ANALYZING INDIA'S SUSTAINABLE ENERGY POLICIES AND STRATEGIES

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation report entitled, "**Analyzing India's sustainable energy policies and strategies**" is based on the results of investigations carried out by me in the Maters of Arts in International Studies at the School of International and Area Studies under the Supervision of Mr Yugank Naik and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities / College will be not be responsible for the correctness of observations / experimental or other findings given the dissertation.

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COMPLETION CERTIFICATE

This is to certify that the dissertation report "**Analyzing India's sustainable energy policies and strategies**" is a bonafide work carried out by Ms Aliya Shaikh under my supervision in partial fulfilment of the requirements for the award of the Master's degree in the Discipline of Masters of Arts in International studies at the School of International and Area Studies, Goa University.

Mr. Yugank Naik

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CONTENTS

PREFACE

The purpose of this dissertation is to analyse India's sustainable energy policies and strategies, the urgency to address climate change, enhance energy security, and foster inclusive growth has propelled the nation towards a transformative energy transition. Through this dissertation, I aim to unfold the complexities and distinctions of India's sustainable energy policies and strategies, shedding light on the challenges, opportunities, and implications that define this critical juncture. My fascination with sustainable energy stems from a deep-rooted belief in the power of innovation, collaboration, and policy coherence to drive positive change. The exploration of India's energy landscape has been a journey of discovery, learning, and introspection, as I navigated through the complicated arrangements, technologies, and market dynamics that shape the country's energy future. May this exploration into India's sustainable energy policies and strategies serve as a piece of knowledge, insight, and inspiration for all those who seek to understand, engage with, and contribute to the transformative power of sustainable energy in the India today.

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"I would like to acknowledge my own dedication, perseverance, and commitment throughout this dissertation. My ability to stay focused, overcome challenges, and see this work to completion has been a significant personal achievement that I am grateful for"

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The Library, at Goa University has been integral for my academic resources, physical as well as electronic and web-based, my sincere thanks to entire staff of Goa University Library, for assisting me through the resources and enhance my research.

Finally, I am grateful to my classmates who have provided me with encouragement, supports throughout this process, their good humour have made this journey all the more enjoyable and rewarding. And also to my family for their unwavering support and encouragement, they have been a constant source of strength and inspiration for me, I am grateful for their patience and understanding as I pursued this dissertation.

Aliya Shaikh

TABLES

FIGURES

ABBREVIATIONS USED

Entity	Abbreviation
Abu Dhabi National Oil Company	ADNOC
Accelerated Power Development and Reforms Program	APDRP
Aggregate Technical And Commercial	AT&C
Atal Jyoti Yojana	AJAY
Below Poverty Line	BPL
Bureau of Energy Efficiency	BEE
Central Electricity Authority	CEA
Central Electricity Regulatory Commission	CERC
Central Financial Assistance	CFA
Centre For Innovation, Incubation, And Entrepreneurship	CIIE
Climate Action Tracker	CAT
Coal India Limited	CIL
Commission For Additional Sources Of Energy	CASE
Compressed Biogas	CBG
Compressed Natural Gas	C.N.G
Concentrated Solar Thermal	CST
Conference Of Parties	COP
Deen Dayal Upadhyaya Gram Jyoti Yojana	DDUGJY
Delayed Recovery Scenario	DRS
Department Of Atomic Energy	DAE
Development Finance Corporation	DFC
Development Financial Institutions	DFIs
Direct Current	DC
Distribution Company	DISCOMs
Electricity Act	EA

Energy Efficiency	EE
Energy Storage Obligations	ESO
Energy Storage Systems	ESS
Energy-From-Waste	EfW
Foreign Direct Investment	FDI
Gas Authority Of India Limited	GAIL
Gigawatt	GW
Global Off-Grid Lighting Association	GOGLA
Government Of India	G.O.I
Green Industrial Policy	GIP
Greenhouse Gas	GHG
Gross Budgetary Support	GBS
Gross Domestic Products	G.D.P
Improved Cook Stoves	ICS
India Vision Case	IVC
India's Green Deal	IGD
India-Middle East-Europe Economic Corridor	IMEC
Indian Oil Corporation	IOC
Indian Oil Corporation Limited	IOCL
Indian Renewable Energy Development Agency	IREDA
Intended Nationally Determined Contribution	INDC
International Energy Agency	IEA
International Solar Alliance	ISA
Inter-State Transmission System	ISTS
Jawaharlal Nehru National Solar Mission	JNNSM
Kilowatt-Hour	KWh
Lifestyle For Environment	LiFE
Light Emitting Diode	L.E.D.
Liquefied Natural Gas	LNG

Market Transformation On Energy Efficiency	MTEE
Megawatt	MW
Million Metric Tons	MMT
Million Tons	MTs
Ministry Of Coal	MoC
Ministry Of New And Renewable Energy	MNRE
Ministry Of Petroleum And Natural Gas	MoPNG
Ministry Of Power	MoP
Ministry Of Science And Technology	MoST
Ministry Of Statistics And Programme Implementation	MoSPI
Morgan Stanley Infrastructure Partners	MSIP
National Action Plan On Climate Change	NAPCC
National Aeronautical Laboratory	NAL
National Clean Energy Fund And The National Adaptation Fund For Climate Change	NAFCC
National Coal Development Corporation	NCDC
National Electricity Plan	NEP
National Hydroelectricity Power Corporation	NHPC
National Indicator Framework	N.I.F
National Institute For Transforming India	NITI Aayoug
National Institute Of Solar Energy	NISE
National Mission For Enhanced Energy Efficiency	NMEEE
National Solar Mission	NSM
National Thermal Power Corporation	NTPC
New Urban Agenda	N.U.A
Oil And Natural Gas Commission	ONGC
Ongc Videsh Limited	OVL
Perform, Achieve, And Trade	PAT
Power Purchase Agreements	PPA
Pradhan Mantri Ujjwala Yojana	PMUY

Press Information Bureau	PIB
Prime Minister Kisan Urja Suraksha Evam Utthaan Mahaabhiyan	PM-KUSUM
Production-Linked Incentive	PLI
Public-Sector Undertakings	PSUs
Renewable Energy	RE
Renewable Energy Technologies	RETs
Repair And Maintenance	R&M
Research And Development	R&D
Research Development & Deployment	RD&D
Smart Cities Mission	S.C.M
Solar Energy Corporation Of India	SECI
Solar Photovoltaic	Solar PV
South Asia	SA
State Electricity Boards	SEBs
Sustainable Alternative Towards Affordable Transport	SATAT
Sustainable Development Goals	S.D.G
Turkmenistan-Afghanistan-Pakistan-India	TAPI
Un Framework Convention On Climate Change	UNFCCC
United Arab Emirates	U.A.E
United Nations	U.N
United Nations Environmental Programme	UNEP
United Nations Sustainable Development Goals	UNSDG
United States Dollar	USD
Viability Gap Funding	VGF
Voluntary National Reviews	V.N.R

ABSTRACT

Energy politics play a vital role in shaping of International Politics. The research provides in-depth analysis of current situation of renewable energy in India, including its strength, opportunities and challenges. The study assessed various policies of renewable energy in India to know its strategy, the outcome and its potential in energy diversification, as well as energy transition. To accomplish this research aim, the study articulated the following research objectives they are: To analyse the effectiveness of India's renewable energy policy strategies in achieving their target, secondly to understand India's renewable energy approach, thirdly to access the country's achievement in the adoption of RE, and finally to analyse its progress and its efforts in energy diversification. The research questions for this study what is the current situation of renewable energy in India, What is its policy strategy and approach. Research approaches used are historical and descriptive; to give insights into the historical development of energy policies, and perspectives, the research was limited from the year 2014-2023 and the primary data was limited to government's websites and official documents. To conclude the findings show that India has fantastic policies with related to renewable energy and energy transition but there are certain challenges which might hold back India in achieving its renewable energy targets set by 2030, and 2070.

Keywords: Renewable energy, Energy Transition, Energy Diversification, Policy Strategies.

CHAPTER 1

ANALYZING INDIA'S SUSTAINABLE ENERGY POLICIES AND STRATEGIES

INTRODUCTION

India, the world's third-largest energy consumer, is at a crossroads in its energy policies and strategies. With increasing global pressure to reduce carbon emissions and the need for energy security, the country must navigate a complex landscape of renewable energy, fossil fuel, and international cooperation. This research study will focus on the development of renewable energy and its current situation in India to meet the clean energy needs of tomorrow. How did it evolve, and why was there a need to create a separate ministry for renewable energy? At the same time, the study will critically assess India's policies to make a better future while addressing all the gaps. It has been found that renewable energy has become a critical aspect that interacts with environmental, economic, and social dimensions for sustainable development worldwide. According to the reports, India and other countries have made significant progress in the renewable energy sector by adopting sustainable development policies. The study will focus on three critical areas: India's progress in renewable energy, India's global policies regarding renewable energy and sustainable development, and India's nationally determined contribution towards carbon emission. The study will also focus on renewable energy development and its current situation. India's ongoing policies for energy transition and its progress towards sustainable development.

Affordable and clean energy for all is essential for sustainable development and to address climate change globally. Lack of access to energy supplies and transformation systems hinders economic and human development; the environment provides renewable and non-renewable energy sources like solar, wind, hydropower, geothermal, biofuels, natural gas, coal, petroleum, and uranium. If there is an increase in the use of fossil fuels globally without taking any action towards mitigating greenhouse gases, it will have climate change implications; increasing the use of renewable energy will contribute to climate change mitigation and reduce the risk of disaster caused by it.

Although India's dependence on fossil fuels is growing constantly, it has a long history of promoting renewable energy; the country has been investing in renewable energy technologies, infrastructure, and policy changes, which will be covered in detail in further chapters. The country is slowly trying to phase out nonconventional energy sources to reach its net zero target by 2070, which sounds unrealistic since most of our energy is still generated from coal, about 60-70%. Moreover, it is the most populous country in the world, surpassing China, which is increasing the demand for energy consumption, be it in the industrial sector, domestic or transportation sector., but the last decade or so, India has been doing quite excellent work on Renewable Energy (RE) sector. One of the exciting policies the G.O.I. has introduced to promote indigenous production of sustainable infrastructure and technologies is the "Make in India" initiative.

The main topics discussed in this work to address the research questions are India's current RE scenario and its potential, the strategies for implementing current RE policies, and India's progress towards S.D.G. 7.

The scope of the study is those important policies that came up since India's independence in the energy sector and the policy strategy the government has taken each time. The specific aspect of the study is that it will discuss India's energy transition and its energy diplomacy. Lastly, the study assessed India's progress in SDG7 to determine if the country will meet its target.

In summary, India renewable energy sector is an interesting sector for research due to its potential of green job creation, economic growth, innovation and contribution to climate change mitigation. The sector‘s growth is essential for sustainable development, and understanding the challenges and opportunities of the sector can provide valuable insights to the research, students who want understand and explore more of India‘s RE sector.

1.1RESEARCH OBJECTIVES

- To analyse the effectiveness of India's renewable energy policy strategies in achieving their target and promoting renewable energy adoption.
- To understand India's renewable energy approach is a market-driven or strategic approach.
- To access the country's achievement in the adoption of renewable energy.
- To analyse its progress and its efforts in energy diversification.

1.2 RESEARCH QUESTIONS

- What is the current situation of renewable energy in India
- What is India’s renewable energy policy strategy?

- Does India's approach to renewable energy follow a market-driven strategy?
- How far has India come in accomplishing the S.D.G. 7 objective?

1.3 HYPOTHESIS

- Despite challenges, India's policies and strategies are focused on promoting the development of RE through indigenous design.
- Through effective collaboration between the government, private sector, and research institutions, India's RE sector will foster innovation, technological advancements, and energy solutions, positioning the country as a leader in the clean energy transition.

1.4 RESEARCH METHODOLOGY

The research methodology used in this study is qualitative and quantitative. Research approaches used are historical and descriptive; these methods will give insights into the historical development of energy policies and their evolution since then and describe the country's approach and perspectives towards conventional energy sources. Data analysis is used to analyze the data content, wherein materials like official documents, news articles, and speeches will provide different themes and trends in India’s sustainable energy policies.

The sources for data collection will be primary and secondary. Primary sources, such as annual reports, official websites, and official publications, as well as secondary sources, like research reports, blogs, journal articles, magazines, books, newspaper articles, and videos, will be used to supplement my findings and make my study more critical.

1.5 THEORETICAL BASES

Constructivism school of thought emphasizes the role of ideas, identities, and norms in shaping state behaviour and international cooperation; this theory highlights the importance of understanding how ideas and values influence state actions, interaction, and development of international structures. Nicholas Onuf has been credited with coining the term constructivism to describe theories that focus on socially constructed characters of international relations. Alexander Wendt (1995) offers an excellent example that illustrates the social construction of reality. (Theys, 2018) In this study, constructivism will provide insights into how shared ideas and norms influence the cooperation and action of states and international organizations in addressing energy access and sustainability.

1.6 CHAPTARIZATION

Chapter 1; Will include Introduction, Rationale of study, Research objective, Research question, Hypothesis, and Literature review.

Chapter 2: Starts with History of Renewable Energy in India, Evolution of policies, institutions of RE, its Strategies in implementing current Renewable Energy policies, India's aim and approach towards climate action, transition, and justice.

Chapter 3: Includes Political Economy of Renewable Energy in India, India's current RE scenario and its potential, the country's move to energy transition, Adoption of Renewable Energy Technologies, and India's investment in RE

Chapter 4: Includes India’s energy diplomacy and partnerships, India’s energy diversification, and its Nationally Determined Contribution.

Chapter 5: Includes Challenges to India’s commitment to SDG7, India’s progress towards S.D.G.7, and Future Outlook.

Chapter 6: Conclusion

1.7 LITERATURE REVIEW

- The article, “Renewable Energy Scenario in India Quest for an Appropriate Policy” by Ashok K Mangotra provides a historical overview of the country's approach to renewable energy policies, focusing on the early stages after independence. It highlights the development of coal and hydro projects, the policy objectives, and the focus on rural energy programs. The Commission for Additional Sources of Energy (CASE) was the first renewable energy policy, and the country opened for 100% FDI in 2005.

- In the article, “Securing India's Energy Options in an Independent World” by Arunav Guha Roy, the author emphasizes the global importance of energy security and the uneven distribution of energy supplies, particularly in developed countries with large reserves. They highlight the energy deficit in developing countries like India, which could be addressed by increasing energy production, reducing import dependency, and diversifying fuel choices.
- The article, “The Political Economy of Renewable Energy Prospects and Challenges for R.E”. by Niharika Tagotra examines the political economy of renewable energy, focusing on the global transition to clean energy, highlighting

the role of international regimes and the Paris Accord 2015. The article highlights the importance of G8 countries in sustainable development.

- The article, “Rise of Renewable Energy Protectionism Emerging Trade Conflicts and Implications for Low Carbon Development” by Joanna I. Lewis' article highlights the growing conflict between domestic energy support and global trade regime principles, impacting nations' ability to transition to a low carbon economy. Countries like India use protectionist policies to encourage domestic renewable energy production.
- The article, “Coal Free by 2070? India's push towards renewable energy will continue coal reliance” by Charmaine Jacob for the next two decades. In the article, the author doubts India's progress in the transition to the renewable energy sector, claiming that India's dependency on coal will continue for the next ten to twenty years. Our dependency on coal and our unreliable renewable energy sources. Highlights issues in investment in the renewable sector.
- The article, “Innovation and Green Development” by authors, Subhashish Dey, Anduri Sreenivasulu, G.T.N. Veerendra, K. Venkateswara Rao, and P.S.S. Anjaneya Babu, evaluate the energy mix evolution in relation to a country's development level, focusing on India's renewable energy sector, They discuss the importance of renewable energy sources, such as solar radiation energy, wind energy, tidal energy, biomass energy, and geothermal energy, which are nonconventional and environmentally friendly alternatives to fossil fuels, The authors also highlight the potential of renewable energy technology to save energy, improve the environment, and reduce carbon emissions, The study suggests that increased investment in renewable energy output, energy efficiency,

and environmentally related technological innovation can encourage renewable energy consumption, It highlights the significant growth in renewable energy use, particularly in electricity generation, and the potential for renewable energy to surpass the output of fossil fuel plants in the near future.

- The article, “energy diplomacy in a time of energy transition” by Steven Griffiths highlights the importance of aligning the interests of multiple parties through multilateral diplomacy in the transition to clean energy. Global energy governance is identified as a crucial form of multilateral diplomacy for a large-scale energy system transformation, aiming to ensure the security of energy supply and demand, economic development, international security, environmental sustainability, and domestic good In the context of the Middle East, the literature discusses the impact of a large-scale shift to electric vehicles on global oil demand and the potential consequences for Middle Eastern countries. The U.A.E. is identified as a critical player in this transition, focusing on downstream activities such as refining and petrochemical production. The U.A.E.'s energy diplomacy efforts include strategic partnerships with Asian countries, particularly China, Japan, and South Korea, which are significant consumers of U.A.E. oil and gas exports; the literature review also includes references to various studies and reports on energy transitions, renewable energy, and energy security, The U.A.E.'s energy diplomacy efforts, particularly with Asian countries, are highlighted as a significant aspect of this transition.

- The book, “Energy Sources and Policies in India” by Rishi Muni Dwivedi aims to show how energy resources and sources are essential and how different policies

are implemented to grow the Indian economy. The book is divided into eight parts; part one discusses energy needs and management in India; parts two, three, and four discuss nonconventional sources of energy, its history, present scenario, and international cooperation; and parts five, six, and seven discuss conventional sources of energy in India.

- The Edited book, “Final Energy Crises” by Andrew McKillop and Sheila Newman, introduces the Hubbert type of curve explained to show the peak of oil production; oil, gas, and coal are used to make fertilizers in countries like China, India, which releases GHG and pollutes environment so authors introduce alternative technology to make fertilizers. What is Kyoto Protocol architecture expected from developing countries and how is it a mismatch?
- The book, “India's Energy Transition Possibilities and Prospects” by Ram Kumar Mishra and V. Balaji Nagendra Kumar gives the classification of energy resources; certain countries control the resources and put prices as per their convenience; the urge India to use its skills and knowledge and develop harness renewable energy, wholly or partly to meet the nation’s energy demands.
- Peter E. Hodgson's book, "Energy, the Environment and Climate Change, presents a comprehensive and detailed analysis of the interplay between energy, the environment, and climate change; Hodgson's book contributes valuable insights into the complex issues surrounding energy production, environmental sustainability, and climate change. By highlighting the urgency of transitioning to cleaner energy sources and advocating for policy change, the author inspires readers to take action toward a more sustainable future and emphasizes the urgent need to transition to cleaner and more sustainable energy systems to mitigate

climate change. The transition to sustainable energy sources like nuclear, wind, solar, and carbon capture technologies is essential for meeting future energy needs while reducing environmental impact; additionally, addressing climate change impacts on energy systems is vital for ensuring a stable energy supply and economic resilience. The conclusion highlights the urgency for global actions towards renewable energy sources to reduce GHG emissions and adapt to climate change impacts.

1.8 LIMITATIONS OF THE STUDY

- I have limited my research findings from the year 2014 to 2023.
- My primary data is limited to the government's websites and official documents and does not include interviews with the ministers in charge and higher authorities.

CHAPTER 2

HISTORY OF RENEWABLE ENERGY POLICIES, INDIA'S AIMS AND APPROACH

2.1 EVOLUTION OF ENERGY

The first industrial revolution, which started in Britain between 1760 and 1820, was defined as a significant economic shift; according to economists, three things are required for a revolution: first, a new way of communicating; in this case, it was the ability to print and use telegram, second new transportation mechanism, in this case, it was steam powered by locomotives, thirdly a new power source, in this case, it was burning of coal, then came to the second industrial revolution this time it was in America started in 1870-1900, the new way of communicating was a phone, radio television, new transportation mechanism was internal combustion vehicles. A new power source was cheap oil, and now we live through the third industrial revolution; the new way of communication is the internet, and hybrid and electric vehicles are a new way of getting around. New power sources are solar, wind, and nuclear. The European Union and China spearhead this revolution (AsapSCIENCE,2020,3:25). Countries like China, India, France, the Netherlands, and Ireland have announced their intention to phase out the sale and registration of vehicles powered by fossil fuels over the next decade.

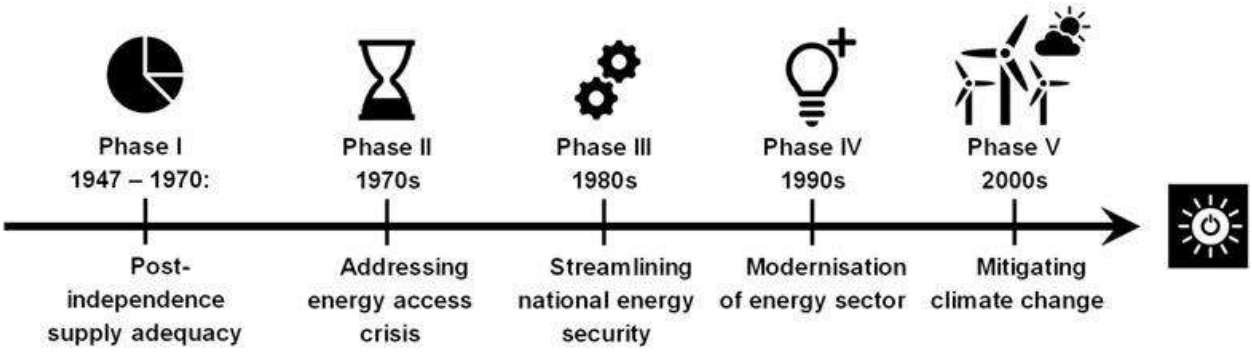
Energy has been obtained over the years in many ways; in ancient times, wood was the primary source of fuel, providing heat for cooking and warmth; because of this, many

forests were destroyed, and still, in many developing countries, nearly two billion people use wood, crop residue, and dried animal waste as a fuel. Soon, coal was found near the surface and later underground. It became the primary energy source in developed countries; it provided power for the Industrial Revolution in places where iron ore was available. During the 19th century, oil was first found in the United States of America and then in many other countries; it had many advantages over coal and could be easily transported through pipelines and tankers. By the 20th century, oil had replaced coal in many countries, and natural gas was found in association with petroleum, providing a convenient lighting and heating source. In the 19th century, there was also the rapid development of electrical industries for communication, heating, and power because electricity was easy to transport from the generating stations to where it was needed; soon, it displaced gas as a source of light and became a convenient power source for factories. Trains and ships driven by coal are now mainly driven by oil.

