price reform, even if politically sensitive, could reduce deadweight loss and improve the long-term fiscal position, allowing for more targeted and efficient use of public resources. In conclusion, while subsidized energy has historically played a central role in the Middle East's development model, its fiscal, economic, and environmental costs are increasingly unsustainable. The continuation of current consumption trends, supported by artificially low prices, threatens both economic diversification efforts and fiscal stability. Policy shifts toward gradual price realignment, investment in renewables, and enhanced energy efficiency are critical to addressing the structural vulnerabilities exposed by excessive domestic energy consumption.

1.5 Policy Responses

Reforming Energy Subsidies in the Middle East Although energy subsidies are widely recognized as inefficient and regressive, their reduction or elimination remains one of the most politically and economically sensitive policy challenges in the Middle East. This is largely due to the significant short-term costs that energy price increases can impose on households and industries, especially in the absence of well-designed compensatory mechanisms. Reform-induced price hikes affect households directly, through higher costs for electricity and household fuels, and indirectly, by raising the prices of energy-intensive goods and services such as transportation, food, and manufactured consumer goods.

The social impacts of subsidy reform are particularly acute for low-income populations, where unmitigated price increases can lead to greater poverty and welfare losses. However, the aspiring middle classes—who have come to rely on cheap energy as part of their cost-of-living expectations—are also vulnerable. In parallel, subsidy reforms risk undermining the competitiveness of domestic industries, particularly in oil- and gas-rich economies, where petrochemicals and other energy-intensive sectors have developed around the comparative advantage of low-cost domestic energy inputs. This dynamic creates an entrenched economic lock-in, reinforced by strong vested interests among industrial groups and socio-political elites, who benefit most from prevailing pricing structures.

These actors often resist comprehensive reforms that would redirect public spending toward more equitable and efficient uses. The political repercussions of subsidy reform were further magnified by the aftermath of the Arab Spring, which heightened government fears that rising living costs could trigger renewed social unrest. As a result, many governments in the region delayed or diluted planned reforms, prioritizing short-term stability over long-term structural adjustment. Despite these constraints, the past decade has witnessed an increase in energy subsidy reform initiatives across the Middle East. A growing number of countries—faced with fiscal pressure, rising domestic energy demand, and a desire to improve energy efficiency—have undertaken price adjustments and implemented targeted compensation programs for vulnerable groups. These experiences offer valuable lessons on the design, sequencing, and communication of reform, and underscore the importance of timing, social safety nets, and institutional capacity. For detailed insights into recent progress and remaining challenges in the region, the works of Sdralevich, Sab, Zouhar, and Albertin (2014, 2021) provide critical analyses of both the economic rationale and the political calculus that shape energy subsidy reform in the Middle East and North Africa.

Yemen

Yemen's failed reform efforts Yemen presents a stark counterexample to successful subsidy reform efforts in the Middle East, underscoring the risks of undertaking such reforms in fragile and politically unstable environments. By the late 2000s, energy subsidies—including those for liquid fuels, liquefied petroleum gas (LPG), and electricity—accounted for nearly one-third of total government expenditure, surpassing Yemen's combined spending on health and education.

These subsidies were overwhelmingly regressive, benefiting primarily the urban upper and middle classes, who had access to energy infrastructure and formal markets. In contrast, approximately half the population, particularly in the geographically remote northern provinces and the former South, lacked access to basic infrastructure, including the national electricity grid and regulated fuel markets. Yemen's already precarious fiscal position was further destabilized in the early 2010s, amid a deteriorating security environment and the broader fallout from the Arab Spring.

The state's oil and gas infrastructure became increasingly vulnerable to attacks, significantly reducing export capacity and exacerbating domestic fuel shortages. To meet shortfalls, Yemen was forced to import increasing volumes of petroleum products, which placed extraordinary strain on government finances. In July 2014, under mounting pressure from international lenders, the Yemeni government implemented a hastily designed and poorly communicated energy price reform, raising domestic prices on several fuels. The reform was launched amid severe political turmoil, widespread street demonstrations in Sanaa, and violent conflict between tribal factions and the central government, many of which operated in regions without any reliable access to electricity or fuel. Public backlash was swift and intense, with many citizens interpreting the reform as yet another manifestation of state failure to ensure basic welfare and equity.