The primary sources of energy at present are coal, oil, and natural gas, of which coal is the most polluting source. These sources are limited and will exhaust faster; eventually, we must learn to adopt alternative fuels. The sooner, the better. India has adopted Western energy models, which is why there is an imbalance in the rural-urban energy supply; the Western energy model is based on a central energy grid system that is easy to borrow, import, and install. To have a more successful energy model, India could have developed an alternative energy path that would relate to its situation and geographical distribution of population, resulting in unemployment and tension in the country. India's reliance on non-conventional energy sources, mainly coal and oil, is estimated to continue for the next two decades.

The lush green fields of India tell us a story of transformation, of a country that was once fighting hunger and starvation to become a global leader in agriculture production; this, as an example, lets us see how India aspires to be a leader in renewable energy (Mint,2023,0:16).

Figure 1.1: Evolution of energy policies in India since Independence.



Source: Wiley Interdisciplinary Reviews.

2.2 INDIA'S ENERGY POLICIES AND APPROACH

Phase I starts from 1947- 1970 during this phase, the energy planning of India focused primarily on electricity supply and growth of the oil and gas sector; the main agenda was to provide policy support for supply adequacy [1]despite the increase in electricity demand which is much higher in the later phase. India also focused on developing infrastructure for the growth of its economy; this period marked the establishment of institutions like the Planning Commission of India, the Central Electricity Authority, and the Energy Survey of India Committee. The planning commission was responsible for efficiently

[1] Supply adequacy refers to the sufficiency of resources within an electricity system to meet the demand for powr consistently.

allocating resources, recommending policy planning, and formulating energy policies during this phase.

The Electricity Supply Act of 1948 recognized the importance of a sustainable power system, which prepared the way for India's energy vision; its primary objective was to rationalize the generation and distribution of electricity and its development on a regional basis; during this phase, State Electricity Boards (SEBs) were introduced by the Central Electricity Authority (CEA), which was founded as a central advisory body for national power planning, policy-making and to monitor progress. Nonetheless, the development of SEB responsibilities carried the original weight of the electricity distribution strategy (Bardhan, et al, 2019). During this time, one of the main goals of energy policy was to regulate the coal-mining industry for the sake of India's energy security; when the British administration built railways in India in 1885, large-scale mining was at its start, and the demand for coal increased to approximately 32 million tons (MTs) by 1950, with railways being the most significant user (31%) and power industry using the remaining 7%.coal board was established in 1951 to ensure mine safety and the conservation of coal resources under Coal Mines Act 1952. By the Coal Bearing Areas Act 1957, the National Coal Development Corporation (NCDC) was established in 1956 to continue coal mining in the public sector. Thousands of mining workers' safety was endangered as the private sector adopted unsafe and unsustainable mining practices for coal; during this phase of the Indian energy policy, climate change adaptation plans and regulations remained a faraway concern (Bardhan, et al, 2019)

The Indian government during this time was clearly focused on taking advantage of economies of scale, which increased attention to the exploration and extraction of natural

gas and oil; the Oil and Natural Gas Commission (ONGC) and the Indian Oil Corporation (IOC) were appointed to handle refining and marketing of oil and its related compounds. The analysis of the energy policy of phase I clarified that in response to the nation's growing energy demand, India concentrated on controlling the primary energy supply sector and attempted to decentralize[2] the power industry.

Following 1970, Phase II started, the emphasis changed to energy conservation in response to the worldwide oil shock[3], which caused the energy crisis; during this time, reducing the usage of petroleum was the main regulatory priority, and one of the achievements of this phase was the regulation of the coal- mining industry, it made it possible for government to divide up earnings from a sovereign resource and make the necessary investments which resulted in coal industry being nationalized in two stages they are; non-coking coal [4]in 1972 and coking coal[5] in1973. Later, in 1975, Coal India Limited (CIL) was formed to develop and design coal mines. This business established the National Thermal Power Corporation (NTPC), and in the same year, it brought regulations and reforms to India's thermal power sector. It also thought about enforcing rules in the "coal-driven" energy industry. While a mandate for conservation evolved in India's energy administration, no steps were taken to replace fossil fuels with sustainable energy sources; during the 1970s, the planning commission chose not to transition to sustainable energy sources but preferred to meet the basic needs of the public by

[2] Decetralized involves generating power from diverse sources such as renewable energy technologies, combined heat and power (CHP) plants, and microgrids which are closer to point of consumption.
[3] 1973 oil crisis also known as "first oil shock" was a period of skyrocketing energy prices and fuel shortages resulting from an embargo by Arab oil producing nations.
[4] Non-coking coal also known as thermal coal, is a type of coal used primarily for power generation, heating, and industrial processes.
[5] Coking coal, also known as metallurgical coal is a type of coal that can be used in the production of coke, a solid carbonaceous residue resulting from the carbonization of coal at high temperaturs in the absence of air.

providing access to electricity and cleaner forms of household energy (Bardhan, et al, 2019).

India's energy situation underwent a significant change in the 1990s with the liberalization from the closed economy; there was Deregulation, privatization, and opening of the energy market to foreign investment. These are policy changes that the Planning Commission of India had implemented.

The primary goal of this phase was the modernization of the energy sector. The creation of the Bureau of Energy Efficiency (BEE) and the writing of the Energy Conservation Bill demonstrate the government's growing concern for sustainable energy policies. Around this time, the environmental aspect of sustainability gained significant importance, and the government started to openly recognize the significance of energy supply-sector policies responsible for climate change. Following 1990, phase III there was a focused push to expand renewable energy sources as the significance of renewables for India's future became important. The Ministry of New and Renewable Energy (MNRE) replaced the Ministry of Non-Conventional Energy Sources (MNES), a distinct ministry founded in 1992. Through long-term supply contracts [6]and power purchase agreements (PPA)[7]with utilities, the Electricity Supply Act was amended in 1991 to permit private investors' widespread participation in foreign investments. The political power that state governments have over the power-distributing sector is one of the fundamental causes of the electricity sector's poor performance, which these changes were unable to remedy. Given this context, the Regulatory Commission Act 1998 was

[6] Long-term supply contracts refers to agreements between a buyer and a supplier for procurement of goods or services over an extended period, typically lasting for several years
[7] PPA is a long-term contract between an electricity generator and a customer.

passed to reorganize the SEBs into the State Electricity Regulatory Commission and establish the Central Electricity Regulatory Commission (CERC). This gave the Indian power industry regulations uniformity, and CERC also introduced availability-based pricing in 2000 and encouraged the use of scientific instruments to settle power contracts.

When economic reforms began in 1991, the public monopoly in the electrical industry was ended. The gross power generation in the nation had increased nine times between the 1970s and the 1990s, with an estimated 480,011 million kWh generated in thermal power plants in 1999. India's top energy suppliers were thermal power, fuelled by coal, with hydro, nuclear, gas, and diesel power plants following. Energy policy was created to protect the environment and ensure an adequate electricity supply for the nation at the lowest possible cost. To promote the development of more environmentally friendly and economically viable technology in the thermal power sector, GOI permitted the private sector to participate in joint ventures and Foreign Direct Investment (FDI) in the power generating sector. During this time, measures to promote sustainability included new capacity creation, plant renovation and modernization, and private sector involvement. insufficient private investment was drawn to the FDI, slowing down the transition to a more efficient coal-based power sector. For the government, replacing these large, inefficient thermal power plants continues to be a significant concern. It continues to be India's most important barrier to sustainable energy strategy

Phase five is India's current phase of climate-active energy planning, which has developed since 2000. The Central Electricity Regulatory Commission (CERC) established availability-based tariffs in 2000, promoting scientific methods for resolving power purchase and sale contracts and establishing the necessary grid discipline. In an

attempt to draw in private investors, the Accelerated Power Development and Reforms Program (APDRP) was introduced in 2002; later, it was substantially enhanced; however, it was undermined by low distribution sector investment and high aggregate technical and commercial (AT&C) loss levels. These policies shaped the Progressive Electricity Act (EA) of 2003 (Bardhan, et al, 2019). Improved competition, accountability, and commercial viability of the industry were the goals of the market-oriented EA 2003 framework. De-licensing thermal generating, encouraging renewable energy and electrification in rural areas, introducing licensed power trading, and establishing a multi-year tariff structure were notable initiatives; EA established open access to transmission and distribution and allowed generators to sell directly to the highest bidder and end users to purchase power from the most economical source

The National Electricity Policy of 2005, the National Tariff Policy of 2006, the Integrated Energy Policy of 2006, and the Hydropower Policy of 2008 were significant policy initiatives after EA 2003. The National Tariff Policy of 2006 and the National Electricity Policy of 2005 played an essential role in creating interstate transmission laws. Furthermore, the establishment of Power Exchange India Limited and Indian Energy Exchange in 2008 improved the nation's state of energy security, they enabled better-informed business and investment decisions, and they also helped to address the supply-demand gap by offering efficient price discovery. An essential first step in reducing grid congestion and broadening the possibilities for market-oriented grid integration of

renewable energy sources was the CERC's adoption of the "smart transmission tariff[8]" in 2010.

In India's sustainable energy policy map, sustainability and energy security received more attention in 2008, the National Action Plan on Climate Change [9](NAPCC). Eight national missions make up the NAPCC, and they all have goals related to the energy sector. These include raising the proportion of solar energy in the primary energy mix and improving energy efficiency through demand-side management, industrial energy savings, and more extensive adoption of energy-efficient appliances and lighting (which include the controversial Bachat Lamp Yojana, which replaced incandescent lamps with subsidized compact fluorescent lights). India made great strides in clean energy and energy efficiency with the passage of the Energy Conservation Act of 2001 and its modification in 2010. The NAPCC prioritized integrating renewable energy sources into the primary energy mix, followed by electricity regulations.

Launched in 2012, the Perform, Achieve, and Trade (PAT) agreement evolved into a market-based energy efficiency trading scheme. Furthermore, the National Mission for Enhanced Energy Efficiency (NMEEE) and Market Transformation on Energy Efficiency (MTEE) were crucial policy tools to instil energy-efficient and energy-saving practices in industries that could meet the high energy demands brought on by the world's rapid urbanization. The decrease in energy intensity [10]

[8] Smart transmission tariffs aimed at promoting the development of smart grids and improving the efficiency and reliability of power transmission network.
[9] NAPCC was introduced by India to address the adverse impacts of climate change and promote sustainable development.
[10] Energy intensity is a measure of the energy inefficiency of an economy, calculated as units of energy per unit of GDP.

Wind energy can be the most appropriate renewable energy source as it already competes with imported coal prices and does not require government support; it can replace power generated from imported coal because wind turbines already exist or can be built with the help of investors. Therefore, it can be easily implemented without any significant support. For solar energy to be widely accessible and reasonable, a robust legislative framework is required.

A crucial part of India's energy subsidy system is regulating power tariff rates[11]. It is more complex since electricity policies and tariff rates vary from state to state and by different consumer class groups. There are subclasses within these classes, and each class has a different tariff rate that varies for consumers in urban and rural areas. India's goal is to integrate renewable energy sources deeply into the nation's energy dynamics, which is impacted by the social cost of fuel subsidies, a crucial price factor in the energy sector.

The thermal power industry of India is focusing on controlling the import of coal pricing as it is the second most expensive Fossil Fuels in India's energy mix; government controls unfairly suppress native coal prices, making coal the most costly Fossil Fuels. Due to subsidies on domestic petroleum products, the oil and natural gas energy industry faces an inconsistency between subsidies and sustainability that impacts the government and oil companies and the monopoly on pricing and greener technology hinders efficiency and competition. This problem is intended to be addressed by the Petroleum and Natural Gas Regulatory Board Act of 2006 (Bardhan, et al, 2019).

In 2015, MNRE set a RE target of 175 GW to be achieved by 2022, primarily from solar PV (100 GW), wind (60GW), biomass (10 GW), and small hydropower stations (5 GW).

[11] The process of setting and adjusting the prices that consumers pay for electricity.

The target is based on regional technology. The following year, in 2016, PM Narendra Modi introduced a scheme called Ujawal Bharat, aiming to electrify areas that are traditionally disconnected by providing 24X7 affordable and environmentally friendly power by 2019, including DISCOMs (electricity distributors) and specific goals which include rural electrification, some villages do not have access to electricity but some who has do not get it for 24 hours, it is essential to note that India generates electricity in excess capacity. Still, there are issues with the transmission and distribution of renewables. The government has solar programs, and significant capacity addition is happening. Even LED lights were distributed at a subsidized rate; they have started this auction process, allowing the project to those who bid to supply electricity at the lowest cost; 7,500 un-electrified villages, as of April 1st, 2015, have been connected to the electricity grid (India Energy Outlook, 2021).

The “Saubhagya 2017” a policy initiative that modified the subsidy load without sacrificing the social cost; under the Saubhagya system, all the households received power through Gross Budgetary Support (GBS), and the families that were included in the 2011 socioeconomic and caste census would receive free energy connections under this initiative while others will have to pay about RS.500 (about USD 7) including five LED lights, a Direct Current (DC) fan, a DC power plug, and five years of repair and maintenance (R&M) comparably Ujjwala Yojana program connects Below Poverty Line (BPL) households to LPG by giving financial assistance these steps aid in transitioning away from the use of highly polluting fuel which contributes to the national burden of diseases. Along with the subsidies, public awareness should be raised about the advantages and disadvantages of renewable energy sources. This will help the citizens

make informed decisions and motivate the government to invest in renewable technologies.

On 11 May 2018, GOI adopted a Scheme to Support the Promotion of Biomass-Based Cogeneration in Sugar Mills and Other Industries in the Country; this program provided Central Financial Assistance (CFA) for projects that utilize biomass like bagasse, agro-based industrial residue, and crop residue, wood produced through energy plantation, weeds, wood waste produced in industrial operations, etc. the CFA will be released in one instalment after successful commissioning and commencement of commercial generation and performance testing of the plant. MNRE also adopted the National Wind-Solar Hybrid Policy in the same year for urban infrastructure and land use; this wind-solar hybrid system would improve grid stability. And extended capital grants for Concentrated Solar Thermal [12](CST) until 2020. The subsidy covers community cooking, solar process heat, and solar cooling.

In 2019, the PM-KUSUM scheme was approved by GOI to provide energy security for the farmers. The scheme aimed to add a solar capacity of 30,800 MW by 2022, and in November 2020 and February 2023, the GOI amended and later extended the PM-KUSUM scheme until 2026 because its aims still needed to be met by 2022 (India Energy Outlook,2021).

"National Mission on Transformative Mobility and Battery Storage" helped India improve its air quality since it has some of the most polluted cities in the world, reduce its oil import dependency, and enhance the uptake of RE and storage solutions. To enhance

[12] Concentrated solar thermal refers to a technology that uses mirrors or lenses to concentrate sunlight onto a small area, typically a receiver, to generate heat.

India's manufacturing competitiveness to attract investments in cutting-edge technology and create efficiencies, enhancing the economic scale and export under the framework of the Atmanirbhar Bharat program with the Production-Linked Incentive (PLI) scheme. In November 2020, PLIs were established for ten sectors, including High-Efficiency Solar PV Modules and Advanced Chemistry Cell (ACC) Battery manufacturing; in September 2021, additional amounts were enacted, focusing on electric and hydrogen-based vehicles and digitalization. India plans to replace its railway system that is operated by Indian railways with "green railways" to achieve net-zero carbon emissions by 2030, including electrifying railways, improving the energy efficiency of locomotives[13] and trains, giving green certification for stations, and switching to renewable sources of energy and 2021, Indian Railways have installed 111 MW of rooftop solar power capacity on various stations and administrative buildings, as of January 2021, a total of 42,354 kilometres of railways have been electrified (Renewables 2023, 2024). The inter-state transmission system (ISTS) fees and losses were eliminated in August 2020 by the Indian Ministry of Power (MoP) for all solar and wind projects that were put into service before June 30, 2023. After that, in June 2021, MoP declared that the waiver would be extended until June 30, 2025 (Renewables 2023, 2024). India has announced an additional capital infusion of RS. 10 billion to Solar Energy Corporation of India (SECI) and RS.15 Billion to the Indian Renewable Energy Development Agency (IREDA) as a part of the Union's 2021-22 Budget; this will enable SECI to tender for 15,000 MW of new solar energy generation capacity attracting investment which will generate 45,000 jobs and also reduce emission by 28.5 million tons of CO2 per year (India energy outlook, 2021) India's Ministry of Petroleum and Natural Gas published a National Policy on Biofuels in 2018

[13] A rail transport vehicles that provide the motive power for trains.

to reduce the import of petroleum by promoting biofuel production; the policy was amended in June 2022. The National Bioenergy Programme, launched in 2022, converted waste to energy and biogas for rural energy generation. Union Cabinet of India approved the National Green Hydrogen Mission, which aims to develop green hydrogen to help reduce GHG emissions by 2030. Thus, GOI has made impressive progress in recent years in increasing citizens' access to electricity and clean cooking; it has set an ambitious vision to give sustainable energy to all its citizens and achieve its biggest goal in the energy sector. Ensuring that all its citizens have access to electricity and clean cooking has been the country's top political agenda; IEA highly commends GOI for shifting towards renewable energy generation, focusing on reaching isolated areas and ensuring reliable electricity supply. India has opened its market for international investors; its institutional framework attracts more investment for its growing needs, makes greater use of market-based solutions, and increases access to affordable energy, raising the living standards of all population segments. According to the Ministry of Commerce and Industry, FDI in India's renewable energy sector stood at USD251 million (Rs 20.5 billion) in the third quarter of the financial year 2023, with the top investing companies being Singapore, Mauritius, the Netherlands, and Japan (Jain,2023). GOI initiatives like Make in India can contribute to broader national priorities in the manufacturing sector. Through this initiative, the government can attract global companies to produce solar PV, lithium, batteries, solar charging, infrastructure, and advanced technologies in India.

Central government policies and initiatives, technological advancements, and significant foreign investment have made India grow remarkably in renewable energy capacity; the government has actively promoted the use of RE sources in various ways through

policies, initiatives, incentives, subsidies, etc., like launching National Solar Mission in 2010 which aimed at installing 100 GW of solar power by 2022 which was later increased to 450 GW by 2030, GOI also launched wind energy program with a target of achieving a capacity of 60 GW by 2022 these targets promotes adoption of RE sources in the country. India has been recognized as a global leader in the energy sector, and IRENA has awarded India the Innovator of the Year award in 2022 for all its efforts in promoting RE through its policies and initiatives; developing countries look for inspiration from India while the country shares its experiences through international forums, including at the International Solar Alliance and the UN Climate Change Conference (Jain, 2023).

There are many drivers for increasing the deployment of RE in India. Chief among them are reflected in the policy debates. They are the desire to reduce GHG emissions from the power and transportation sector substantially and to identify more reliable and long-term energy sources. Most of its oil and gas comes from politically unstable regions. Its reliance on foreign oil is one of the energy security challenges, and moving to renewable energy sources will create green jobs.

It’s a challenging task for policymakers to provide enough energy without damaging the environment. Also, energy has emerged as a critical resource needed to activate all economic activities in the country; emerging economies like India face the twin challenge of achieving a higher standard of living for the people while containing the impact of climate change. (Kaul,2018)

India has historically taken a different approach to policymaking in the energy sector, partly because it had different needs and priorities and also because it had a different

system of government. These factors make it challenging to analyze the policies or find their approach in the energy sector; nevertheless, the critical role of policy will continue to play in the country. India's RE policies are termed as market-oriented due to its emphasis on creating a dynamic power market that increases trade and[i] utilization of renewable energy; the country is transitioning from extended term Power Purchase Agreements (PPAs) to a more flexible and efficient market, enabling better integration of RE sources to the increasing power demand and manage intermittency. (Michael,2024[ii]) Initiatives like the market coupling [14]proposed by the Central Electricity Regulatory Commission (CERC) aim to enhance electricity for procurement efficiency, promote price transparency, foster competition, and drive innovation in renewable technologies; by adopting a market-driven approach, India seeks to leverage its renewable energy potential effectively attracting investment to achieve the targets in this sector.

India’s shift towards a power dynamic market aligns with its goal of increasing renewable energy capacity and reducing reliance on fossil fuels. This shows a strategic transition towards a more market-oriented RE policy framework. India’s approach in the energy sector is focused on achieving a more inclusive and sustainable energy system; the country has made significant policy choices in its energy transition, focusing on eliminating energy poverty and achieving universal access to energy; its approach and policies reflect on India’s efforts to transition towards clean energy, address energy

[14] Market coupling is a mechanism that connects multiple electricity markets to create a single, integrated market place for electricity to flow seamlessly across borders.

trilemma [15]challenges and achieve ambitious targets while emphasizing the need for policy support, subsidy reallocation, and infrastructure improvement.

A policy is just as good as its implementation; in the context of India, rather than policy design, which is absolutely a stunning design in the renewable energy sector, its weakness is program implementation, which remains a hurdle in achieving optimal outcomes, the key to achieve success in India's strategic energy action plan lies in designing an effective implementation strategy, adopting and proliferating the use of smart grid in the energy distribution system is the most important and immediate step needs to be taken.

2.3 POLITICAL SYSTEM AND ENERGY SECTOR GOVERNANCE

The Prime Minister is in charge of the vast energy portfolio that is divided between the federal and state governments, with some degree of state autonomy over energy policy. India does not have a single ministry in charge of the energy policy, but GOI has at least five ministries that are responsible for energy; the Ministry of Power (MoP), the Ministry of Petroleum and Natural Gas (MoPNG), the Ministry of New and Renewable Energy (MNRE), the Ministry of Coal (MoC) and the Department of Atomic Energy (DAE).

The MoP governs India's electricity sector and hosts the Bureau of Energy Efficiency (BEE). The Central Electricity Authority (CEA) is the principal advisor of the MoP and is also responsible for technical coordination and supervision of programs and data collection through the five-year National Electricity Plan. Public-sector undertakings (PSUs) under the MoP include Power Finance Corporation (PFC) and Rural

[15] Energy Trilemma refers to the challenges of finding a balance between three critical factors inenergy policy: energy security, affordability, and sustainability.

Electrification Corporation, which are non-banking financial institutions that provide loans for power sector development, National Thermal Power Corporation (NTPC) and National Hydroelectricity Power Corporation (NHPC) is the largest hydropower producer.

Some energy-related departments are directly under the Prime Minister's Office, including the DAE, which works on the development of nuclear power technology and application of other radiation technologies, and NITI Aayoug is an official think tank and policy advisory body of GOI which co-ordinates activities that are inter-ministerial in nature. The MNRE is in charge of the development of solar, wind, and other renewables in India; under the MNRE are the National Institute of Solar Energy, the National Institute of Wind Energy, and the Indian Renewable Energy Development Agency (IREDA); MoPNG manages biofuels.

The MoC is responsible for exploring, exploiting, and developing coal and lignite resources in India. India's largest coal mining company, Coal India Limited (CIL), is under the authority of MoC.

The MoPNG is in charge of policies related to the petroleum and natural gas sector; most of the oil and gas companies in India are PSUs, which are organized through MoPNG which include the largest oil and gas producer, Oil and Natural Gas Corporation (ONGC) and the largest refiner and retailer Indian Oil Corporation Limited (IOCL) and India's largest state-owned natural gas company Gas Authority of India Limited (GAIL), with activities in production, transmission, distribution, and sales.

The Ministry of Commerce and Industry and its Department of Promotion of Industry and Internal Trade are in charge of the Make in India program to develop domestic manufacturing, including in the energy sector; other ministries that are indirectly dealing with energy issues are the Ministry of Finance which looks into subsidy programs and financial health and restructuring of the energy sector, the Ministry of Railways manages India's rail network and operations, Ministry of Science and Technology (MoST) organizes and coordinates science and technology activities, ministry of Statistic and Programme Implementation (MoSPI) in charge of collecting and disseminating a broad range of statistics adding to it the Department of Chemicals and Petrochemicals under Ministry of Chemicals and Fertilisers responsible for policy making, planning, developing and regulation of chemicals and petrochemical industries in India.

The energy policy system in India does not have a single window operation and implementation system. However, it is managed autonomously by different ministries for their sector; thus, considering vital future growth in the energy sector, a permanent framework for long-term energy policy is highly recommended to establish clarity for all stakeholders in the energy sector. Another hurdle in the energy policy is concurrent competence matter in India, with power authority in the hands of state government for setting their mandates, standards, and energy subsidy programs; differences in the availability of resources and economic development lead to diverse policies across the country, this causes complexity in the coordination of energy policy for GOI, therefore implementation and administration of policies and measures should be improved.

2.4 INDIA'S AIM AND APPROACH TOWARDS RE, ITS RESPONSE TO CARBON EMISSION, AND CLIMATE CHANGE

India has recognized the urgent need to address climate change and reduce its footprint. The GOI has set ambitious targets to increase the share of renewable energy in its total energy mix; its target included achieving 175GW by 2022 with 100GW from solar energy, 60GW from wind energy, and remaining from other sources like biomass and small hydro projects. India has specific aims to create a sustainable future. GOI is committed to reducing total projected carbon emission by 2030 to 1 billion tonnes; it also aims to reduce the carbon intensity [16]of the nation's economy by less than 45% by the end of the decade and achieve net zero carbon emission by 2070. India has invested in solar parks and became the first nation to have a solar park in Gujarat. It aims to have solar cities approved to set up 57 solar parks of 39.28 GW across the country. Union Cabinet approved the National Green Hydrogen Mission with an initial outlay of INR 19.744Cr (India's Solar Power Revolution: Leading the way in Renewable. nd, 2023).

In 2018, a wind-solar hybrid policy was announced to promote an extensive grid connected to solar PV and wind-hybrid systems for efficiently utilizing transmission infrastructure and land. This also addresses the challenge of one renewable power source: combining solar and wind to achieve better grid stability. AatmaNirbhar Bharat scheme was introduced to manufacture solar PV and impose a 25% essential customs duty on solar cells and 40% on solar PV modules (India's Solar Power Revolution: Leading the way in Renewable. nd, 2023). India's private sector has shown strong support for

[16] Carbon intensity refers to the volume of carbon emissions per unit of activity, like generating a product or economic output. It measures the amount of carbon dioxide and other greenhouse gases emitted per unit of activity, highlighting the environmental impact of production processes.

government efforts to promote energy transition, like the Reliance group increased its energy transition commitments aiming to install at least 100GWs of renewable energy generation capacity by 2030, including a fully integrated solar giga factory in Jamnagar.

Solar energy has emerged as a focus area in India's energy transition. There is a significant increase in the installation and use of solar energy, driven by low cost.

In 2021, India's Prime Minister addressed the COP26 held SEC Centre in Glasgow, Scotland, United Kingdom, announced the "Panchamrit" or the five-point agenda to fight CC, including reaching 500 GW energy capacity from non-fossil by 2030, fulfilling 50%of its energy requirements through RE by 2030, reducing total projected carbon emissions by one billion tons till 2030, reducing carbon intensity of economy by 45 % by 2030 over 2005 levels, and achieving the target of net zero emission by 2070. (ITA,2024) the country is using new ideas and economic development models, avoiding an intensive approach like other countries have already persuaded in the past; it will also provide a blueprint for other developing economies. Even though fossil fuels dominates its power sector, the country has set ambitious goals to increase the share of renewable and nuclear energy; according to GOI Press Information Bureau, the share of non-fossil fuel in total electricity production during the year 2022-23 was 22.45 % significant efforts are made to reduce the growth of GHG emissions and dependence on energy imports, at the same time enhance India's energy security. (ITA,2024)

India is one of the first nations to establish the National Action Plan on Climate Change (NAPCC) in 2008, acknowledging the necessity of global initiatives and methods to

address the climate crisis, it participated in the 2015 Paris Accord's conclusion, which included specific national commitments, and India also committed to achieving its aim.

The vision of NAPCC is to enable India to be a prosperous and efficient economy that is self-sustaining for both present and future generations. The four principles of this action plan are deploying a sustainable development strategy that reduces poverty, vulnerability, and its impact on climate change, secondly attaining India's growth objectives through a shift in energy practices that encourages sustainability while leading to a decline in GHG emission, thirdly developing and installing technologies at a rapid pace that aid in the adaption and mitigation of GHGs and lastly establishing new market and voluntary mechanisms that stimulate sustainable development.

India signed a climate change agreement under the UN Framework Convention on Climate Change (UNFCCC) at the Conference of the Parties (COP21) in Paris in December 2015. Countries participating in COP21 have submitted their Intended Nationally Determined Contribution (INDCs), which specifies their emission reduction commitments through 2025 or 2030. Moreover, India has also submitted INDC. Its plan for climate mitigation under the Paris Agreement stands out for its ambitions against weaker commitments from the top emitters. The Climate Action Tracker maintained by a consortium of scientists evaluating the efficacy of NDCs that countries submitted to the UN rates India's plan as the only NDC among the top ten emitters to be "compatible" with the Paris Agreement's 2^{o} Celsius. (Outka U, 2020)

The need for climate finance has become more urgent as the world confronts the climate crisis, with the COP28 under the UN Climate Change Conference. India has contributed 3% of the accumulated stock of GHG emissions that is responsible for the current climate crises; various global indices rank India among the most climate-vulnerable countries, making it a claimant to a share of the loss and damage funds; it's ready to take firm actions and adaptation in climate mitigation after taking financial assistance, irrespective of whether loss and damage funds are available to India, it will tackle climate impacts. (Kashwan, 2023) Its participation at COP28 gives us the chief importance of climate financing in shaping a sustainable future for all. India's approach at COP28 recognizes that adaption and equity are cornerstones in the fight against climate change. Climate justice means vulnerable countries should receive financial support and infrastructures needed to combat the impacts of CC; India's Secretary of the Ministry of Environment, Forest and Climate Change emphasizes the necessity for action and discussion on loss and damages along with operationalization of the loss and damage fund this shows India's steadfast commitment to addressing the human and economic toll of Climate Change. Yet, financial challenges are ahead, and addressing the climate crisis requires massive financial obligations. It is estimated that the global transition to a low-carbon economy will require an annual investment of four to six trillion USD by 2050; however, to achieve net-zero emission by 2030, the RE sector alone necessitates an investment of at least four trillion USD yearly, moreover developing countries will require approximately six trillion USD between 2022-2030 to successfully implement their climate action plans, to meet this at least 5% of the global GDP must be channelled towards climate action each year (Choksi,2023). And that this can only be secured when wealthy countries take the lead in combatting climate change.

India has taken significant steps to address the issue of climate finance, realizing the importance of the situation, like the introduction of the Green Credit Initiative [17]at COP28, demonstrating its commitment to the environment; the goal is to establish an international trading platform that would enable the sharing of cutting-edge environmental policies and tools. The introduction of LiFE, the Lifestyle for Environment project, highlights India's proactive stand made by Prime Minister Narendra Modi. Mission The goal of life is to reduce the average person's carbon footprint by encouraging thoughtful use rather than unnecessary consumption.

The National Clean Energy Fund and the National Adaptation Fund for Climate Change (NAFCC) are two notable instances of India's dedication to supporting clean energy and climate-resilient infrastructure. However, despite these admirable initiatives, there are still significant financing shortfalls. With only RS 64 trillion already accessible and ₹54 trillion uncontrolled, the Climate Finance Working Group estimates that ₹118 trillion would be needed to address climate change. This calls for creative funding alternatives. India's commercial banks and Development Financial Institutions (DFIs) must be critical players in sourcing money domestically and directing foreign resources to close this gap effectively. (Choksi,2023)

India is a prime example of climate finance advocacy due to its proactive participation, cooperative efforts with established and emerging nations, and chronic commitment to addressing climate issues. However, wealthy countries must meet their financial

[17] The initiative is to incentivize environmentally conscious practices and promote sustainable development, aiming to create market-based mechanism for providing incentives in the form of Green Credits to various stakeholders.

obligations and significantly change the international monetary system to provide climate financing at the scale required to deal with the global climate problem.

The world is focused on India and its plans for climate finance as we set off on the path to COP28. The country's constant dedication and determination are a ray of hope for a sustainable future at this critical point. The world community needs to unify to pursue climate financing and a compelling journey toward a sustainable future for future generations. The moment for action is now.

CHAPTER 3

POLITICAL ECONOMY OF RENEWABLE ENERGY IN INDIA

3.1 INDIA'S RENEWABLE ENERGY SCENARIO

India, home to around 1.3 billion people, has a vast energy need to support its quickly expanding economy. India was an energy-deficient country when it gained independence, but attempts to make it energy-independent have persisted for more than 70 years. We are a power surplus nation today with more than four lakh MW of installed electricity capacity. India is rapidly changing its power generation mix to include more renewable energy that is in line with sustainable development goals. India is the third global producer of renewable energy, with non-fossil fuel sources accounting for 40% of the country's installed electrical capacity (Press Information Bureau Delhi, 2024).

When India gained its independence, it was still a developing country and mainly relied on coal to supply its energy needs. India has always been dedicated to exploring alternative energy sources for sustainable growth. Major hydroelectric power projects first emerged in India's energy landscape, marking the beginning of the energy era. Numerous legislative and regulatory actions have encouraged the growth of hydropower and made investments easier over time. We currently rank fifth worldwide for the potential to produce helpful hydropower.

The Bhabha Atomic Research Centre (BARC) was established in the 1950s to ensure the nation's long-term energy independence. We are currently the only developing country with nuclear reactors for generating power that have been conceived, tested, and installed domestically. Over several decades of intensive scientific research and technology development have made this possible.

The National Aeronautical Laboratory (NAL) in India produced windmills in the 1960s, mainly for irrigation water supply. This marked the beginning of work on wind energy in that country. Wind's continual movement, particularly in the Southern, Western, and North Western regions, India own the world's fourth-greatest wind power capacity.

Significant number of Indian has benefited from solar energy-based applications that provide environmentally benign energy for cooking, lighting, and other uses. India has led the International Solar Alliance (ISA), an action-oriented, member-driven, cooperative platform for more significant deployment of solar energy technologies due to its considerable success in solar energy solutions. All United Nations members are eligible to join the ISA; currently, 107 nations have ratified the ISA Framework Agreement. The Alliance wants to make the world greener by effectively using solar energy to lessen reliance on fossil fuels.

India has likewise relied heavily on biomass as a source of energy. It is carbon-neutral, abundant, renewable, and has the potential to provide a sizable number of jobs in rural areas. Technological advancements at a breakneck pace have made thermal power plants more affordable and energy-efficient. Since the middle of the 1990s, India has implemented a biomass power/co-generation program in thermal plants throughout the

nation to lessen its carbon footprint in the production of thermal power. More than 800 biomass power and bagasse/non-bagasse cogeneration projects have been erected nationwide to input electricity into the grid.

Since 2000, the amount of energy consumed has more than doubled due to substantial economic expansion and the population increase of India, which is about to become the largest country in the world. 2019 saw the achievement of nearly universal home access to electricity, which means that in less than 20 years, over 900 million people have acquired an electrical connection (world energy outlook, 2021).

India's energy sector and policymakers will face enormous challenges due to the country's ongoing urbanization and industrialization. Significant energy consumption and service quality variations exist between states and rural and urban areas. Per capita energy use is significantly less than half of the worldwide average. For consumers in India, the cost and consistency of the energy supply are the two main issues (world energy outlook, 2021).

India is the third-largest global emitter of CO2. Specifically, its power sector has a carbon intensity that is significantly higher than the worldwide average. Particulate matter emissions also play a significant role in air pollution, which has become one of India's most delicate environmental and social challenges. In 2019, ambient and home air pollution caused over a million premature deaths.

India has implemented numerous regulations to ensure a sustainable and safe energy supply in the future. No one opinion is expressed in this Outlook regarding what India's energy future may hold. Instead, it is based on a thorough analysis of today's energy markets, technologies, and regulations (world energy outlook, 2021).

According to the Stated Policies Scenario [18](STEPS), by 2021 the epidemic will gradually be brought under control. In light of this, it evaluates the likely path that the current policy framework and aims appear to take the Indian energy industry, accounting for various practical considerations that may impact their actualization. The India Vision Case [19](IVC) adopts a more upbeat perspective regarding the rate of long-term growth and economic recovery, as well as the likelihood of India achieving its declared goals for energy policy; in contrast to the STEPS, the Delayed Recovery Scenario (DRS) looks at the effects of a longer-lasting pandemic that has a more significant influence on a variety of social, economic, and energy-related variables, Using a different methodology, the Sustainable Development Scenario (SDS) looks at what mix of measures would be required to accomplish specified international climate, clean air, and energy access targets including the Paris Agreement working backward from these goals.

India is the world's third-largest energy consumer. According to the REN21 Renewables 2022 Global Status Report, India ranks fourth in the world for installed capacity of renewable energy (including large hydro), fourth for wind power, and fourth for solar power. The nation has increased its ambition to 500 GW of non-fossil fuel-based energy by 2030 at COP26. Under the Panchamrit[20], this has been a crucial commitment. This is the most significant renewable energy expansion plan in the world (Renewable Energy in India- Indian power industry investment, 2022).

[18] STEPS is a projection that assesses the likely direction of India's energy sector based on current policy settings and targets. https://www.iea.org/reports/india-energy-outlook-2021/energy-in-india-today
[19] IVC presents an optimistic view of India's energy future, focusing on economic recovery, structural reforms, and transition to "gas-based economy" https://www.iea.org/reports/india-energy-outlook-2021/energy-in-india-today
[20] Panchamrit refers to India's commitment towards achieving net-zero carbon emissions by 2070 through a comprehensive strategy.

With large hydro and nuclear included, India's installed non-fossil fuel capacity has expanded by 396% in the last 8.5 years to exceed 190.97 GW, or over 44% of the nation's total capacity as of February 2024. With a 9.83% annual growth in renewable energy additions in 2022, India had the highest growth. As of February 2024, the installed solar energy capacity has grown 30 times during the previous nine years to 75.57 GW. The National Institute of Solar Energy (NISE) has projected that India has a solar energy potential of 748 GWp. Since 2014, the installed capacity of renewable energy, especially large hydro, has expanded by over 128%. (Renewable Energy in India- Indian power industry investment, 2022).

3.2 RENEWABLE ENERGY POTENTIAL OF INDIA

3.2.1 Solar

India has vast solar energy potential, with about 5,000 trillion kWh per year over its land area. Solar Photovoltaic power can be harnessed to increase the scale and rapid capacity addition, and its Off-grid decentralized and low-temperature applications are advantageous for rural and urban areas; solar energy has benefited millions of people in the Indian villages by meeting their cooking, lighting, and other energy needs in an environmentally friendly manner, it supports sustainable growth and is essential for energy security. India’s National Institute of Solar Energy (NISE) has assessed the country’s solar potential for 748GW, with the National Solar Mission (NSM) as a critical mission; it was launched in 2010 and aims to promote ecologically sustainable growth and address energy security challenges, also aims to establish India as a global leader in solar energy, aligning with India’s Nationally Determined Contribution targets (MNRE

annual report,2023). GOI has launched various schemes to encourage the generation of solar power, like the Solar Parks, Viability Gap Filling (VGF) scheme, Central Public Sector Undertaking (CPSU), Defence Scheme, Canal bank and Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme and more, government has announced several measures to promote RE including allowing 100% FDI, wavering Inter-State Transmission System (ISTS) charges for solar and wind power projects, establishing a Project Development Cell and implementing tariff-based competitive bidding processes. Additionally, the government has issued orders for timely power payment, promoted renewable energy through Green Energy Open Access Rules 2022, and launched the Green Term Ahead Market for renewable energy power sales, now India stands 5^{th} in solar PV deployment across the globe as of 2022, and its solar power installed capacity has reached around 70.10GW as of 30-06-2023 (MNRE annual report, 2023).

The Off-grid Solar PV Applications program aimed at providing solar PV-based applications in areas without grid power; it covers various applications like solar home lighting, street lighting, power plants, pumps, lanterns, and study lamps, the National Solar Mission of 2010 has set targets of 2000MW equivalent of solar off-grid and decentralized PV system by 2022. The program has been expanded in three phases, focusing on rural development and 118 MWp equivalent solar power capacity by 31.03.2021 (MNRE annual report, 2023).

The government has launched Pradhan Mantri Kisan Urja Suraksha evam Uttan Mahabhiyan (PM KUSUM) to install solar pumps in off-grid areas and solarize existing agriculture pumps. The Ministry of Power launched the Atal Jyoti Yojana (AJAY) in

2016 to install solar street lighting systems in states with less than 50% of households covered with grid power; the program was extended to other states in 2018 and was closed for new sanctions due to COVID-19 pandemic. The government also distributed 70 lakh solar study lamps to school-going children in five states, with 50% un-electrified households (MNRE annual report, 2023).

India's solar power sector is rapidly growing, supporting sustainable growth and energy security. The government has launched various schemes to encourage solar power generation, including Solar Park, VGF, CPSU, Defence, Canal bank, Bundling, and Grid Connected Solar Rooftop Schemes. As of 30-06-2023, India has commissioned 70.10 GW of solar projects, including ground-mounted, rooftop, and off-grid projects. (MNRE annual report, 2023).

3.2.2 Wind sector

India's wind energy sector, led by the indigenous industry, has grown significantly, with a robust ecosystem and manufacturing base of about 15000MW annually. The government promotes wind power projects through private sector investment, providing fiscal and financial incentives like Accelerated Depreciation benefits and concessional custom duty exemption. The government has also implemented measures to promote wind capacity installation, such as declaring a trajectory for Wind Renewable Purchase Obligation up to 2030, waiving ISTI charges for projects, and implementing guidelines for a transparent, cost-effective procurement process. (MNRE annual report, 2023)

The National Institute of Wind Energy (NIWE) has installed over 900 wind-monitoring stations nationwide, indicating a gross wind power potential of 695.50 at 120 meters and 1163.9 GW at 150 meters. (MNRE annual report, 2023)

3.2.3 Green Hydrogen

India aims for energy independence by 2047 and a net zero by 2070, with Green Hydrogen playing a significant role in achieving these goals. Green Hydrogen is produced through electrolysis, a process where water is split into hydrogen and oxygen using renewable energy sources like solar, wind, or hydropower. It can replace fossil fuels in sectors like transportation, shipping, and steel and be a backup energy source for renewable energy plants. It can also be used in fuel cells for vehicles, heating systems, and chemical and fertilizer production. India has launched the National Green Hydrogen Mission with a target of 5 million tons of Green Hydrogen per annum. Green Hydrogen's importance in achieving energy independence is significant, as it reduces dependence on fossil fuels and provides a stable and reliable energy source.