The country's weak central authority was unable to withstand the political pressure from organized non-state actors—most notably the Houthi movement—who demanded the immediate reversal of price increases. The rollback of reforms under duress revealed the limits of technocratic policy solutions in environments where state legitimacy has eroded and public trust is absent. Yemen's experience vividly illustrates the critical importance of political stability, institutional capacity, and public engagement in the design and implementation of energy subsidy reform. Once a state has lost credibility and fiscal control, pursuing even economically rational reforms becomes politically untenable, if not impossible.

Egypt

Egypt's 2014 Five-to-Midnight Reform Egypt's burgeoning fiscal deficit, driven largely by rising expenditure on energy subsidies amid surging domestic demand, had become a persistent challenge under the Mubarak regime since the mid-2000s. Initial reform plans formulated in 2010, aimed at adjusting domestic energy prices to curb consumption and improve fiscal balance, were swiftly derailed by political upheaval following the popular protests that culminated in Mubarak's ouster in February 2011. The subsequent transitional governments avoided pursuing contentious subsidy reforms, fearing that such measures might exacerbate political instability. Concurrently, Egypt faced a steep decline in natural gas exports due to increased domestic consumption and stagnant production growth, further widening the budgetary gap exacerbated by over a decade of artificially low domestic energy prices.

By mid-2014, this fiscal imbalance had become unsustainable. In response, the Egyptian government enacted substantial price increases—some petroleum products saw price hikes of up to 70% overnight—in July 2014. While these increases were bold and significant, they are anticipated to have only a marginal effect on narrowing the fiscal deficit, with subsidy phase-out expected to be a gradual and prolonged process. The government has remained vague regarding the timeline and scale of future price adjustments. The reforms, however, represent a landmark effort given the prevailing political and social turbulence engulfing Egypt. Defying many analysts' expectations, the steep price hikes did not trigger mass protests or widespread civil unrest. Several factors contributed to this muted response: the reforms were announced shortly after President Abdel Fattah El-Sisi's rise to power, which was accompanied by a surge of nationalist sentiment and a crackdown on opposition groups, including the Muslim Brotherhood. This repressive political environment arguably discouraged large-scale demonstrations. Moreover, although the government's communication strategy was less systematic than those of some other countries undertaking subsidy reforms, it successfully framed the reforms as a necessary shared sacrifice, highlighting the inequities of subsidies and the imperative to redirect financial resources towards vital public services such as health and education. Key political figures, notably President El-Sisi and Prime Minister Ibrahim Mahlab, played pivotal roles in championing the reforms, bolstering public support at a time when the Egyptian electorate was yearning for political and economic stability. Additionally, there was a broad recognition among the population and policymakers alike that maintaining the subsidy regime would eventually precipitate an economic and energy crisis.

Nonetheless, the sustainability and ultimate success of Egypt's energy subsidy reform hinge on the government's capacity to protect vulnerable populations from adverse impacts. To this end, the government introduced mitigating measures such as freezing prices on essential subsidized food items—bread, rice, sugar, tea, flour, and oil—and expanding the food subsidy system to include additional staples like meat and chicken. Importantly, the price of liquefied petroleum gas (LPG), a crucial fuel for low-income households, was exempted from the latest price hikes. Despite these efforts, significant frustration persists among low- and middle-income Egyptians concerning the rising cost of living. Skepticism remains about the government's ability to translate fiscal savings into tangible improvements in public welfare. The absence of effective social protection and safety nets further complicates reform implementation. For instance, the World Bank has highlighted that eligibility criteria for ration cards—targeting pensioners and public sector employees—are neither adequately pro-poor nor rigorously enforced, resulting in a substantial portion of subsidized benefits accruing to non-poor households. Furthermore, the government must establish credible and sustained commitments to reform.

A key rationale for subsidy reduction is to create fiscal space for public investment in infrastructure and services. However, without regular adjustments to domestic energy prices in line with global market trends, fiscal gains may rapidly erode, undermining the government's capacity to fund compensatory measures. Failure to meet reform promises or effectively communicate achievements risks diminishing public support, potentially stalling or reversing progress.

Iran

The Iranian reform experience Iran's targeted subsidy reform, initiated in December 2010, represents the most comprehensive energy pricing reform undertaken thus far by any country in the Middle East region—and is particularly notable given Iran's status as a major oil and gas producer. The reform followed over a decade of intense political controversy surrounding Iran's domestic oil prices, which had been among the lowest globally. Surging domestic energy demand, compounded by prolonged international sanctions that severely limited Iran's ability to develop its vast reserves, had left the country—the holder of the world's largest natural gas reserves—dependent on supplemental imports to avoid widespread power outages.