3.2.4 Hydro Power

Hydro Power projects are classified as large and small based on size. In India, plants with a capacity of 25 MW or below are classified as Small Hydro. The Ministry of Power was responsible for hydropower before 1989, and in 1989, a plant capacity of up to 3MW was transferred to the Ministry of New and Renewable Energy. The Ministry promoted Small Hydro through initiatives and entrusted plant capacity to the MNRE in 1999. (MNRE annual report, 2024)

3.2.5 Bioenergy

India aims to achieve 50% of its electricity capacity from non-fossil fuel-based resources by 2030 and net zero by 2070. India is utilizing domestically available renewable energy alternatives, including modern bioenergy, to achieve these targets. This energy recovery from biomass and waste offers social and environmental benefits, including pollution mitigation, job creation, and reduced energy import bills. The Ministry of New and Renewable Energy has notified the National Bioenergy Program for Rs.858 crore, including waste-to-energy, biomass, and biogas programs. (MNRE annual report, 2023)

MNRE has been implementing a Program on Energy from Urban, Industrial, Agricultural, and Municipal Solid Waste since 2018. The new 2021-22 to 2025-26 guidelines will provide Central Financial Assistance for large biogas, BioCNG, and power plant projects. India aims to produce 15 MMT of compressed biogas-CBG from 5000 plants by 2023, with the BioCNG component supporting Sustainable Alternative Towards Affordable Transport [21](SATAT) initiatives. It has been promoting Biomass Power and Bagasse Cogeneration since the 1990s. The Biomass-based Cogeneration Program, launched in May 2018, aims to maximize biomass resources in sugar mills and industries. The program now supports manufacturing pellets [22]and briquettes[2324] for power generation, reducing stubble burning in northern states. Central Financial Assistance will be available

[21] SATAT is an initiative to promote compressed Bio-Gas as green and sustainable transport fuel. https://www.hindustanpetroleum.com/pages/satat

[22] Biomass pellets are cylindrical sticks made from various biomass materials, compressed under high pressure to form uniform shapes, size, and high energy content, commonly used in residential heating, industrial heating and power generation.

[23] Both pellets and briquettes are utilizeds as solid biofuels. https://steamaxindia.com/pelletization-and-briquetting/

[24] Biomass briquettes are denser blocks or stick with defined shapes like cylinders or squares, produced by compacting biomass under high pressure. They are used in power generation, co-fired with coal or independently in power plants to produce electricity.

for pellet and briquette projects from 2021-22 to 2025-26. The ministry has supported small biogas plants since 1981-82 for rural cooking and lighting. Since 2005-06, it has supported medium-sized biogas plants for decentralized power generation and thermal energy applications. The new 2021-22 to 2025-26 scheme offers enhanced financial assistance for biogas plant setups. (MNRE annual report, 2023)

3.2.6 Energy Storage age system

India aims to achieve 50% non-fossil fuel-based energy capacity and reduce GDP emission intensity by 45% by 2030. However, incorporating variable and intermittent renewable energy challenges grid stability and uninterrupted power supply. Energy Storage Systems (ESS) can help reduce variability, improve grid stability, and reduce peak deficits and tariffs. They also reduce carbon emissions and defer transmission and distribution capex, The Central Electricity Authority's (CEA) National Electricity Plan (NEP) 2023 projects that in 2026–2027, the required energy storage capacity will be 82.37 GWh (47.65 GWh from PSP and 34.72 GWh from BESS). The Ministry of Power has also been informed of the long-term trajectory for Energy Storage Obligations (ESO) to guarantee that obligated entities have enough storage capacity. According to the trajectory, the ESO will rise by 0.5% annually, starting from 1% in FY 2023–2024 and ending at 4% in FY 2029–2030. This requirement will only be deemed satisfied when, annually, at least 85% of the total energy stored comes from renewable energy sources. There are numerous energy storage technologies accessible, including chemical, mechanical, thermal, and electrochemical storage systems. (MNRE annual report, 2023)

Table 3.1 Renewable Energy Mix by Source (GW)

Source	As of 2022	As of 2023	Target for 2030
Wind Power	40.35	42.86	140
Solar Power	53.99	67.07	280
Biomass Power	10.20	10.24	10
Small Hydro	4.84	4.94	70
Waste-to-Energy	0.477	0.55	No Target
Total	109.88	125.69	500

Source: Indian Central Electricity Authority

India has massive RE potential that is yet to be fully exploited; it's a large developing economy with massive energy demand growth, and the country not only needs to make a seismic shift from FF to RE but also has new incremental demand that needs to be met through additional RE capacity. India is facing a much more significant challenge than many other countries. On top of that, it must set up a considerable amount of RE capacity, which will require cheaper financial resources and greater access to clean energy technologies. Also, wind and solar energy are interconnected, so India needs to build an entire ecosystem around renewable energy.

This involves investing in flexible generation sources like battery storage and pumped hydro, expansion of transmission and distribution networks, modernization and digitalization of gird, domestic manufacturing of inputs like solar modules, solar cells, wafers, and electrolyzers, promoting electric vehicles, and more decentralized renewable energy like rooftop solar. (Garg,2022)

3.3 INDIA'S ENERGY TRANSITION

The energy transition is not new; in the past, we have seen substantial energy shifts like the transition from using wood to using coal in the 19th century or from coal to oil in the 20th century. What distinguishes this transition from its predecessors is the need and urgency to protect the planet from the most significant threat it has ever faced, "climate change." The energy transition is essential to protect the planet from climate change's effects. Using renewable sources will benefit the environment, and electrification will reduce pollution and improve air quality. Also, energy transition affords enormous opportunities to boost economic well-being, growth in employment, and social development of the community involved.

Technology has become an integral part of our modern life; we are so dependent on technology, which is making our life easier, but to develop this technology or to make use of it, knowing or unknowingly, we have been damaging our environment little by little causing pollution, and depletion of natural resources that has high risk of problems caused by climate change.

Global climate change is mainly caused by worldwide GHG and CO_2 emissions by developed and developing countries; these countries are highly dependent on fossil fuels

like Coal, oil, and gas. When climate change has become a reality, countries are now trying to reduce these emissions by reducing their dependence on fossil fuels and finding alternative energy sources like renewable energy. Today, 80% of our energy production is through fossil fuels, but clean energy is gaining momentum.

It is believed that a crisis like climate change has provided us with opportunities to change the course of development, to have a model where people benefit, and to have less environmental emissions, like India's Green Deal [25](c). This deal does not compromise on the need to improve the living standards of the ordinary people of India. India's transition to green energy will be possible at the cost of development, which is undesirable. It's true that economic development requires energy, but that energy does not need to be generated by fossil fuel. Developing countries like India should not consider the growth model of the North for development, which we know is not only responsible for the greatest artificial crisis in history but is also a failed model of development. Instead, the country should take the lead in developing RE technologies like what China has done in solar energy; India should break away from the north-dependent development model and make use of the abundance of renewable natural resources available in the country, also chalking out an independent, greener path of development can provide countries in the South the moral ground to force the North to come to the table for negotiations. Despite all the misery caused by COVID-19, there was a small silver lining: a decline in carbon and other harmful gas emissions resulting from a halt in the production of commodities other than producing that is essential, which reminded us of the real solution to the problem of the climate crisis, data on the emission across the world shows a significant

[25] IGD proposes a comprehensive strategy to address India's economic slowdown, healthcare challenges and environmental concerns through a commitment to spend 10% of GDP on green energy programs.

dip in carbon emission during the lockdown, no international treaty or green energy transition in the world has ever brought the emission down to this extent. Therefore, it has opened up the possibility of discussing ways to tackle the climate crisis.

As the world comes to terms with the enormity of the threat posed by the Climate Change, India has emerged as one of the world's most extensive clean energy expansion programs. Climate change is also one reason countries are shifting towards renewable energy. The critical thing in energy transition is that it should be inclusive and must not leave anyone behind. The energy transition is a political decision that is driven by the social, economic, geopolitical, and environmental objectives of a country; the decision to shift away from a particular energy mix can be because of a change in the country's political stand on energy and domestic factors, various RE programs contribute significantly to employment generation, for example, biomass power generation attracts investment of over Rs.600 crores (120million USD) which generated more than 5000 million units of electricity and employment for more than 10 million in rural areas and other renewable energy sources like solar, wind also have similar benefits of employment, so transition to clean energy can also be influenced by socio-political factors. The country's economic targets drive energy consumption growth to meet its net zero targets by 2040 and have energy security. India prioritizes diversifying fuel sources and improving domestic supply capabilities; ensuring continuous energy supply is crucial, so increasing the share of alternatives is essential to meet economic targets and facilitate the transition. Geopolitical challenges significantly impact energy transition policies in the countries. For example, in the 1970s, because of Arab oil embargo from the Persian Gulf

regions led to changes in policies in countries like Brazil's Pro-alcohol [26]policy and promoted ethanol production, the United States increased biofuel production, and nuclear power was promoted as a significant supply alternative and in India initiatives like Energy Conservation Act 2001, Electricity Act 2003, Integrated Energy Policy and Draft Renewable Energy Policy have catalyzed the energy transition in the country. (Janardhanan,2012) environmental factors have concerned many countries to prioritize energy transition shifting away from FF to environment-friendly low-carbon energy sources such as renewables; as the country aims for 10% GDP growth, target energy consumption is also expected to grow, so keeping in mind the environmental factors and to address climate mitigation, large-scale investment is being made in renewable energy infrastructure, technology, and energy access. (Janardhanan,2012)

There has been a sharp increase in the investment of the RE sector from domestic and foreign sources, with more than $42 billion of investment since 2014 and around $7 billion in foreign direct investment (FDI) between 2000 and 2018, multilateral and bilateral agencies as well as sovereign wealth funds have pumped FDI into the Indian green energy space, in solar and wind power generation firms, electric vehicles and storage projects. (World Economic Forum,2022) The wind sector attracted almost half the total investment of 3.4 billion USD, but it was the lowest since 2009. On the other hand, solar was the only sector with investment growth in India in 2014.(Kumarankandath,2015) Moreover, it helped the country maintain its position as the world's 7th largest clean energy investor. It was said that the government elected that year supported clean energy reforms, including unbundling power distribution,

[26] Pro-alcohol policy as known as proalcool program launched in 1970 to promote the use of ethanol as a fuel for vehicles aiming to reduce country's dependence on imported oil.

enforcement of renewable purchase obligations, and introducing renewable generation obligations on power producers. In the years ahead, India attracted billions of FDI. We aimed to achieve 175GW of renewable power, including 100GW of solar power, by 2022. Each sector's installation capacity was increased compared to the previous years. The RE sector in India saw substantial investments, with the country offering financial and promotional incentives like capital subsidy, accelerated depreciation, waiver of inter-state transmission charges and losses, Viability Gap Funding (VGF), and permitting FDI up to 100% under the automatic route. The government encouraged renewable energy sector investment by providing them with financial assistance in various forms. The solar energy sector secured funding of 1.55 billion in 2023; International Finance Corporation [27](IFC), Villgro and U.S. International Development Finance Corporation (DFC) emerged as the most active investors in the space with "Centre for Innovation, Incubation, and Entrepreneurship" (CIIE), Social Alpha, and Villgro leading seed-stage investments [28]and Acumen, CIIE, and Falcon Maan solar power LLC [29](FMO) dominated early-stage investments. The top late-stage investors are Axis Bank, British International, and Kohlberg Kravis Roberts (KKR). (ETEnergyWorld,2024) India relies on imports to expand its capacity for solar-powered energy generation, and the Indian market's demand outpaces the current domestic supply. The central government requires an additional 35GW of solar panel generation capacity installed annually, yet the country has only 4GW of operational solar cell manufacturing capacity as of 2023. A $425 million loan from DFC to TP Solar Limited, a subsidiary of Tata Power Renewable Energy Limited,

[27] IFC is a leading financier of low-cost renewable energy, https://www.ifc.org/en/what-we-do/sector-expertise/infrastructure/energy
[28] Seed stage investment refers to initial round of financing that a start-up receives in its early stages of development.
[29] FMO, AVAADA ENERGY PRIVATE LIMITED, https://www.fmo.nl/project-detail/42893

will finance the construction and operation of greenfield 4GW solar cell and 4GW solar module manufacturing facilities in India; this investment will support India's ambitious program to increase renewable energy generation while advancing global energy transition to diversify supply. (DFC, Building solar capacity in India[iii]) renewable energy-focused deep technology start-up Renkube announced that it has secured RS 2.4 crores in a seed funding round led by CIIE.CO. Renkube is the world's first company to offer a motion-free tracking solution embedded in glass design for solar panels. (ETEnergyWorld, 2022) Avaada Energy Pvt Ltd is an independent power producer of renewable energy projects based in India; FMO invested 25 million USD in early 2019 and is giving top-up investment of 10 million USD to achieve 3GW-4GE of operational capacity. Serentica is focused on industrial decarbonization in India. It provides round-the-clock clean energy solutions to help transition on a large scale, energy-intensive industries to clean energy; its activities include providing long-term power purchase agreements (PPAs) and working with customers to design pathways to net zero electricity. (Segal, 2023)

India's energy supply has been increasing day by day with its increasing population. In the last few years, it has given millions of its citizens electricity through green energy (Pathak,2023). Based on India's current progress in the RE sector, green hydrogen will significantly impact India's overall energy sector; it will provide a sustainable solution for the transport sector. India has invested in various green energy projects to promote renewable energy sources while trying to reduce carbon emissions.

The country is working on building the world's largest renewable energy project called Khavda Renewable Energy Park, near its border with Pakistan, located in the Rann of

Kutch in India's western Gujarat state; the project will use solar and wind equipment to produce electricity which will cover an area of 762 sq km costing at least 2.26 billion USD. The project is currently under development and is making significant progress; it generates 30GW of electricity annually, which can power nearly 16-18 million homes, and will take at least five years to complete. Upon completion of the Khavda Renewable Energy Park, it will be a significant milestone in India's renewable energy sector and a global leader in RE installation (Ap, 2023)

3.3.1 Green Hydrogen Mission

India's Green Hydrogen Mission is focused on making the country a global hub for producing, using, and exporting green hydrogen. Its aim is to contribute to making India self-reliant in clean energy, reducing the dependency on imported FF, and leading the global clean energy transition. It will create opportunities to export green hydrogen that can be used for domestic consumption. The mission includes strategic interventions like the development of green hydrogen production capacity, renewable energy capacity addition, and emission of GHG. The objective of this mission is to develop green hydrogen production capacity of at least 5 million metric tons (MMT) per annum, with adding around 125GW of RE capacity by 2030, it aims to result in abatement of nearly 50 MMT of annual GHG emission by 2030 (National Green Hydrogen Mission, 2023). From 2020 to 21, India imported about 10 MMT of urea, 5 MMT of diammonium phosphate (DAP), and 3 MMT of ammonia. This translates into an annual import value of over USD 6 billion. With the expected reduction in the price of Green Hydrogen, there will be economic benefits to producing these fertilizers domestically, using Green Hydrogen/Green Ammonia as a substitute for imports.

Steel production is one of the potential sectors where Green Hydrogen can replace fossil fuels. The National Steel Policy 2017 states that Natural Gas is a greener alternative to meeting India's goal of reducing the carbon intensity of GDP; as the costs fall of renewable energy and electrolyzers, it is expected that Green-Hydrogen steel can become cost-competitive in the coming decade. Giving carbon credits and imposing market barriers on carbon-intensive steel will likely further enhance Green Hydrogen-based steel's viability (National Green Hydrogen Mission, 2023).

Financial assistance will be provided to close the viability gap due to the relatively higher capital cost of Fuel Cell Electric Vehicles (FCEVs) in the initial years. The Mission will also explore possibly blending Green Hydrogen-based Methanol/Ethanol and other synthetic fuels derived from Green Hydrogen into automobile fuels.

Shipping and port operations are vital sectors likely to drive the future demand for Green Hydrogen and trade. Maritime transport and Ports have significant potential for decarburization by using Green Hydrogen or its derivatives, such as Green Ammonia and Green Methanol, as fuel for propulsion and other operations. The government shall develop Green Hydrogen/Ammonia refueling hubs at Indian ports; develop the operation of Green Hydrogen/Ammonia fuelled vessels; use Green Hydrogen/Ammonia to fuel zero-emission technologies for vehicles and terminal equipment at ports; and develop supply chains and capabilities for support future export of Green Hydrogen/Ammonia from India.

India can produce low-cost electricity from the solar photovoltaic system. This will help scale up the production of green hydrogen in the future; the only concern will be the

water consumed by electrolyzers, which needs to be discussed. Electrolysers consume about 9 liters of water to produce 1 kg of hydrogen. Seawater electrolysis may be helpful in this case, but it requires further development and research. The country is exploring alternative energies, but hydrogen is still not on focus; this obfuscation characterizes the Indian government's green hydrogen mission; many companies are still working on fuel cell technologies, which will help in facing the challenges related to green hydrogen for now, we have two hydrogen refuelling stations in India and future we will massive growth in refuelling stations and heavy transport sector electric trucks with zero emission.

The Indian government has pledged to invest 4.5 billion USD in green technology to clean up the country's economy and create jobs; GOI has announced the implementation of many programs for green fuel, green energy, green farming, green mobility, green buildings and green equipment and policies for effzaicient use of energy, this will help in reducing the carbon intensity of the economy and will also provide green job opportunities. The Indian government has promised to invest 350 billion rupees ($4.3bn) towards the country's energy transition. The government will subsidize private sector projects for battery energy storage; this technology will store electricity from intermittent power sources like renewables when the sun is not shining and the wind is not blowing. Pump storage is a way to store energy using hydropower. When electricity is abundant, it is used to pump water up into a dam, and when there is demand, the water can be released to produce hydroelectricity. (climate home news,2023) as India decarbonizes its economy, hydrogen may be needed, mainly to make fertilizers for agricultural purposes and zero-carbon steel production. At the same time, we also need solar and wind power to reduce dependence on coal. This will create a burden on land and water resources also be

considered; however, the viability of India's Green Hydrogen Mission has been in focus because Adani's business participation was a crucial driver in partnership with TotalEnergis, the French oil and gas company. However, after the crisis engulfing Adani's business lately, TotalEnergies has stopped the project. (Singh, Pirani,2023)

Indian Union Budget of 2023 considered green growth as one of the key priority areas that will guide the Indian economy through the next 25 years; there is a 45% hike in the MNRE allocation in the RE sector, the same year, India also launched the National Green Hydrogen Mission to support green hydrogen production, use, and export; regions capable of supporting large-scale production or use of hydrogen will be identified and developed as green hydrogen hubs (Nidhi Sharma, 2023). GOI will spend 197bn ($2.4bn) in developing carbon-free-fuel, which can replace FF in manufacturing steel, shipping, and aviation; green hydrogen is like a "sunrise sector" for India; the country aims to produce five million metric tons by 2030, the IEA has said that for the world to limit global warming to 1.5C, it should produce about 100m metric tons of green hydrogen by 2030. No alternatives will reduce our dependence on coal and gas. However, energy efficiency measures and continued electricity sector reform could reduce gas and coal use while improving access quality. (Singh, Pirani,2023)

3.3.2 National Solar Mission

Under this mission, the target is to achieve 100GW of installed solar power capacity by 2022 through various policy decisions and schemes such as Solar Parks and Ultra-mega Solar Power Projects, Central Public Sector Undertaking (CPSU), (Government Producer Scheme), Production Linked Incentive scheme for 'National Programme on High-

Efficiency Solar PV Modules,' Prime Minister Kisan Urja Suraksha Evam Utthaan Mahaabhiyan (PM-KUSUM), Rooftop Solar Program. The country achieved 63.30GW as of 2022, including 53GW from ground-mounted solar, 8.08GW from rooftop solar, and 2.22GW off-grid solar; based upon availability of land and solar radiation, the potential solar power in the country has been assessed to be around 750 GW, and It is expected that a capacity of around 15,000 MW will be installed under different solar programs during the Financial Year 2022-23. This scheme mandates the usage of domestically manufactured solar PV cells and modules. Under the PM-KUSUM, there are three components: Component-A, which is 10,000 MW of Decentralized Ground Mounted Grid Connected Solar Power Plants; Component-B: Installation of 20 lakh Standalone Solar Powered Agriculture Pumps. Component-C: Solarisation of 15 Lakh existing Grid-connected Agriculture Pumps, Example: Gujarat is the top solar-powered state in India. It launched its solar policy in 2021 and has witnessed a 55% reduction in emissions, and it also dominates solar module production with a 53% share(Saur Energy, 2023)

After looking at Gujarat, other states like its neighbour Rajasthan opted for solar and wind energy transmission; Rajasthan is also investing in the RE sector and influencing another state in energy transmission; with this, Gujarat has attracted a lot of FDI in the energy sector also creating job opportunities and economic growth.

3.4 RENEWABLE ENERGY TECHNOLOGY

There is an excellent opportunity for RETs in India. It provides a promising solution in not only meeting the ever-increasing energy demand but also in mitigating adverse environmental effects; it is essential to tackle the energy crises by using abundant RE

resources that are available, such as wind, biomass, and solar, as these sources are going to be a permanent solution for future energy needs. Among various other sources, wind is a promising source not only at a global level but also at the domestic level, and it is one of the fastest developing RETs across the globe, including in India. Wind energy provides a power source that completely avoids the emission of CO2 and GHG.

India is putting much effort into accelerating the innovation of energy technologies in order to meet climate targets, boost economic growth, improve energy availability throughout the nation, and control air pollution. In India's innovation system, remarkable success stories have surfaced recently. The public sector, particularly the central government, dominates India's energy research, development, and demonstration (RD&D) landscape, encompassing various ministries and allied institutions. Looking ahead, it is anticipated that the role of private sector players in technological innovation will grow in significance. The "Make in India" campaign aims to increase domestic technology development and deployment by leveraging private actors' Research, Development, and Deployment (RD&D) skills through public-private partnerships.

In addition to financial support, India's innovation-specific policy support and national missions have significantly promoted the development of critical energy technologies[30] in recent years. Funding has increased significantly recently, particularly as India strives to treble its expenditure on clean energy R&D over five years under Mission Innovation (MI). In addition, India has traditionally taken the lead in multilateral initiatives like the Technology Collaboration Program run by the IEA and MI.

[30] Critical energy technology is a range of technologies essential for the energy transition towards sustainability, these technologies heavily rely on critical materials for their production and operation.

In the future, India could gain from taking a more strategic approach to energy RD&D. Some of the ways it could do this include a) enhancing interministerial coordination to align innovation priorities better; b) laying out a long-term roadmap for energy RD&D to better integrate programs into more extensive energy policies and direct innovation towards national objectives; and c) fortifying institutional and legal frameworks, such as those about intellectual property. Data on energy RD&D would be better collected and tracked consistently for such an endeavor. India's draft National Energy Policy emphasizes energy technology innovation to enhance energy supply at affordable prices and deliver it efficiently and sustainably. The policy acknowledges government support in acquiring technologies, encouraging research and development, and funding innovation. India has been researching various areas of energy supply and demand in recent years.

The government has initiated energy-related National missions to address specific technology areas, building on the National Action Plan on Climate Change, National Mission for Enhanced Energy Efficiency, National Solar Mission, National Electric Mobility Mission, National Smart Grid Mission, National Mission on Advanced Ultra Super Critical Technology, National Mission on Transformative Mobility and Battery Storage.

A vibrant knowledge society is facilitated by human capital, which is the backbone of a nation's innovation ecosystem (e.g., researchers and engineers). Experience with current technologies and the capacity to learn, retain, and share knowledge about emerging technologies domestically and internationally strengthen innovation processes. A range of indicators, including national academic achievement scores, the number of graduates, PhD candidates, or patents in a particular field, the availability of research support staff,

the level of domestic collaboration, the kinds of skills developed in academia, and the connections between academia and industry, can aid policymakers in establishing a vibrant knowledge society (Global Energy Review, 2020).

Dynamic global networks: Novel technology and concepts can be made available to markets through multiple tiers of networks. Finance networks make investments in startups at different phases of their growth. Information is shared through associations, conferences, and worldwide partnerships with public and private stakeholders by academic and scientific networks. Corporate networks establish standards, create strategic partnerships, and assist in creating supply chains to distribute new products.

Robust establishments: A robust legislative framework that includes provisions for intellectual property, safety, environmental, and social requirements for products and supply chains, as well as market activities, is necessary for an efficient innovation ecosystem. Customer preferences and social norms for behavior may also be taken into account.

India’s energy transition in rural areas is necessary to address because people in rural areas mostly use a non-conventional form of energy resources for power generation and domestic use, which is affecting the sustainable development of these areas, making them economically weaker states in the country. Moreover, these areas are rich in coal reserves, making them vulnerable to the environment. Rural areas should not be left in this process as the country moves towards green energy. GOI has brought various schemes in the rural areas to address this transition; as we know, energy transition can be measured by the pace at which alternate Renewable Energy Technologies (RETs) are evolved and

disseminated to the intended users, provided alternate energy that is cleaner and greener such as liquefied petroleum gas (LPG), it is also about how these alternate energy sources, new and emerging technologies are getting accepted and assimilated in the way of life of the rural household, the acceptance and assimilation of these new technology depend further on the social and cultural norms and how these norms get influenced by different institutions and administrations. Energy transition has gained prominence as it is connected with economic growth and development. In the context of cooking, rural households use multiple fuels simultaneously as a deterrent in the transition process to Improved Cook Stoves (ICS). Despite the challenges, there is a clear imperative to expedite the energy transition due to health and climate mitigation benefits that arise from reduced energy consumption or shifting towards cleaner fuels (Goswami, et al, 2023). Transition to alternative for cooking purposes continues to be the weakest link in the energy transition as there are 54% of households continue to use traditional solid fuels either exclusively or by stacking them with LPG, traditional fuels such as firewood, dung cakes, agriculture residue, and kerosene for cooking increases indoor air pollution. Studies show that LPG stoves and forced draft stoves such as Oorja and Eco-Chula are highly effective in reducing in-house air pollution compared to conventional cook stoves. Factors that influence household energy choices include education, household dwelling type, household size, employment, and income group (Goswami, et al, 2023).

A study shows that education, modern housing, paid employment, and higher income increase the adoption of cleaner energy, and employment in the informal sector increases the likelihood of using nuclear energy. Institutional and structural factors potentially influencing energy transition in cooking include the market-oriented approach, making

the energy market accessible and attractive to local investors, communities, and consumers. Public awareness about the importance of the fuel type and technology can also influence the adoption of ICS. In 2014, a program to promote ICS based on traditional biomass in Indian vernacular as Unnat Chula Abhiyan was launched to promote energy transition in cooking by using ICS; there was low adoption of ICS because of a mismatch between design and user expectation, low willingness to pay because of low awareness of knowledge on perceived benefits (Global Energy Review, 2020).

Since 2015, 80 million free LPG connections have been provided to poor households under PMUY to transition from firewood for cooking to LPG. Even if there is an increase in the income of the rural household, they still use non-conventional sources of fuel; this behavior indicates that even if conventional fuels are made affordable, people from rural areas will continue to use firewood or biomass for cooking as it has become their social or cultural behavior to use such fuels (Goswami, et al, 2023).

The health effects of indoor household air pollution resulting from burning solid fuels for cooking are substantial. Between 2011 and 2018, the percentage of Indians consuming biomass and kerosene fell by 16 percentage points, with precisely half of the country's population now utilizing cleaner fuels like liquefied petroleum gas (LPG). The primary objective of GoI's clean cooking initiatives is to empower women and enhance their health by promoting the use and financing of LPG. The Pradhan Mantri Ujjwala Yojana (PMUY) program aims to give free LPG connections, subsidized refills, and LPG usage training to women below the poverty line. In just a few years, it has reached tens of millions of Indian women, in contrast to the GoI's vow to deliver 50 million free LPG

connections by 2019, 80 million connections were intended to be provided by 2020 were provided in 2019 (Global Energy Review, 2020).

Nonetheless, 680 million people in India are expected to still lack access to clean cooking supplies in 2018 and mostly cook with biomass. According to IEA forecasts based on declared plans, the proportion of the population that uses traditional biomass for cooking will continue to decrease, starting at about 500 million and reaching a third of the population in 2030 and a quarter by 2040. Despite these advancements, conventional cooking continues to strain women heavily, particularly those who spend over 1.5 hours a day on average gathering fuel wood more than 100 billion lost working hours (Global Energy Review, 2020).

3.4.1Rural electrification through RE sources

Electric power is the key driver of economic growth and prosperity. However, access to it is still a dream for most of the rural population in India after 100 years of Edison's statement, "We will make electricity so cheap that only the rich will burn candles." Rural villages of India still do not have 100% access to electricity for 24 hours; with the increasing population, electricity demand also increases, and it is estimated that by 2030, global electricity generation will reach 30.36 trillion kWh. India is the fastest-growing economy globally and ranks third in worldwide energy consumption. Currently, most of India's energy demand is met through fossil fuel, such as coal, gas, and diesel-fired power plants, which account for 66% of the country's total electricity-generating capacity (Kulkarni, Anil, 2014)

Decentralized power generation technologies means “An electric power source connected directly to the distribution network or on the customer side of the meter.” (Kulkarni, Anil, 2014)Under a decentralized energy generation system, the electricity needs of the people are met by power stations located in the villages based on locally available raw materials.

For the past 15 years, the Government of India (GoI) has prioritized universal home and village electricity access, emphasizing rural areas. The GoI declared in April 2018 that India had accomplished its aim of having power in every village (600,000 villages). According to the official data, the GoI declared in April 2019 that, one year later, it had successfully connected 26 million households that were willing to do so. Two primary government initiatives, the Saubhagya and the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), aim to provide energy access to every family and village, respectively. September 2017 saw the launch of the Saubhagya scheme, which aided in connecting the remaining mile of residential electrification. It was connected with the help of the Saubhagya scheme, launched in September 2017. According to the IEA, over 95% of Indians who have gained access to electricity since 2000 have done so due to grid extension. Since 2000, over 75% of the additional electrical availability has come from coal power, with the remaining 20% coming from renewable sources. In order to ensure that electrification goals are by improving air quality and lowering greenhouse gas emissions, increasing the use of clean energy will be crucial. However, the paradigm for access is evolving. Promising improvements in mini-grid policy indicate that renewable energy sources can play a more significant role in guaranteeing access to electricity (India Energy Outlook, 2021)

In 2016, a draft national mini-grid strategy for renewable energy was released to create 10,000 microgrids and mini-grids totaling 500 megawatts of capacity. The IEA predicts that fast progress will continue in India based on declared policies, with everyone in the country enjoying continuous access to energy. India's leading renewable energy source has been hydropower for a long time. Hydropower alone produced around 40% of the world's electricity in the late 1970s. Hydropower has continually expanded in supply, but its proportion in the total electricity generated has decreased to about 10%. The total share of renewables has remained steady at 16–17% over the past ten years because of an exceptionally significant increase in power from wind, solar PV, and biofuels. Throughout the ten years from 2007 to 2016, the average annual growth rate of wind power output was 14%. In 2017, wind power accounted for 3.3% of all electricity generated. With the help of auctions for new PV installations and the 2022 target, solar power has only just begun to increase. The average annual growth in solar power generation during the five years 2013–17 was 64%. Power generation from bioenergy is likewise rising. The primary source is cogeneration facilities that use bagasse wastes from the considerable sugar industry in India. Compared to residential usage, biomass for power generation is a more sustainable use of bioenergy resources (World Energy Outlook, 2023)

Energy-from-waste (EfW) projects that use waste and residues from industry, agriculture, and cities account for a small portion of the electricity produced. EfW can help India's waste management industry and supply electricity where needed. There is potential for the EfW sector to grow further due to the pressing waste management difficulties that cities face due to increasing urbanization and economic expansion. EfW projects in India

include initiatives like the waste-to-energy plant in Maharashtra, which processes municipal solid waste to produce electricity, contributing to sustainable urban infrastructure development in line with India's Smart City Mission. Hitachi Zosen Corporation, through its subsidiary Hitachi Zosen India, has been involved in constructing EfW plants in India, such as the project in Maharashtra. (Hitachi Zosen Corporation,2021)

3.4.2 India's Green Industrial Policy (GIP)

Keeping up with the trend of sustainable development, India's Green Industrial Policy prioritizes the production and consumption of clean energy; this policy seeks to develop and adopt new technologies and essential policy changes; this policy is different from conventional industrial since it requires different policy instruments and involves more robust state engagement in markets, under GIP state will not only promote sustainable pathway by pricing[31] resource consumption and efficient technologies through market transformation. There is an upsurge in adopting GIP globally in developed and developing countries, as it creates globally competitive domestic firms spinning off development and environmental benefits. Energy is the primary input for industrial processes and a significant contributor to industrial emissions. (Swain, 2014)

[31] fixing value that a manufacturer will receive in exchange of services and goods

3.5 DOMESTIC MANUFACTURING OF RE

The government of India has implemented several policy measures in the renewable energy industry to encourage Indigenous manufacturing and lessen the country's reliance on imports. Particular attention has been paid to the home production of Electrolysis, battery energy storage devices, and solar parts. The Indian solar manufacturing industry has significantly benefited from the Ministry of New and Renewable Energy's actions. Implementing the production-linked incentive (PLI) program has secured an additional 40 GW of module manufacturing capacity in the nation by the conclusion of the 2024–25 fiscal year. With a target annual output of 30 GW, this addition strategically prioritizes backward integration, guaranteeing a dependable supply chain for residential solar installation, India has approved the National Green Hydrogen Mission; the scheme has two financial incentive mechanisms: for domestic manufacturing of electrolysis (Component I) and green hydrogen production (Component II). The incentives will be provided in terms of Rs per kW, with a base incentive of Rs 4,440 per kW in the first year and a reduction to Rs 1,480 per kW in the fifth year. The Solar Energy Corporation of India will implement the scheme through a transparent selection process. Industry stakeholders have also taken proactive steps in this space, such as Larsen & Toubro, Bharat Heavy Electricals Limited, and Green H Electrolysis. (Renewable Watch,2023)

The Indian government has taken steps to increase domestic manufacturing capability, but concerns over excessive barriers have been raised. There are several tariffs and non-tariff barriers to avoid imports and protect domestic manufacturers. However, these barriers have been criticized for their limitations in promoting domestic manufacturing and maintaining quality.

The Production Linked Incentive (PLI) program in India is providing a boost to domestic manufacturing, including through the provision of nearly USD 2.4 billion under the second phase of the High-Efficiency Solar PV Modules PLI that began in October 2022 and USD 2.5 billion under the Advanced Chemistry Cell Battery Storage PLI announced in late 2021. (Renewables 2023, 2024) India should also identify manufacturing opportunities in new technology areas such as hydrogen; Indian companies have acquired foreign technology licenses and research but require more investments in design and research; the development of indigenous capacity for manufacturing solar energy can create jobs, its current domestic capacity is 3GW whereas the demand is 20-30GW per year, imports fill the difference. The government has increased import tariffs on renewable products to help domestic manufacturers face competition. In the past, uneven protection has hurt the solar industry, and the exclusion of thin films in India's domestic content requirement (DCR) scheme has resulted in a contradiction in crystalline silicon production, highlighting the need for change. India needs low-cost financing for solar energy production to compete with Chinese goods, but access to competitive finance remains a challenge due to capital-intensive technology and foreign currency risk; India's renewable sector initiatives, including the JNNSM, MSIP, and 'Make in India' aims to boost domestic production but faces challenges due to cost-effective imports and low demand, the government needs to explore innovative financing methods and credit enhancement for developers. India can learn from Brazil's thriving renewable energy financing model, which offers low-cost, long-term financing through the National Social Economic Development Bank. India must also invest in R&D to keep up with technological advancements and adapt to larger solar cell and module sizes while exploring international collaborations and developing a clear roadmap for next-generation

technology; the industry needs strategic planning to indigenize the supply chain and boost domestic manufacturing, lower import duties and tax exemptions can help achieve this, an ecosystem including land, credit, research funds, and incentives is needed, Renewable Purchase Obligations are crucial for manufacturing in RE (Nova, 2021)

The National Energy Policy of India, 2017 proposes to achieve 100 percent electrification of all census villages by 2018 and universal electrification with 24 x 7 electricity by 2022, the main objective of this policy is to make energy poverty vanish in India by making it accessible and affordable. Solar and wind energy dominate the sustainable energy policies; since solar and wind are dependent on climatic conditions, it will affect power generation to a large extent. Nuclear energy is an option that can support the transition from carbon-dependent energy to a completely sustainable energy mix. Nuclear plants can support renewable sources and create a more reliable grid, and when the reactors are operating correctly, nuclear energy is not harmful to the environment. Studies have found that nuclear energy has certain ecological benefits, and if the spent fuel is recycled correctly, the concern of nuclear waste is also addressed. The fundamental policy change that will enhance India’s chance of improved international nuclear fuel access will be to allow private investment in the sector. Allowing private investment in any sector gets massive criticism in India; having shared captive power generation using nuclear fuel is a way for industrial growth, and existing thermal captive facilities can be converted into nuclear facilities. To move forward and secure clean energy and energy security, India should make some apparent policy changes concerning its nuclear program, like allowing private investment in nuclear energy and allowing captive power plants for large industries; it should also take some actions to reassure the National Security Group

members to gain confidence but not at the cost of its security interests (surendran, Ahmad, 2017)

Achieving the energy transition goals requires India to be visionary and realistic and overcome challenges. India is in a period of transition and growth, a transition from physical cash to digital payments, from fossil fuels to renewables, and from informal to formal economy. India is developing rapidly, and the energy transition is the most salient. It has positively impacted our environment, the health of the citizens, and our economy. India ranks as the world's seventh-largest energy-producing country and fifth-largest energy-consuming country; it is also the fifth-largest oil importer and gas importer globally. India is the third largest and most attractive country to invest in renewable energy after the USA and Germany, as it has a separate ministry for renewable energy development. (Goswami, 2023) India’s efforts to reduce emissions will also be a model for other emerging economies; India’s renewable electricity is growing faster than any other major economy. The energy transition is crucial to combat climate change, reduce pollution, improve air quality, and foster economic growth, employment, and social development. India aims to achieve net zero emissions by 2070 and is exploring alternative energy sources for long-term development from different parts of the world; GOI came up with various initiatives at national and international levels. The Indian government is promoting international cooperation in renewable energy transition through initiatives like the National Solar Mission and Memorandum of Understanding (MoUs) with countries like Finland. India's priorities under the G20 presidency include addressing technology gaps, diversifying supply chains, transitioning industries to low carbon, responsible energy consumption, and access to clean energy; this move of India

was highly appreciated by the developed and developing countries. The transition to green energy has positive impacts on, of course, the environment; more greenery can be seen, human health improved with fewer women and children inhaling bad quality, polluted smoke, and economy, our potential and attractive unique ideas for green energy transition attracted foreign investment in this sector, India wants to become a leader in renewable energy and direct the developing nations in adopting renewable energy, it is aiming to install 500GW of renewable energy by 2030. However, India faces challenges such as substantial investments, increasing annual average spending on clean energy, and bridging the emission gap. A well-designed policy can reduce greenhouse gas emissions and limit trade-offs between affordability, security, and sustainability.

CHAPTER 4

INDIA'S ENERGY DIPLOMACY AND PARTNERSHIPS

India faces several challenges in meeting its current energy demand; it imports 41% of its energy demand as of 2023, and the future market is expected to increase by 95% in 2030 (Mostaque, 2023). Despite having large coal and natural gas reserves, its domestic energy production could be faster, leading to increased energy imports. Its ambition of energy transition involves expanding the share of renewables in the energy mix; diplomacy is crucial to address these challenges, including finding new energy sources, addressing environmental concerns, and ensuring stable imports [32]from existing sources.

India is exploring new and existing energy destinations such as Saudi Arabia and Iran for oil, Qatar for gas, Australia for coal, and Thailand for RE installation equipment, Energy is viewed in international politics as a potent instrument [33]for preserving diplomatic and commercial ties between nations. Global energy dynamics throughout history demonstrate the strategic advantage enjoyed by those in control of this industry. As a result, nations have always competed to gain control of it. Countries have been developing their foreign policies to safeguard global energy resources to advance their sphere of influence; conflicts between nations vying for energy resources are frequent; however, energy resources can be employed to sway political opinions and win over support.

[32] Stable imports refer to a situation where quality and value of imported goods remain consistent or predictable over time, without significant fluctuations.
[33] Potent is generally refered to something that has great effectiveness.

Until recently, Western powers have dominated the global energy system; however, a dramatic shift has occurred due to the rise of China, India, and other growing countries as significant energy consumers. Competition and friction are inevitable as India searches for new and diverse energy sources and works to secure energy transit routes; South Asia, being the home of India, is a hotbed of activity in the energy race, numerous extra-regional powers have been drawn to it because of its strategically significant location and mainly untapped energy potential, countries with has energy resources, capital and technology are trying to increase their influence in the region, to secure its energy objectives, India wishes to engage in proactive energy diplomacy. (Mostaque,2022)

4.1 ENERGY DIPLOMACY

Energy is a relatively new addition to foreign policy; it focuses on securing access to energy supplies abroad and promoting bilateral cooperation in the energy sector. Andreas Goldthau defines it as “the use of foreign policy to secure access to energy supplies abroad and to promote (mostly bilateral, that is, government to government) cooperation in the energy sector.” Other definitions include government-related foreign activities aimed at ensuring the country’s energy security and promoting business opportunities related to the energy sector; energy diplomacy is used to access energy supplies and develop sustainable production and use of energy. The energy goal differs for each country; the US focuses on the role energy could play in advancing strategic interests abroad. Access to energy supplies can be secured through threats, economic sanctions, or force using brutal power tactics.

Griffith and Druif argue that most countries need more resources to implement a challenging power approach in energy policy, leading to a focus on cooperation rather

than threats of force. Energy diplomacy is seen as a soft power approach, where the effectiveness of diplomatic relations depends on a country's power or influence with its counterparts. The US uses coercive approaches, while the EU adopts multilateralism, an economic incentive-oriented approach due to its lack of military power and standard foreign policy. (Mostaque,2022)

India's energy diplomacy has evolved, focusing on international cooperation and establishing an energy security division. The Ministry of External Affairs, Petroleum and Natural Gas (MoPNG), and the Ministry of New and Renewable Energy collaborate with various governments and organizations to sign Memorandums of Understanding (MoU) for cooperation in their respective fields. India's energy policy strategy since 1947 has been centered on meeting the growing energy demand. However, the country's focus on self-sufficiency has shifted towards developing alternative energy sources, like nuclear, solar, and wind energy. As India's energy crisis is set to increase due to a fall in domestic production and a rise in demand, it is believed that India's energy security can be guaranteed by buying oil, gas, and coal assets in foreign countries. This would provide supply security and fuel price stability and help India diversify its portfolio. Despite the risk of supply disruption and increasing the country's trade deficit, India has been growing its energy imports. India's energy diplomacy has evolved, focusing on developing alternative energy sources and diversifying its portfolio. India's energy diplomacy combines various philosophies to simultaneously gain resources, partnerships, and technology. It encourages Indian companies to acquire foreign oil and gas blocks[34]

[34] "Blocks" typically refers to specific geographic areas designated for exploration and production.

and stakes [35]in exploration and production companies abroad. India has offshore gas and oil projects in 26 countries and plans to increase this number. It is also looking to participate in transnational natural gas pipeline projects, diversify its Liquefied Natural Gas (LNG) contracts, and use diplomacy to ensure supply from Saudi Arabia and the UAE. India's energy diplomacy is also preparing for a post-fossil fuel future, and the Modi government's ambitious energy transition plan has attracted more aid, subsidized loans, and overseas capital and technology in the power sector. India's nuclear energy program has been a significant part of Narendra Modi's foreign policy, with civil nuclear arrangements with 14 countries; it is the only country outside the Nuclear Non-Proliferation Treaty (NPT) that allows for the trade of nuclear material.