By the late 2000s, Iran's domestic energy subsidy burden, calculated at opportunity cost, was estimated at around USD 100 billion annually, exceeding the country's oil export revenues, which then stood at approximately USD 70–80 billion. The initial phase of subsidy reform in 2010 sought to eliminate USD 50–60 billion of subsidies (approximately 15% of GDP) almost overnight, by sharply increasing prices on key energy products: gasoline prices rose by 300%, natural gas by 50%, and diesel by 900%. The government aimed to align domestic energy prices to 90% of international market values within five years, coinciding with Iran's Five-Year Development Plan. The architects of the reform emphasized that price increases needed to be substantial and front-loaded to effectively suppress demand. Modest or gradual price adjustments were seen as vulnerable to rapid erosion in real terms due to inflation, fluctuations in international prices, or exchange rate depreciation. This approach was essential to generate significant fiscal savings swiftly, which formed the financial basis for Iran's pioneering mitigation mechanism—a comprehensive cash transfer program. Central to Iran's reform strategy was the redistribution of proceeds from subsidy reductions through targeted cash grants. Initial plans allocated 30% of the savings to domestic industries in cash, enabling investments in energy efficiency and adjustment to higher energy costs; 20% was directed to government institutions for similar purposes; and at least 50% was earmarked for direct cash transfers to households to offset the burden of higher living costs. The government initially sought to target transfers to lower-income households, but practical challenges led to the adoption of a universal cash transfer system, whereby payments were made to heads of households on a per-adult basis. The average payment, approximately USD 180 per four-person household during the reform's first six months, represented about half the national minimum wage, offering significant relief particularly to low-income groups.

To pre-empt public backlash, the reform was accompanied by a meticulously planned and coordinated communication campaign led by a government-appointed spokesman. This campaign mobilized multiple channels—including television, radio, newspapers, websites—as well as political, business, social leaders, and academics to advocate for the reform. The messaging stressed the wastefulness of prior subsidies that disproportionately benefited wealthier households, while highlighting the equitable benefits of the new universal cash transfer program. The communication strategy underscored the policy shift from subsidizing energy products to directly supporting people, promising enhanced social equity, improved industrial competitiveness, and greater economic diversification. To mitigate inflationary pressures, the government signaled its intent to deploy monetary policy measures actively and preemptively built large stockpiles of basic goods to forestall panic buying and hoarding. Despite these precautions, the reform faced significant challenges. The intensification of international sanctions after mid-2012, alongside a sharp depreciation of Iran's currency, dramatically increased the cost of living and complicated the reform process. A planned second phase of subsidy reform scheduled for October 2012 was suspended. The International Monetary Fund (IMF) noted that such external shocks could undermine the stability of Iran's currency and the intended relative price adjustments. Moreover, as the 2013 presidential elections approached, the cash transfer program became politically contentious. Despite its original intent as a temporary, universal benefit, the program gained widespread popularity, creating political pressure to maintain or even expand payments. Critics—including politicians and oil and gas industry stakeholders—argued that the government was incurring rising fiscal costs by sustaining near-universal cash transfers, which increasingly outpaced savings and limited funds available for compensating industrial consumers. In response, a second round of energy price increases was introduced in early 2014, accompanied by reductions in monthly household cash transfers. This phase aimed to achieve additional savings of approximately USD 19.1 billion for the

Iranian fiscal year 2014/15. Evaluating the impact of Iran's subsidy reform on energy consumption remains challenging due to the short time elapsed since the reform's initiation, as well as confounding factors such as economic sanctions and currency depreciation.

Additionally, demand for electricity and natural gas is largely supply-driven, with shortages in some provinces limiting consumption independently of price effects. Nonetheless, there is general consensus among Iranian analysts that the initial price hikes in 2010 significantly curtailed demand for fuel products and natural gas in the months following their implementation, though the longer-term consumption effects are less clear.

CONCLUSION

Reforming energy subsidies across the Middle East remains a politically charged and economically sensitive endeavor. While the imperative for reform grows increasingly evident, many governments remain cautious, apprehensive about potential social unrest and political backlash. The Arab Spring was a pivotal moment that heightened governments' fears of public dissatisfaction—even in countries that experienced relatively limited upheaval.