India's approach to securing energy supplies, particularly its oil, is characterized by 'mercantile'[36] and 'realist' approaches. It has used political tools to develop closer bilateral ties with energy-rich countries and has not hesitated to work with countries considered pariahs,[37] even by its close allies. Countries under US sanctions, such as Iran and Venezuela, have been India's top energy exporting countries. India has also leveraged its robust Middle Eastern ties for oil imports from Saudi Arabia, Kuwait, and the UAE. The government has pursued a diversification strategy due to fears of natural gas and oil supply disruptions, geopolitical uncertainty, supply disruptions, and price volatility.

Despite its close relations with the US, India has maintained good relations with Russia in the energy sector. India's decision to import LNG has diversified its gas exporter country

[35] "Stakes" represent the ownership interests or investments that entities hold in these areas.
[36] Mercantile approach focuses on economic interest and trade benefits, viewing energy resources as commodities that can be leveraged for economic gain and national prosperity.
[37] Pariahs refers to states that are considered outcasts or marginalized due to their actions, policies, or international behavior that contravene accepted norms or standards.

list and secured an investment of US$ 13 billion from a Russian company to purchase a 20-million-ton refinery and a network of petrol pumps (Mostaque,2022). India has also been working closely with Russia on nuclear cooperation. In recent years, India and China have come to a proposed agreement to form a buyer's block[38] to bargain collectively with oil supplies, setting up a joint working group on energy. India's foreign policy is set within a Realist understanding of global contradictions and follows the path of realist nationalism. The former President of India, A.P.J. Abul Kalam, stated that his efforts to make nuclear weapons for India were to tell the several million masses of India never to feel small or helpless. India's energy diplomacy is driven by realist considerations and the nationalist ideology that India should and will do what it can to achieve its goals in world politics. The essence of India's energy diplomacy is tailoring itself according to the situation, importing and exporting energy resources and technology, and competing and cooperating with other actors when and how it considers fit.

4.2 INDIA'S ENERGY DIPLOMACY

4.2.1 Asia

India looks at the South Asian region as its domain of influence; this region is always vulnerable to intervention in the region by external powers in the energy sector; though the region depends on imports for traditional energy resources, the region also has potential in the renewable energy sector. It is geographically situated around energy-hungry countries, making it an essential part of the clean energy market. Within the South

[38] https://timesofindia.indiatimes.com/blogs/talkingturkey/buyers-bloc-india-and-china-working-together-in-energy-will-give-asian-importers-a-huge-fillip/

Asia (SA) region, India has two main energy routes to India; one is through the western part of South Asia via Afghanistan and Pakistan, which can connect India to two primary energy-rich regions: the Middle East and Central Asia. The other one is through the eastern part of South Asia through Myanmar, connecting the Southeast Asian region; India faces challenges in accessing energy supply from the western part due to its stern relationship with Pakistan and the volatile political situation of Afghanistan. Meanwhile, India has participated in two major pipeline projects, but both were unsuccessful. In addition to the deadlock on the Iran-Pakistan-India (IPI) pipeline, India is concerned about the TAPI gas pipeline, which enters through the Afghanistan-Pakistan border.

India has abandoned plans to build transnational pipelines from Myanmar to India through Bangladesh due to various political backlashes; despite the difficulties faced by India due to China's presence in the region, Myanmar remains an essential partner for India to ensure energy supply in the Northeast of India, the country is also working on building Liquefied Natural Gas (LNG) terminals in Ennore, Vizag/Kakinada, and Dhamra and supplying diesel to Myanmar from Numaligarh refinery in Assam. India is considering building an LNG terminal in Sittwe, Myanmar, to provide energy products and LNG to Mizoram once the Kaladan multi-modal transport project[39] is completed. (Mostaque,2022)

India is investing heavily in RE, particularly hydropower in Bhutan and Nepal. Its hydropower imports are a vital part of its foreign policy strategy with these countries; it has invested in developing hydroelectric infrastructure in Bhutan and has brought power from it since 2008. Nepal has implemented several hydroelectric schemes with India's

[39] A joint initiative between India and Myanmar to create a multi-modal mode of transport for cargo shipment, aimimg to link Kolkata with Sittwe seaport.

assistance. India is also providing 100 million USD to Sri Lanka for solar energy projects; in Bangladesh, India is one of its leading partners in energy, with a joint initiative by Bangladesh Power Development Board and India's Reliance Power for a 3,000 MW LNG-based power plant. In Maldives, both countries have an MoU for collaboration in energy efficiency and RE (Mostaque,2022). The signing of a tripartite agreement between India, Russia, and Bangladesh to work together on the Rooppur Nuclear Power plant in 2018 was seen as a step forward in ensuring global acceptance of India's nuclear capacities.

India is engaged in discussions with Southeast Asian countries such as Singapore and Thailand to facilitate the cross-border trade of RE electricity. It plans to establish underwater and land grid connections, contingent on cost factors. This initiative aims to significantly increase India's cross-border electricity sales presently, which involves Nepal, Bangladesh, Bhutan, and Myanmar, with a combined power transfer capacity of around 4,423MW. The move is also considered a treatment to deepen diplomatic relationships in the region, highlighting its ambitions to become a significant producer.

Southeast Asian countries aspire to have a regional grid for their multilateral power trade, but the practical progress is limited due to various challenges, including the region's energy.

Due to a lack of transit infrastructure connecting Central and South Asia and India's limited participation in the region's energy market, the mutual support between the two countries is encouraging, especially for India in the areas of energy and transit expansion to improve energy security as part of its national energy diplomacy; the Indian

government has encouraged both public and private sector businesses to compete for external asset procurements starting in the 1990s. It has also attempted to use its national NOCs in this endeavor: Oil and Natural Gas Corporation (ONGC), Oil India Ltd. (OIL), Bharat Petroleum Corporation Ltd (BPCL), Hindustan Petroleum Corporation Ltd. (HPCL), GAIL India Ltd., and other Indian firms are present in Central Asia. The country is trying to adjust to the competition from China. Oil and Natural Gas Corporation announced an investment of $1.55 billion in the Kurmangazy oil field with Russia and Kazakhstan (Kurian,2020)

Furthermore, India has energy-related agreements with Tajikistan and Uzbekistan that grant Indian corporations the freedom to explore without requiring them to pay an equal portion of any discoveries made. Although Indian companies sometimes faced difficulties competing with Chinese companies in global energy purchases, Beijing welcomed the Indian idea for joint bids in 2006, and the two countries merged it into five memoranda on energy cooperation.

Moreover, the Caspian Sea region, Central Asia, Africa, and Latin America are the four key focus areas for a joint bilateral working group tracking the advancement of collaboration. Sinopec, China Oil and Gas Corporation (CNOOC), Beijing Gas, and GAIL have entered into production and exploration contracts, respectively, with CNPC and ONGC.

4.2.2 Africa

India has been engaged in many energy activities and investments in Africa; natural resources dominated African imports to India, mainly crude oil and minerals, to secure

the requirement of a rapidly growing economy, about one-fifth of India's crude oil imports that is 21.4 million tons (mt) come from Africa, its energy export to India are 60% oil, 2.7% gas, and 3.5% coal. As a result, Africa's importance has increased, and India has become the principal investor in the continent, not only in the energy sector but also in sectors like infrastructure, health, agriculture, and industry (Dendenne,2023). Indian oil and Natural Gas Corporations have successfully acquired exploration and development stakes across the continent, with ONGC Videsh (OVL) being the leader in acquiring exploration and development stakes. Mozambique is the target of the most essential Indian energy investments in Africa, with OVL acquiring 10% of the Rovuma gas field for 2.6 billion dollars; India has also invested in Egypt's energy sector, with Shapoorji Pallonji Capital Company investing 6.8 million dollars to generate a 50MW solar power plant there. Other investments include OVL acquiring a 25% stake in Sudan's Greater Nile Oil Project in 2006 and IOC investing 1 billion dollars in an offshore block in Côte d'Ivoire. India's energy security is obtaining energy resources and safely protecting transportation roads. To maintain a strong position in the Indian Ocean, India founded the India-Africa Forum Summit (IAFS) in 2008, which has led to defense agreements with Madagascar, Mauritius, Mozambique, Seychelles, South Africa, and Tanzania (Dendenne,2023).

The country is ready to share its technology and expertise in Africa's energy sector, including exploration, distribution, refining, storage, and transportation. India has invested in infrastructure projects in Angola, Ethiopia, Gabon, and Chad, as well as agricultural equipment plants and military assistance. China and India have engaged in severe energy competition outside the Asian continent, with China extending its influence

due to energy resources and multi-trading relationships. India's prime oil company, ONGC, and Indian Oil Corporation have invested in African countries to ensure India's energy security.

Francophone Africa has become a significant source of hydrocarbons for India, with American and Chinese oil companies making a beeline to the region[40]. India's ONGC Videsh has already invested in Ivory Coast. ONGC-Videsh Limited (OVL) and OIL have entered production contracts in many oil fields worldwide, including Block CI-112 of Cote d'Ivoire[41]. OVL acquired 23.5% participating interest in this promising area with high hydrocarbon concentration. (Pathak,2007)

4.3 INDIA'S ENERGY PARTNERSHIP

4.3.1 India-US Energy Partnership

The Indo-US Energy Dialogue, launched in May 2005, aims to enhance mutual energy security, promote increased energy trade and investment, and facilitate the deployment of clean energy technologies. It has been renamed the US-India Strategic Clean Energy Partnership (SCEP), and the Ministerial meeting is co-chaired by the Hon'ble Minister of Petroleum and Natural Gas and the US Secretary of Energy. The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy and India's Bureau of Energy Efficiency are working together under the Power and Energy Efficiency Working Group to develop and implement energy-efficient policies and best practices to achieve

[40] Heading directly and quickly towards a specific place or direction.
[41] Block CI-112 in Cote d'Ivoire has been a subject of significant activity and interest in the oil and gas sector, ONGC Videsh Limited decided to abandon block CI-112 in Cote d'Ivoire making a shift in their exploration strategy in the region. https://www.petrowatch.com/synopsis.php?artld=515&w=1

national energy efficiency goals and reduce greenhouse gas emissions, with specific projects identified in the Working Group.

The US Department of Energy (DOE) and the Bureau of Energy Efficiency (BEE) are working together to improve energy efficiency and savings in the industrial sector through a comprehensive energy management system by ISO-50001[42]. This includes waste heat recovery, industry deep-decarbonisation, and hydrogen use.

The DOE is working with Lawrence Berkeley National Laboratory (LBNL) to develop the India Grid-integrated Efficient Buildings [43](GEB) Feasibility Framework, which could enable significant value streams for energy planning, reporting, energy efficiency, flexible load management, cost savings, revenue generation, and social benefits such as energy resilience, equity, and awareness. USDOE and ORNL are also working on the MEASURE tool suite, a platform developed by the Advance Manufacturing Office (AMO) under DOE to help manufacturers identify opportunities and calculate potential energy savings.

The United States and India are collaborating on four pillars of cooperation: Power and Energy Efficiency, Oil and Gas, Renewable Energy, and Sustainable Growth. These pillars aim to modernize the power grid, improve efficiency, promote sustainable economic growth, enhance energy security through trade and infrastructure investment, advance renewable energy development, and reduce market barriers. The United States

[42] ISO-50001 is an international standard that focuses on energy management system, aiming to help organisations improve energy performance, efficiency and reduce energy costs and greenhouse gas emission.
[43] GEB refers to buildings that optimize energy use by combinig efficiency measures with smart technologies such as solar battery storage and integrated building controls.

Gypsum Corporation (USG) supports India's efforts under the Asia EDGE [44]initiative and establishes India as a vital energy partner in the Indo-Pacific region. The US-India Partnership to Advance Clean Energy-Research (PACE-R) is leading joint research and development on smart grids and energy storage to increase grid resilience. The US has announced new research areas on transformational power generation based on supercritical CO2 power cycles and advanced coal technologies for power generation and hydrogen production. The US has also announced continued bilateral R&D engagement on advanced civil nuclear energy technologies through the U.S.-India Civil Nuclear Energy Working Group (Press Information Bureau Delhi, 2023) They have agreed to collaborate on Strategic Petroleum Reserves operation and maintenance, a public-private Hydrogen Task Force, and India's first-ever Solar Decathlon [45]India in 2021. The South Asia Group for Energy (SAGE), supported by United States Agency for International Development (USAID), aims to develop and deploy advanced clean technologies. The countries also agreed to explore and cooperate on sustainable biofuel production and use, including bioethanol, renewable diesel, and other advanced biofuels. They also discussed information exchange regarding policies and regulations and potential investments in the private sector.

As India pursues its renewable energy targets, both the countries are collaborating on the deployment and integration of renewable energy and new technologies into the grid, modernizing the power distribution sector, supporting state-level planning for renewable energy, deploying distributed energy technologies, electric vehicles, rooftop solar, and

[44] Asia EDGE initiative, is officially known as Enhancing Development and Growth through Energy, is a comprehensive U.S. whole-of-government effort focused on advancing sustainable and secure energy markets across the Indo-Pacific region.

[45] Solar Decathlon is a global competition for universities to design, build, and operate small experimental solar-powered buildings.

battery storage, redesigning markets, and increasing off-grid energy access. Work is underway to enhance flexible operations of coal power plants to address increased renewable energy penetration and variable power demand. The countries agreed to collaborate on advanced high-efficiency coal technologies [46]with low-to-zero emissions through carbon capture, utilization, and storage (CCUS) (Press Information Bureau Delhi, 2023).

New areas of technical cooperation include applying renewable energy in economic sectors, developing new business models and decision-making tools for renewable energy, skill-building, and training programs, and adopting emerging digital technologies and advanced IT management tools to enhance the cyber security of renewable energy systems.

The US and India have seen a significant increase in bilateral hydrocarbon trade since establishing the Strategic Partnership for Energy (SEP), reaching US$ 9.2 billion during 2019-20, a 93% increase since 2017-18. The US and India have formed new commercial partnerships through the U.S.-India Natural Gas Task Force, developing policy and regulatory recommendations to support India's vision to increase natural gas share in the energy sector. The two sides have held public-private dialogues to discuss challenges and opportunities for trade and investment in the energy sector. They also acknowledged their governments' commitment to civil nuclear cooperation and welcomed progress on the

[46] High- efficiency coal technologies often referred to as High- Efficiency, Low- Emissions (HELE) technologies, encompass a diverse group of advanced methods aimed at improving combustion rates, reducing emissions, and enhancing energy efficiency in coal-fired power plants.

Westinghouse commercial reactor [47]project at Kovvada in Andhra Pradesh. Both sides agreed to support each other's energy sector development vision and encourage investment (Press Information Bureau Delhi, 2023).

The India Energy Modelling Forum, launched by USAID and NITI Aayog, aims to build a network of modeling communities and link them with the government for analytical work and policy-making exercises. The growing energy trade between India and the US has been a significant factor in their bilateral progress, with both countries committing to a sustainable energy transition. The two sides have agreed to support each other's national hydrogen missions, emphasizing the importance of green/clean hydrogen as a critical energy source for global decarbonization.

To advance the positive agenda outlined by Prime Minister Modi and President Biden in their Joint Statement of June 22, 2023, the sides welcomed the establishment of the public-private Energy Storage Task Force, deepened collaboration to scale and accelerate deployment of hydrogen technologies, and the launch of the U.S.-India New and Emerging Renewable Energy Technologies Action Platform (RETAP) to accelerate the development of critical technologies to advance common ambitious clean energy goals, both the Ministers discussed the importance of reducing carbon emissions in the transportation sector through zero-emissions vehicles and continued collaboration on securing funding and enabling affordable and accessible debt and equity financing for the e-mobility industry. They also highlighted the importance of the "Electric Vehicle (EV) financing services facility," which will create dedicated funds for e-mobility, the sides

[47] Indian government in collaborating with Westinghouse to set up six nuclear reactors at Kovvada with discussions ongoing to finalize project details such as costs, construction timelines and pre- construction activities.

also welcomed cooperation to advance research, development, and commercialization of technologies in the emerging fuels arena, including bio-ethanol, renewable diesel, sustainable aviation fuels, and other advanced biofuels. They affirmed the vision of Prime Minister Modi and President Biden for establishing the Global Biofuels Alliance, which will play a role in strengthening markets, facilitating global biofuels trade, developing concrete policy lesson-sharing, and providing technical support for national biofuels programs worldwide.

The sides acknowledged the collaboration of USAID with various Indian agencies, including Indian Railways, NTPC Green National Skills Development Corporation, Skills Council for Green Jobs, and the Forum of Regulators. They welcomed USAID's support on the feasibility of Green Chemicals for NTPC and cooperation between USAID and Indian power PSUs to create clean energy financing policies.
The sides also noted the importance of robust life cycle assessments and building modeling capacity to assess low carbon technologies costs and emissions, as well as best practices for modeling and analytics of energy consumption. They also praised the joint R&D under the Partnership to Advance Clean Energy-Research (PACE-R), including the US-India Collaborative for Smart Distribution System with Storage (UI-ASSIST) consortium.

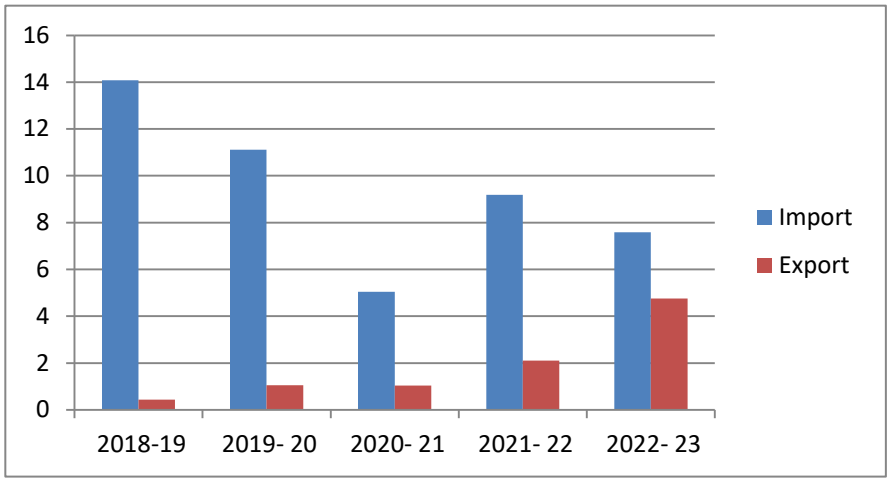
Renewable Energy Technology Action Platform (RETAP) under the Strategic Clean Energy Partnership a platform, led by DOE Deputy Secretary David Turk and MNRE Secretary Bhupinder Singh Bhalla, aims to advance new and emerging renewable technologies for deployment and scaling. The initial focus will be on green/clean hydrogen, wind energy, long-duration energy storage, geothermal energy, ocean/tidal

energy, and other emerging technologies. The RETAP's work plan is guided by five themes: Research & Development, Piloting & Testing of Innovative Technologies, Advanced Training & Skill Development, Policy and Planning for Advancing Renewable Energy and enabling Technologies, and Investment, Incubation and Outreach programs. The delegations shared information about emerging technology developments in each country, including hydrogen, energy storage, wind, geothermal energy, and marine renewable energy technologies. The DOE and MNRE plan to enhance RETAP collaboration by creating a RETAP Steering Committee, joint working groups, and cooperation among subject matter experts (Press Information Bureau Delhi, 2023)

4.3.2 India Latin-America Energy Partnership

The relationship between India and Latin America (LA) is flourishing. It has become a critical element of India’s foreign policy mainly because LA is home to several oil-rich nations, such as Trinidad and Tobago. Guyana and India want to diversify their oil and gas sources; given the current geopolitical situation, nations like these provide alternatives for India to its energy portfolio, and the country is exploring the possibility of investing in the RE sector in the region.

Figure 4.1: shows the trend in energy export and import between LAC and India between



Source: Trade Statistics- Ministry of Commerce and Industry, India.

Total energy trade between the two regions in 2022 reached US$12.32 billion, and the value of India's exports from the region was about US$4.75 billion, while imports were roughly US$7.58 billion in 2022, making it an essential import commodity for India from the LAC region, The LAC currently boasts one of the greenest energy matrices[48] in the world. For example, 45% of energy originates from Chile, which aims to attain 70% renewable energy by 2030; by 2021, 13% of the world's energy supply will come from renewables, with 33% coming from LAC alone, and in the same year, hydroelectric power made up 9% of all RE sources in LAC while biofuels, solar, wind, and geothermal energy accounted for 24% (sandals,2019).

Renewable energy (RE) investments have surged recently, with developing countries leading the charge towards alternative energy economies. Latin America has become a new leader in RE, with ambitious targets resulting in low bids in electricity generation

[48] Greenest energy matrices refers to energy matrices that prioritize renewable energy sources with minimal environmental impact.

auctions. ReNew Power, India's largest renewable independent power producer is considering expanding its presence in Latin America. A team was tasked with developing a market entry strategy for Latin America, prioritizing five of the largest economies: Argentina, Brazil, Chile, Colombia, and Mexico. The team analyzed each country's macroeconomic growth, electricity market reforms, policy incentives, regulatory frameworks, foreign currency risk, current projects, electricity payment structures, foreign direct investment environment, potential barriers, and competitors. Brazil was the most attractive country for RE investment in the short term. The team proposed three recommendations across all countries: deepen market entry analysis, establish connections with local presence, and explore corporate offtake agreements[49].

The resource richness of Latin America, particularly its energy and mineral resources, is crucial to the policy priorities of the India-Latin America relationship. The trade composition is heavily influenced by energy-related products, making the relationship "essentially energy-driven[50]." To analyze the significance of this energy relationship, India's energy policy prerogatives [51]of access, security, and climate mitigation are studied in conjunction.

The International Solar Alliance (ISA) is a global initiative to address the challenges faced in large-scale solar energy deployment, particularly regarding technology, finance, and capability. The ISA seeks to mobilize member countries, international organizations, and the private sector to support rural and decentralized applications, affordable finance,

[49] An offtake agreement is a crucial contact between a producer and a buyer, ensuring the purchase of a specific resources, it provides stability for both parties, guaranteeing consistent supplies and demand.
[50] Essentially energy driven refers to solutions, technologies, or products that are primarily focused on optimizing energy efficiency, reducing energy consumption, and promoting sustainability.
[51] Prerogatives refers to exclusive rights, privileges and priorities outlined in the country’s energy policies to achieve specific objectives.

island and village solar mini-grids, rooftop installations, and solar e-mobility technologies[52]. Despite its success in 2020, the ISA has achieved universalization of its membership. Several Latin American and Caribbean countries have signed and ratified the ISA Framework Agreement, including Argentina, Brazil, Bolivia, Chile, Costa Rica, Cuba, El Salvador, Guyana, Paraguay, Peru, Suriname, and Venezuela. Cuba, El Salvador, Guyana, Peru, Suriname, and Venezuela have also submitted their instruments of ratification (Misra,Briceño,Hurtado,2021).

India's commitments to achieve 100 GW of solar power by 2022 and to the ISA represent significant potential for multilateral cooperation between India and the region. The signing of the ISA agreement by Argentina in 2019 was seen as an essential first step for cooperation in renewable energy. The ISA represents the long history of south-south collaboration between India and the region, particularly in their mutual search for autonomy, commitments to common but differentiated responsibility, and voice of the developing world's concerns. These projects require technology coordination and the supply of essential mineral and metal resources, which Latin America may be able to supply to fuel India's ambitious solar energy development plans.

India's energy security is crucial, and it has campaigned for membership in the Nuclear Suppliers Group[53] (NSG) to access advanced technology and meet international commitments at the Paris Climate Summit. As of 2016, India identified Latin America as a crucial region for NSG membership, with Mexico, Brazil, and Argentina all supporting India's claims. However, China's refusal to support India's bid to join the NSG remains

[52] Solae e-mobility technology refers to the integration of solar energy with electric mobility solutions such as electric vehicles (EVs), to enhance sustainability and efficiency in transportation.
[53] NSG governs the transfers of civilian nuclear material, equipment and technology to ensure they are not used for military purposes.

essential due to the economic and political linkages between the two countries.(Misra,Briceño,Hurtado,2021)

India’s commitment to renewable energy, particularly biofuels and bioethanol, and its commitment to increase blends in traditional fuels, technology transfer, and sharing best practices have gained traction [54]in India-Brazil conversations. India’s commitment to increasing renewable energy share in its energy basket and projected increases in battery reliance suggest that essential minerals like lithium, abundant in Latin American countries like Chile, will continue to grow in importance for the country. Latin America, like India, is committed to the fight against climate change, and cooperation on climate change is often mentioned alongside cooperation on energy issues. Countries like Brazil’s position as a global South and their determination to fight for a more representative world order and sustainable solutions for developing countries spell a promising future for cooperation in renewable energy between India and the region. However, industrial trade relies on crude oil and gas, especially energy.

India's status as a net exporter of refined petroleum products is particularly significant in its energy relations with Latin America. The largest import from the region was crude oil, which India imported to the tune of USD 11,009 million. The largest importers of crude oil to India were Venezuela, followed by Mexico, Brazil, Colombia, and Ecuador (Misra,Briceño,Hurtado,2021)

Indian oil companies and private energy players are involved in almost all aspects of energy in Latin America, from exploration to refining. The Latin America region accounts for 14%-20% of India's oil imports by quantity since 2012. India represents a

[54] Advancement or momentum.

sizeable democratic market for Latin America, reducing its dependence on the USA and China. However, India has aimed to distinguish itself from China through its regional investments, with value-added industry investments being the norm. Indian businesses are also proving to be valued employers in the area, with over 150 Indian companies maintaining an active presence there.(Misra,Briceño,Hurtado,2021)

The Latin America-India relationship is trade-driven, business-first, and resource-dependent The dynamics of this relationship will be shaped by their energy cooperation, which is the most developed area of their relationship. India's drive towards renewable energy influences the relationship between alternative sources like natural gas and technologies like shale. The relationship is defined by energy cooperation, which acts as a bridge between potential and actual practice. The Essar Group [55]bid for Petrobras' Bahia [56]refinery in 2020, indicating intent to enter the Latin American energy.

The Indian government has emphasized the strategic importance of Latin America in its foreign policy goals, with External Affairs Minister S Jaishankar visiting several countries in the region in 2023. The visit highlighted the range of issues, including mining, energy, climate change, and trade, on which India seeks to engage with the region, India's engagement with regional organizations such as the Caribbean Community (CARICOM) and the Association of Caribbean States (ACS) provides a platform for India to engage on a wide range of issues, including climate change, security, and regional integration.

[55] Essar Group is an Indian multinational conglomerate company known as Essar Global Fund Limited (EGFL) and owns a varirty of assets in the core sectors of energy (oil refining, oil and gas exploration and production, power), infrastructure and logistics etc.
[56] Petrobras Bahia is the Brazilian oil and gas giant, involved in various projects and partnerships.

India's energy partnership with Latin America is driven by several factors, including energy security, diversification of energy sources, and economic opportunities. With its oil-rich nations such as Trinidad and Tobago, Guyana, and Suriname, Latin America provides an attractive alternative for India to diversify its energy portfolio and reduce dependence on unstable Middle Eastern sources. The region's oil-rich nations and potential for renewable energy investment make it an attractive partner for India. India's engagement with the region extends beyond energy to include economic opportunities and regional cooperation.

Additionally, India is exploring the possibility of investing in the renewable energy sector in the region, capitalizing on the vast potential for growth in this area.

4.3.3 India’s Energy Partnership in the Middle East

India and Israel are focusing on energy cooperation to strengthen their ties. Following signing a Memorandum of Understanding in 2018, the two countries have gained momentum in this field. As Israel becomes a critical natural gas exporter in the Middle East and India diversifies its energy sources, cooperation is a promising area for both countries. The increasing importance of renewable energy sources may facilitate further cooperation. India currently engages in energy exploration and drilling activities in the Mediterranean, but both countries are keen to scale new heights in their bilateral relationship. Initiatives such as the oil-gas MoU, collaboration agreements, and joint ventures indicate their efforts to strengthen cooperation in the energy sector.

Although India’s energy import from Israel has yet to begin, India's growing role as an exporter and increasing energy imports from Israel could lead to a more robust Indo-

Israeli energy trade. India could rely on Israel as an energy source alongside traditional Gulf suppliers like Saudi Arabia, Iraq, Kuwait, Qatar, and the UAE. This expansion aligns with India's foreign policy goal of deepening strategic ties with the broader Middle East, including Israel, which accounts for 53% and 41% of India's oil and gas imports, respectively. (Ningthoujam,2021)

The energy cooperation aims to transform the two states' ties from a patron-client dynamic [57]to promote joint ventures in other areas of the bilateral relationship. Israel's discovery of the Leviathan gas field [58]in 2010 has allowed India to initiate cooperation in a new sphere. Indian firms entered the Israeli energy sector in 2018 when the Israeli energy ministry granted a license to Indian companies for oil and gas exploration and drilling in Israel's waters.

Both countries have technological skills and investments to jointly develop renewable energy domains, such as the Indian Oil Corporation's agreement with Israeli start-up Phinergy to manufacture Aluminum-Air systems in India. However, as renewable energy is still nascent, there is still much room for further growth.

In the long run, China could compete in oil and gas exploration in Israeli gas fields in the Mediterranean, where Indian involvement is present. Israel has also worked to promote energy ties with China, and researchers from both countries have begun joint projects, resulting in the development of "stable, efficient solar cells." Given the existing tensions between India and China, trilateral energy collaboration between these countries would take much work.

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[57] A social relationship where one party, the patron, holds a position of authority, social status, or control over resources while the other party, the client benefits from the support provided by the patron.
[58] https://newmedenergy.com/operations/leviathan/

India and the United Arab Emirates (UAE) have formed a significant partnership in the renewable energy sector in 2023, focusing on sustainable and greener futures. The partnership has led to a surge in solar energy projects, with India investing in the Mohammed bin Rashid Al Maktoum Solar Park in Dubai, one of the world's largest solar parks. The UAE is also exploring wind energy, with the Gulf of Mannar Wind Farm in India and the Al Dhafra Wind Farm as prominent examples.

The UAE's sovereign wealth funds and Indian companies have formed partnerships to invest in renewable energy projects worldwide, fostering technological innovation and promoting economic ties between the two nations. India and the UAE also focus on green hydrogen initiatives to achieve energy sustainability and reduce carbon emissions. Both countries actively engage in international forums and agreements related to renewable energy, championing the cause of clean energy on global platforms and sharing best practices with other nations. The collaboration between India and the UAE in the renewable sector has led to numerous job creations, with skilled workers from India finding employment in various projects in the UAE, contributing to the economic growth of both nations.

The UAE-India Business Council [59](UIBC) and Nangia Andersen LLP[60] came up with a new report which was titled “Modern Energy: India-UAE Collaboration for a Sustainable Future” in March 2024; the report emphasized the collaboration between India and UAE in the RE sector aiming to foster a Sustainable Future in addition to the UNSDG, the report will guide companies who are seeking to enter or expand their operations in the RE

[59] UIBC is the official joint business chamber established by the governments of the UAE and India to foster economic synergy between both the nations, aiming to provide economic space for stakeholders
[60] Nangia Andersen LLP is a premier business advisory firm offering compressive range of professional services, including growth strategy and transaction

sector between two countries, the report highlights policy framework and initiative such as India's National Solar Mission and UAE's Energy Strategy 2050[61], which are necessary to promote RE adoption. Both countries have become strong advocates for a sustainable future through collaborative efforts and continuous innovations (Economic Times Bureau, 2024).

On August 14, 2023, the Abu Dhabi National Oil Company (ADNOC) and the Indian Oil Corporation Limited (IOCL) completed the first-ever crude oil transaction under the Local Currency Settlement (LCS) framework to fortify the economic partnership between India and the United Arab Emirates (UAE). One million barrels of crude oil were exchanged in this historic transaction, significantly changing the two countries' attitudes toward cross-border trade. This latest crude oil deal is the second time India and the UAE have used the LCS mechanism. On July 15, 2023, the Memorandum of Understanding (MoU) encouraging the use of local currencies (INR-AED) for trade settlement was signed. This marked the first transaction (Briefing India, 2024)

India and the UAE have achieved significant trade milestones in FY 2022-23, with a 16 percent year-on-year increase in trade volume from $72.9 billion to $84.5 billion and an annual growth of 14% during the implementation of the Comprehensive Economic Partnership Agreement. (Briefing India, 2024)

India and Saudi Arabia have signed a Memorandum of Understanding (MoU) in New Delhi on 10th September 2023. The MoU outlines cooperation in renewable energy, energy efficiency, hydrogen, electricity, grid interconnection, petroleum, natural gas,

[61] 0 UAE's Energy Strategy 2050 aims for a 50% clean energy capacity mix and a 40% reduction in final energy demand by 2050, focusing on sustainability, economic productivity, and climate challenges.

strategic petroleum reserves, and energy security. It encourages bilateral investment in renewable energy, electricity, hydrogen, storage, and oil and gas. The MoU also promotes the circular economy and technologies to reduce climate change effects, digital transformation, innovation, cyber-security, and artificial intelligence in the energy field. The MoU aims to develop qualitative partnerships to localize materials, products, and services related to all energy sectors, supply chains, and technologies. It also strengthens cooperation with energy-specialized companies. The MoU will support India's efforts to transition to energy and transform the global energy system to combat climate change. (Press Information Bureau Delhi, 2023)

The agreement was reached over the weekend after Prime Minister Narendra Modi announced the India-Middle East-Europe Economic Corridor (IMEC) at the 18th G20 Summit. One of the IMEC's original partner nations is Saudi Arabia. In his opening remarks, Prime Minister Modi stated, "This corridor will not only help bring the two countries together, but will also lead to greater synergies in economic cooperation, energy sector, and digital connectivity between Asia, West Asia, and Europe." "The two countries stressed the importance of supporting the stability of the world's oil markets by encouraging dialogue and cooperation between producing and consuming countries and ensuring the security of energy supply sources in the world markets," The two sides highlighted the importance of energy cooperation as an important pillar of the strategic partnership between the two countries. (Pant, 2023)

Therefore, the two countries will promote digital transformation, innovation, cyber security, and artificial intelligence (AI) in the energy sector. Efforts will also be made towards developing qualitative partnerships between the two countries to localize

materials, products, and services related to all energy sectors, supply chains, and technologies. Saudi Arabia, the largest and most populous country in the Arabian Peninsula, has been trying to diversify its economy away from an overdependence on oil by focusing on investments in technologies like artificial intelligence (AI) and blockchain, gaming, encouraging foreign investments, and tourism under its Vision 2030 document.

4.3.4 India and Russia on energy partnership

The Ukraine crisis has led Western oil and gas companies to stop joint energy projects with Russia in the Arctic due to fear of economic sanctions and opposition against Russia's military operation in Ukraine. Major energy giants like British multinational oil and gas company (BP), Equinor[62], ExxonMobil[63], and Shell are finding suitable exits from Russian energy projects. Sakhalin-1[64], an international consortium of oil and gas development companies in the Russian Far East, has seen similar trends. ExxonMobil, which owns a 30% stake in Sakhalin-1, has stopped operations and is expected to exit formally. Other entities in Sakhalin-1 include Sakhalin Oil & Gas Development Co. Ltd. (Japan), ONGC Videsh Ltd. (India), and Sakhalin mornefte gas-Shelf and RN-Astra [65](Russia).

Sakhalin-2, an international energy development consortium of Gazprom (Russia), Shell (US-based subsidiary of Royal Dutch), Mitsui & Co. (Japan), and Mitsubishi Corp.

[62] Equinor is a Norwegian state-owned multinational energy company.
[63] ExxonMobil is a American multinational oil and corporation
[64] Sakhalin-1 project is an oil and gas development initiative located off the coast of Sakhalin island in the Russian far East.
[65] RN-Astra is a subsidiary of the Russian oil company Rosneft that holds an 8.5% stake in the Sakhalin-1 consortium.

(Japan), also faces pressure to terminate their partnership with Russia. Japan has resisted this pressure, but uncertainty remains about the prospects of this cooperation, Sakhalin-1 and Sakhalin-2 are Russia's most crucial integrated oil and gas development projects operating in harsh climate conditions.

Russia needs reliable long-term partners to develop its Far Eastern regions and sustain its economy during the Ukraine crisis. If European and Western countries reduce their oil and gas dependency on Russia, the most viable option for Russia is to tap energy markets in East, South East, and South Asian countries. Sakhalin-1 and Sakhalin-2 could become promising projects for supplying Russian oil and gas to these markets. (Sharma,2022)

India's oil and gas trade with Russia remains low due to shipping distance, cargo delivery time, and cost escalation. India's energy engagements with Russia are through ONGC Videsh Limited's direct investments in Russian energy projects. Despite Russia's offer to supply cheaper crude oil after the Ukraine crisis, Indian companies increased their oil import volumes from Russia. The Western exit from Russian oil projects could allow Indian oil companies to directly invest in Russian energy projects to secure the country's long-term energy needs. This would strengthen and diversify India's energy supply chains and reduce its dependency on Middle Eastern countries for oil imports.

India's purchase of discounted Russian crude oil has significantly boosted the trade between the two countries, reaching nearly $50 billion from 2022-2023. This trade boom will increase as Russia's economic ties with India expand from traditional exports to automotive, electronic parts, or renewables. As India seeks to reinvent itself as a central manufacturing hub, trading powerhouse, and influential services provider, it will likely

look to Russia as a significant global market (Panda,2024) In contrast, the Indian government is rethinking any major new strategic collaborations with Russia amid concerns that it will stall India's growth and modernization due to current geopolitical constraints on Moscow. India's delicate downgrading of its relationship with Russia is further exemplified by forgoing the once-annual prime minister-level summit with Russia while holding multiple foreign minister-level meetings. India seems to be staying firm to its narrative of "India First," whether it is buying Russian oil or positioning itself in the Indo-Pacific.

India imported Russia's Ural oil at an average discount of nearly 9% a barrel in the 2022-23 financial year, compared to its second largest source, Iraq. This discount increased to 14% in April 2023, fuelling a surge in crude oil imports from Russia. The discounted oil imports helped India address its macroeconomic problems, primarily due to rising petroleum product prices. Cheap crude oil imports also benefited India's export business. (Dhar,2024)

4.3.5 India’s energy partnership with the EU

India and the EU work closely together to assist each other’s energy and climate goals as part of their partnership on clean energy.

The EU-India Clean Energy and Climate Partnership (CECP), founded in 2016 by the EU and India, supports research and the creation of creative solutions while facilitating access to the distribution of clean energy and climate-friendly technologies. This collaboration supports cooperative projects and research and serves as a framework for the EU-India energy and climate policy conversation. Collaboration areas include integrating

renewable energy and storage, smart grids, biofuels, offshore wind energy, rooftop solar and solar parks, and energy efficiency in buildings.

Senior authorities gather annually as an energy panel. Energy security, efficiency, and renewable energy are the topics of active working groups in the energy sector. Furthermore, in these energy sectors, energy cooperation occurs through conferences, study tours, exchanges, business contacts, cooperative research, and other means. In partnership with the Florence School of Regulation[66], The EU hopes to help India's ambitious climate mitigation targets and clean energy transition in their relationship while deepening their renewable energy cooperation. Early in September 2022, Energy Commissioner Kadri Simson participated in two EU-India seminars to advance the EU-India collaboration in solar energy and hydrogen. The clean energy technologies group will concentrate on green technologies, Including investments and standards, focusing on research and innovation, in alignment with the EU-India Clean Energy and Climate Partnership. India is a significant player in the fusion energy industry. It is a part of the global International nuclear fusion research and engineering megaproject[67] (ITER) fusion project with the US, China, South Korea, Japan, and Russia. Under the terms of their bilateral Euratom Cooperation Agreement on Fusion Energy Research[68], the EU and India work together.

The Bureau of Energy Efficiency (BEE) and the French Environment and Energy Management Agency (ADEME) are working to develop tools for collecting, using, and

[66] FSR is a renowned institution dedicated to independent discussion and dissemination of knowledge on various regulatory topics such as Energy, Climate, etc.
[67] ITER-India https://www.iterindia.in/
[68] Euratom Cooperation Agreement on fusion energy research aims to enhance collaboration between the European Atomic Energy Community and other parties in the field of fusion energy research

analyzing energy efficiency data across sectors. The project aims to monitor energy consumption trends and the status of energy efficiency in India through Energy Efficiency Indicators. The ADEME team and ENERDATA[69] specialize in analyzing and modeling global energy markets and their drivers. The project aims to improve sustainable mobility and track global emissions for India's Independent National Capital.

The Indo-German Energy Forum (IGEF) was established in 2006 between Germany and India to promote dialogue and cooperation in energy security, efficiency, renewable energy, investment in energy projects, and collaborative R&D. The forum has four sub-groups: efficiency enhancement in fossil fuel-based power plants, renewable energy, demand side energy efficiency, and low carbon growth strategies, and green energy corridors. The Bureau of Energy Efficiency (BEE) leads subgroup 3, which focuses on enhancing energy efficiency through constructive dialogue between government and private sector decision-makers. Current activities include working on energy efficiency in industry, cooling, and shifting electricity demand peaks at night when solar power is unavailable. The forum also organizes workshops and seminars on CO2 markets, energy-efficient brick manufacturing[70], and building energy efficiency.

The "Energy Efficient Cooling – EE-Cool[71]" project, initiated under the Indo-German Energy Programme, supports the Bureau of Energy Efficiency (BEE) in implementing the India Cooling Action Plan (ICAP) for energy-efficient centralized space cooling systems. The project, financed through Germany's International Climate Initiative, considers the

[69] ENERDATA is an independent research and consulting company specializing in the analysis and modelling of global energy markets and their drivers.
[70] energy-efficient brick manufacturing refers to process of producing bricks with reduced energy consumption compared to traditional methods
[71] EE- Cool initiative is a significant endeavor commissioned by German Federal Ministry for the environment, nature conservation and nuclear safety.

positive climate effects of non-partially fluorinated [72]or partially halogenated refrigerants[73]. (Bureau of Energy Efficiency, 2024)

4.4 INDIA'S ENERGY DIVERSIFICATION

India is expanding its range of renewable energy sources by combining investments, partnerships, and government programs. India's primary renewable energy sources include solar power, wind, hydropower, and biomass. In February 2024, solar power accounted for 57.9% of all renewable energy produced in the country. By 2030, the government hopes to have installed 450 GW of renewable energy capacity, which will come from solar, wind, hydropower, and other renewable energy sources (Hydromo Administrator, 2023). To accomplish this, the Indian government has launched several programs and policies, including the Wind Energy Development Program, the Solar Park Scheme, and the National Solar Mission. These programs and initiatives provide a range of incentives, such as tax breaks, subsidies, and preferential tariffs, to support and promote renewable energy projects. (Mukherjee, 2023) In addition, the government and Saudi Arabia have inked a Memorandum of Understanding (MoU) to forge a closer energy collaboration that will aid India's attempts to transition to a cleaner energy source and restructure the world energy system to fight climate change. (Press Information Bureau Delhi,2023) India is internationally diversifying its renewable energy mix through various initiatives, partnerships, and collaborations. The country has been sharing its experience and knowledge with other developing nations through international forums,

[72] non-partially fluorinated are those that do not contain any fluorine atoms in their chemical composition.
[73] partially halogenated refrigerants are refrigerants that contain halogen atoms but not in a complete or full manner.

including the International Solar Alliance and the UN Climate Change Conference, inspiring other countries to follow suit.