What initially served as a deterrent to reform now offers an important lesson: long-term political stability and economic resilience depend on a more equitable and transparent allocation of national resources. In the short term, however, fiscal pressures remain the primary catalyst for reform. The unsustainable burden of energy subsidies—particularly in energy-importing or low-production countries such as Jordan, Lebanon, Egypt, Syria, and Yemen—has rendered change unavoidable. Yet reforms are often hurried and reactive, driven by external pressures from international lenders and implemented during periods of weak governance. Such approaches risk intensifying public discontent and undermining the durability of reform outcomes. Government capacity and credibility are therefore critical determinants of successful reform. Yemen exemplifies the risks associated with poorly managed reforms, while the more deliberate, phased strategies pursued in countries like Jordan, Morocco, Egypt, and Iran highlight the potential for positive and sustainable results. These cases emphasize the importance of initiating reforms proactively—before economic or political crises emerge. Nonetheless, many Middle Eastern governments face deep structural and institutional constraints that hinder their ability to act preemptively. Iran's experience is especially instructive.

Despite facing significant internal political divisions and external sanctions, Iran demonstrated that reforming domestic energy pricing is both technically achievable and politically viable. This example is particularly pertinent for the wealthier Gulf Cooperation Council (GCC) states, which possess stronger fiscal reserves and institutional capacity. With careful planning and targeted compensation mechanisms, these countries are well-positioned to rationalize energy consumption while safeguarding social stability. Looking forward, energy subsidy reforms must be embedded within comprehensive strategies encompassing economic diversification, social protection, and institutional reform. For the Middle East, such reforms are not merely a matter of fiscal efficiency—they are essential to securing long-term political legitimacy, fostering social cohesion, and ensuring sustainable economic development.

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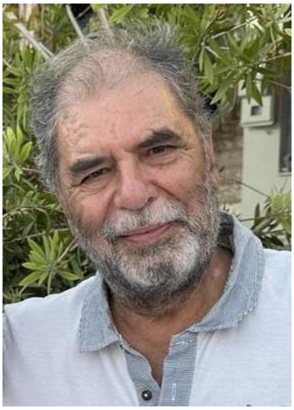

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Professor John N. Hatzopoulos obtained a diploma in Rural and Surveying Engineering from the National Technical University of Athens, Greece (1971), ranking first among 94 graduates. Was granted a research assistantship from the University of Washington, USA (1975) and obtained an MSCE degree (1976) and Ph.D. degree (1979), specialized in photogrammetry and remote sensing. Was hired as an associate professor by the California State University, Fresno - CSUF (1980) Surveying and Photogrammetry Program and was promoted to professor with tenure (1984). Resigned from CSUF to be elected as a professor at the University of the Aegean, Greece, Department of the Environment, teaching Topographic Mapping (1989). Retired as Professor Emeritus (2015). His research interests are in Surveying, Photogrammetry, Remote Sensing, GIS, and Philosophy, having written several books and many publications in relevant conferences and scientific journal

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Throughout his career, Prof. Ahmad has made significant contributions to science and technology. He has authored over 360 scientific publications, including journal articles, book chapters, technical reports, and manuals. He has held leading roles such as program chair, technical chair, and tutorial chair at more than 610 international conferences, many organized under the auspices of IEEE. He has also delivered over 37 keynote addresses and invited talks, and conducted numerous workshops and short courses worldwide.

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The book Energy and Power in International Political Economy stands out as a comprehensive and timely contribution to the field, shedding light on the complex interplay between global energy dynamics and political power structures. I wholeheartedly commend Prof. Dr. Arzu AL for her visionary editorial leadership, and extend my congratulations to all contributing authors for their scholarly excellence. This work will undoubtedly inspire further research and dialogue in international political economy.

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Energy and Power in International Political Economy is an impressive scholarly endeavor that brings together diverse perspectives on one of the most pressing issues of our time. I extend my sincere appreciation to Editor Prof. Dr. Arzu AL for curating such a rich and thought-provoking volume, and congratulate all contributing authors for their valuable academic input. This book is a must-read for anyone interested in the evolving nexus of energy, politics, and global power.

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The valuable work Energy and Power in International Political Economy offers a significant contribution to the field by addressing the energy-politics nexus through an interdisciplinary lens. I sincerely congratulate Editor Prof. Dr. Arzu AL and all contributing authors for their insightful efforts. This high-quality publication stands as a strong reference for both academic circles and policymakers.

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