The Indian government has worked to establish a competitive renewable energy environment based on the 'Aatma Nirbhar' philosophy, which includes significant incentives for growth in capacity and supportive policies for research-driven innovation, like the National Solar Mission, which is scaling up our solar energy in the last 15 years, The international relations division of MNRE has continuously engaged with several Ministries/Departments of the Government of India, Indian Missions, Foreign Diplomatic Missions located in India, Multilateral International Organizations and Agencies, Regional Groupings, and development banks, among others, for promoting international cooperation in the field of Renewable Energy.

The reports for 2022-23 say that India signed various MoUs with countries like Finland; the MoU was signed between the Ministry of Economic Affairs and Employment of the Republic of Finland and MNRE on cooperation in renewable energy (MNRE annual report,2022-23). An Indo-German Green Hydrogen Taskforce was between India and Germany; it is a Joint Declaration of Intent (JDI).

India's engagement with the International Renewable Energy Agency (IRENA), an intergovernmental organization that supports countries in their process of transition to sustainable energy in the future, IRENA is a leading platform for international cooperation, technology, financial knowledge on renewable energy; it promotes the use of all forms of renewable energy including bio-energy, geothermal, hydropower, ocean,

solar, wind energy, in the pursuit of energy access, energy security, low carbon economy growth, etc.

During India's G20 presidency, some of its priority areas under energy transition were addressing technology gaps, diversifying the supply chain, transitioning industries to low carbon, energy consumption in a responsible way, fuels of the future, and access to clean energy and transition.

Cooperation under the QUAD framework, leaders of Quad announced that the Quad Climate Working Group would strengthen climate actions globally with core themes like climate ambition, innovation of clean energy and its deployment, and adopting clean energy by countries.

India Norway Task Force on the energy sector constituted an India- Norway policy dialogue for adopting best practices, share learning, clean energy technology transfer, availing for low-cost finance, business tie-ups, etc.

President Macron's state visit to New Delhi marked a historic agreement between France and India to combat climate change and advance clean energy. The collaboration includes the International Solar Alliance, green hydrogen, and nuclear power, enhancing bilateral relations and promoting global solar energy promotion.

The International Solar Alliance (ISA) is leading the global solar industry with ambitious targets of mobilizing $1 trillion in investments by 2030. The ISA supports member nations in accelerating solar energy adoption, requiring collaboration from governments, industries, and communities. To meet net-zero targets, global solar PV capacity must increase to 600GW/year from 2023 to 2030 and 1000GW/year from 2030 to 2050. The

ISA's SolarX Grand Challenge, focusing on Africa, aims to find new ideas and solutions in solar energy, with over 100 startups participating (MNRE annual report,2022-23).

India and France are collaborating on solar projects in developing regions, particularly Africa, with the announcement of a solar academy in Senegal under the STAR-C program. They are also working on green hydrogen to reach carbon neutrality targets by combining their hydrogen ecosystems for a sustainable value chain. India's Green Hydrogen Mission, with a budget of INR 19,744 crores, aims to invest over INR 8 lakh crore and create over 6 lakh jobs by 2030. The initiative aims to reduce CO2 emissions and save INR 1 trillion on fuel imports (MNRE annual report,2022-23).

4.5 NATIONALLY DETERMINED CONTRIBUTION

India's dependence on fossil fuels is increasing despite securing the fourth position globally in installing renewable energy capacity in 2022. The country's coal and gas-fired power plants operate at peak capacity to meet seasonal electricity demand due to record-hot summers. Long-term planning is crucial for dealing with volatile energy demand and prioritizing a definitive transition from fossil fuels. India's emissions are expected to rise beyond 2030 under current policies, but with international support, it could expedite faster reductions. The Climate Action Tracker (CAT) overall rating of India's climate targets and action needs to be revised. Long-term planning is crucial for India to meet its developmental goals and contribute to the global climate crisis.

The Indian government has implemented various policies to promote renewable energy, including capacity targets, administrative improvements, incentives for domestic solar technology production, and green hydrogen production. However, reliance on coal power

remains challenging, with no plans for additional coal capacity beyond 2026-27. The National Electricity Plan (National Electricity Policy, 2023), adopted in May 2023, eliminates a small amount of new gas power and reduces reliance on nuclear power throughout the decade. The total added 31 GW has raised solar capacity, but the plan foresees slightly less wind power for an overall increase of 21 GW in non-hydro renewable energy capacity. The current policy scenario is based on the IEA's World Energy Outlook 2023 (World Energy Outlook, 2023), which projects India's total energy-related emissions will peak around 2035 under the Stated Policies Scenarios (STEPS), while emissions from the power sector will peak around 2030. Overall reliance on coal-based power generation remains around 55%, marginally lower than the 2022 update. Solar capacity additions have increased, but wind capacity additions have declined; India is experiencing a surge in summer electricity demand due to extreme heat waves and prolonged summers. The government has directed coal plants to operate at maximum capacity and increased gas plant use to meet peak demand. Both domestic coal production and coal imports reached record highs in 2023 (World Energy Outlook, 2023)

India has made significant strides in climate change mitigation policies, including increasing power distribution companies' minimum renewable purchase obligation from 24.6% in 2023 to 43.33% in 2030. The Ministry of Power has also adopted guidelines for pumped storage projects, but concerns about the environmental clearance process have yet to be raised. The government has started auctions under a production-linked incentive program for green hydrogen production. To further its climate action, India needs to commit to phasing out fossil fuels at COP28, develop a sustainable plan for early retirement of coal power capacity, avoid a dependency on LNG imports, and strengthen

its climate targets. India is already on track to meet and exceed its 2030 targets, but achieving emissions reductions to limit warming to 1.5°C will require significant international support. An ambitious conditional target could indicate India's willingness to take action if support is made available.

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India's National Electricity Plan 2023 (NEP2023) outlines ambitious renewable energy plans, with a share of 57% and 66% in 2026-27 and 2031-32, respectively. The government provides financial incentives to promote renewable energy, including import duties to protect local producers. However, India's reliance on coal and gas is increasing due to rising summer heat waves. The NEP2023, which outlines a strategy up to 2026-27, envisages a 150% increase in additional coal capacity in the decade's second half. India needs to phase out coal use from its power sector by 2040 and reduce it by 2030. The

government is also advancing its green hydrogen policy, setting a target of five million tonnes of green hydrogen production annually by 2030 (World Energy Outlook, 2023).

India's National Development Goals (NDG) include a 45% reduction in emissions intensity by 2030, a 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, and a carbon sink of 2.5-3 GtCO2e through additional forest and tree cover. However, the target is rated as "Highly insufficient" compared to the reductions needed to limit warming to 1.5°C. India's target is at the least stringent end of global efforts and is inconsistent with the 1.5°C limit unless other countries make deeper reductions and more significant efforts. More information on these elements could improve the transparency of India's target. India's net carbon sink was still 308 MtCO2e in 2016, but it plans to increase this to 24.6% by 2030 through additional forest cover. (World Energy Outlook, 2023).

CHAPTER 5

CHALLENGES TO INDIA'S COMMITMENT TO SDG7

5.1 CHALLENGES FACED BY INDIA IN ACHIEVING SDG 7

India's energy sector has undergone numerous policy reforms over the past 20 years aiming to liberalize it to a market-based system; however, political complexity and socialist economic practices have hindered this progress, leading to sub-optimal outcomes; the sector is struggling to deliver secure energy supply amid rising demand and fuel imports. The financial capacity of energy sector players is undermined, and India faces geopolitical risks and increased competition.

India faces many challenges in achieving SDG7, which is affordable and clean energy for all; as we know, 70% of our energy demand is meant by coal, limiting the use of fossil fuel, addressing Fossil Fuel challenges involves reducing consumption and production, GOI has implemented several policies to constrain Fossil Fuel production such fossil fuel subsidies that encourage wasteful consumption while providing support for renewable energy development, next is Clean Environment Cess is a tax on the use of coal that discourages its production, moreover Renewable Energy Certificates for RE generation, the National Green Hydrogen Mission aims to reduce consumption of imported Fossil Fuel and others shows how India is trying to phase out FF as a source to generate energy. The solution suggested by the experts to reduce Fossil Fuel production for long-term solutions is a global climate agreement.

Migrating towards diversified RE matrices, the implementation of RETs in the country has seen an increase in capacity. However, the rate at which it is increasing is insufficient to match the rate of increase in Fossil Fuel usage. Thus, achieving SDG 7 by 2030 via a diversified RE matrix is unlikely to be fully implemented; as a developing country with economy, population, and energy growth intertwined, the economy is heavily invested in these energy sources; this problem is deep-seated and is worsening over time. To diversify and promote RE sources such as bioenergy, the government provides financial assistance for setting up community biogas plants in villages and promoting blending biomass in existing coal-powered thermal power plants

Despite the potential for energy efficiency in India, its implementation has several challenges. One of the significant challenges is the lack of awareness and knowledge about energy efficiency measures among consumers and businesses, lack of financing for projects, and lack of enforcement of regulations. Consumers are often unaware of the benefits and incentives for adopting energy-efficient measures. At the same time, businesses may lack the financial resources to implement them; innovative financing mechanisms like energy service companies can help promote energy efficiency adoption. However, India can promote energy efficiency through government incentives, project financing, and more vigorous enforcement of regulations. On the other hand, businesses can reduce energy consumption and contribute to sustainable development by reducing their carbon footprint. At the same time, consumers can adopt energy-efficient appliances and building designs, making informed choices (Guru et al., 2023).

5.1.1 in the power sector

Availability of Power is one of the biggest concern in the field of RE, power generation depends on natural resources that are uncontrollable by human for example solar and wind energy generation depends on sunlight availability and wind speed, requiring delicate balance to maintain consistent energy generation, uncertainty in RE production complicates integration, as low wind speed prevents turbine rotation and too much wind damage, another challenge is low quality of power, high power quality is crucial for network stability and efficiency, reducing costs and ensuring reliability, however poor quality power can lead to equipment failure, high costs and adverse effects on the power grid and industrial processes, further more resource location is also one of the challenge where plants of RE requires ample space and are often influenced by location, which can be a disadvantageous to the users, location affects cost and efficiency while factors like weather, climate and geographical location also affect the suitability of energy generation, additionally development of RE faces hurdles due to high initial installation costs, high investment in wind and solar power plants and expensive storage systems makes it challenging to produce megawatts

5.2.2 Access to the Clean Cooking sector

Challenges for Clean Cooking Access: Global awareness of clean cooking solutions is increasing, leading to improved policy frameworks and investments in clean cooking technologies. Countries like India are transitioning to cleaner energy technologies, reducing air pollution and carbon emissions; urban areas are seeing improved clean cooking due to better infrastructure, narrowing the urban-rural divide. Several challenges

impede progress toward universal clean cooking access, like increased investments in innovative financing mechanisms and public-private partnerships to overcome financing gaps and ensure sustainable funding for clean cooking initiatives. It will also emphasize the importance of empowering women in decision-making processes for equitable access. Empowering women in decision-making processes is crucial for achieving equitable clean cooking access as it addresses gender inequalities and exposes them to health risks; the tracking SDG 7 Energy Progress 2023 report identifies several key strategies and initiatives to accelerate progress in clean cooking access, such as clean cooking should be made a part of Nationally Determined Contributions (NDCs) and Sustainable Development Goals, policy support and capacity building are crucial likewise clean fuel subsidies and incentives can make clean fuels more affordable especially in rural areas and collaboration between governments, international organizations, and private sector entities can drive innovation, investment, and market development for clean cooking solutions (Patrick K., 2023).

Our next challenge is to provide an adequate energy supply to meet the growing population's demand, which the country cannot deliver from its domestic production, making it more dependent on imported fuel. Increasing import dependency exposes to more significant geopolitical risks, fluctuating market prices, and intensifying international competition; India should pass its current patchwork of energy policies in favor of a comprehensive and clear-cut policy that encourages economic and social development through reliable energy supplies

India requires significant investment to meet its increasing energy demand and give access to all its citizens, particularly modern and clean sources of energy; thus, the

investment should focus on adopting the latest green growth energy technology and creating necessary framework conditions such as moving away from import substitution policy. Effective implementation of energy policies is required through the improvement of bureaucratic and administrative processes to assure that projects are completed on time; this will also contain unnecessary cost escalation of complex projects; thus, coordination between central and state governments should be enhanced. It should first complete the unfinished reforms in the energy sectors; there should be consistent political messages and effective public communication to obtain public support for necessary reforms in the energy sector.

5.3 INDIA'S PROGRESS TOWARDS SDG7

To Track SDG 7: The Energy Progress Report is produced annually by five custodian agencies; it provides a global summary of progress on energy access, energy efficiency, renewable energy, clean cooking, and international cooperation to advance Sustainable Development Goal 7. The report presents updated statistics for each indicator and provides policy insights on priority areas and actions needed for further progress on SDG 7 and related SDGs; despite some progress across the indicators, the current pace is inadequate to achieve any of the 2030 targets. Major economic factors impeding the realization of SDG 7 globally include uncertain macroeconomic outlook, high levels of inflation, currency fluctuations, debt distress in many countries, lack of financing, supply chain bottlenecks, tighter fiscal circumstances, and soaring prices for materials. The effects of the COVID-19 pandemic and the steady rise in energy prices since the summer of 2021 are expected to further drag on progress, particularly in vulnerable countries and those already lagging (sdg7.report, 2022).

The government of India came up with a draft containing an action agenda to advance SDG 7 of sustainable energy for all with the Paris Agreement on Climate Change goals. It has India's ambition to achieve SDG7 by 2030; what are the actions the government has to take to achieve the ambition, and what will be the possible outcome of it? It also mentions the resources and support required and how it will impact us, and we can monitor the progress through official websites.

India's targets for SDG7 are as follow.s, 7.1ensure sustained universal energy access, 7.2 increase the renewable energy installed capacity to 450GW by 2030, 7.2.2 Develop and implement a National Hydrogen Energy Mission to scale up green hydrogen production and utilization across multiple sectors, with a target of -1 million tonnes annual green hydrogen production by 2030, 7.2.3 Production Linked Incentive PIL scheme for high-efficiency solar modules to create an additional 10,000MW of integrated solar PV manufacturing capacity by 2025, 7.2.4 Create production capacity for 15 million metric tonnes MMT of compressed biogas CBG by 2024, 7.2.5 Achieve 20% ethanol blending in petrol by Ethanol Supply Year ESY 2025-26, 7.3.1 Enhance energy efficiency in agriculture, buildings, industries, and transportation sectors while also promoting energy-efficient appliances/ equipment

In the context of target 7.1, ensuring sustained universal energy access, its timeframe was 2022 in May 2016, Pradhan Matri Ujjwala Yojana PMUY 1.0 with a target of 50 million deposit-free LPG connections for below-poverty-line households; however, the target was expanded to March 2018 to 80 million connections achieved in August 2019.

To ensure universal access to clean cooking fuel, an additional 10 million connections under the PMUY 2.0 scheme for those low-income families who could not be covered under the first phase of PMUY. The outcome was that female participation increased in formal economic activities, there was improvement in the health sector, and there were fewer premature deaths (sdg7.report, 2022).

Target 7.2.1 Increase the renewable energy installed capacity to 450 GW by 2030

India's NDC at COP21 is to achieve a 40% share of non-fossil fuel-based installed capacity by 2030; India already has 153GW installed based on non-fossil fuel, and 62GW is under implementation, which equates to more than 39%, so India has enhanced its target to 450GW by 2030. It includes solar, wind, bioenergy, hydropower, and emerging green hydrogen and geothermal areas. Actions such as programs to promote solar and wind generation at the national and subnational levels include solar rooftop installation and distributed RE systems such as mini/microgrids for agriculture. Estimated to create 7,00,000 new jobs by 2030, it has already employed 1,00,000 full-time skilled and unskilled workers. To achieve this target, an investment of INR 17 00,000cr (221 billion) is required (sdg7.report, 2022).

Our next target is to develop and implement a National Hydrogen Energy Mission to scale up green hydrogen production and utilization across multiple sectors, with a target of -1 million tonnes annual green hydrogen production by 2030

The MNRE is developing a national Hydrogen Energy Mission to increase green hydrogen production and utilization to make India a global hub for producing and exporting green hydrogen. This will reduce our dependence on imported fossil fuels and

the decarbonisation of the economy. This mission will focus on creating demand, incentivizing indigenous manufacturing, supporting the production and supply of infrastructure, and public-private partnerships in R&D for green hydrogen. India can contribute to the global hydrogen economy through exports.

They are moving on to the next Production Linked Incentive (PLI) Scheme to create 10,000MW of integrated solar PV manufactured by 2025. It is linked with India's plan of installing 450GW RE. This solar module will be implemented nationwide by MNRE via the Indian Renewable Energy Development Agency IREDA. 4,500 crore has been allocated under the PLI scheme

The next target is to create a production capacity of 15 million metric tonnes MMT of compressed biogas by 2024. Sustainable Alternative Towards Affordable Transportation (SATAT) was launched in 2018 to promote CBG; SATAT was promoted as an alternative green fuel, which will help in the management of biomass and organic waste; CBG will replace fossil fuel-based natural gas in the transport sector; it will also reduce dependency and increase food security. Financial assistance or subsidies are also available to set up CBG plants and promote new projects.

Achieve 20% ethanol blending in petrol by Ethanol Supply Year (ESY) 2025-26.

GOI encourages sugar mills and distilleries to enhance their distillation capacity by facilitating loans and subvention of up to 6%; public sector oil companies process this ethanol. This will save 30,000 crore in foreign exchange by reducing crude oil imports, and GOI expects a 41,000 crore investment to meet the target (sdg7.report, 2022).

Our last target is to enhance energy efficiency in agriculture, buildings, industries, and transportation sectors.

India's NDC at COP21 includes reducing the emission intensity of its GDP by 33-35% over the 2005 level by 2030, but it has already achieved an emission reduction of 28% and is all set to exceed its NDC commitment before 2030 (sdg7.report, 2022).

The National Mission for Enhanced Energy Efficiency NMEEE is a key component of the national action plan on climate change. NAPCC focuses on achieving energy efficiency in all sectors of the economy. The revised version of NMEEE is the Road Map of Sustainable and Holistic Approach to National Energy Efficiency ROSHANEE, released in 2019, which includes potential areas for energy efficiency.

The Bureau of Energy Efficiency BEE is the implementing agency to enhance energy efficiency; under the Perform, Achieve, and Trade PAT, the PATE target is set; if they achieve higher than that, they get an Energy Saving Certificate (ESCerts).

Under the Street Lighting National Program (SLNP), India will replace street lights with LED lights. Under this program, more than 12.18 million LED streetlights have been installed across the country, resulting in energy savings (sdg7.report, 2022).

The Standard & Labeling program, 2006, informs consumers about energy and cost-saving potential if energy efficiency products are adopted.

Indicator I: The population with access to electricity is the SDG that is achieved and is on track or is maintaining SDG achievement; as of 2020, the value is 99.00. The long-term objective for this indicator is a value of 100 (IEA, IRENA, UNSD, WB, WHO, 2024)

Figure5.1: Population with access to electricity

Source: Sustainable Development Goals report

Impressive progress in Electricity has slowed due to the challenges of reaching those hardest to reach.

India has made significant progress in increasing population access to electricity, but there are still challenges in ensuring equitable access and reliable supply, particularly in rural areas. Ongoing efforts to address these challenges include the Saubhagya scheme, which aims to provide last-mile connectivity to all electrified households, and DDUGJY, which focuses on improving the quality of electricity supply.

Indicator II population with access to clean fuels and technology for cooking, challenges remain; this indicator is on track or is maintaining SDG achievement with a 67.90% value as of 2020. The long-term objective for this indicator is a value of 100%. Under WHO guidelines, kerosene is excluded from clean cooking fuels. (World Health Organisation report, 2024)

India has made significant progress in achieving clean fuel access, particularly cooking fuels. However, there are still challenges in ensuring that households are entirely switched to clean fuels and that these fuels are affordable and accessible to all. Including the marginalized communities, ongoing efforts to address these challenges include PMUY aiming to provide poor households with access to LPG and promotion of electricity and solar as cooking fuels.

Indicator III: CO_2 emissions from fuel combustion per total electricity output. Significant challenges remain; the score is moderately improving but insufficient to attain a goal; the value is 1.54 as of 2019. The long-term objective of this indicator is a value of 0 (sdg7.report, 2022). India has made significant progress in increasing the share of RE in the electricity mix and reducing its reliance on coal. However, there is still a need for more aggressive action to meet its net-zero emission targets by 2070 and to reduce its overall CO_2 emissions from fuel combustion for total electricity output.

Indicator IV: Renewable energy share in total final energy consumption. The significant challenges of this indicator remain: the score stagnates or increases at less than 50% of the required rate. The value is 15.90% as of 2019, and the long-term objective of this value is 55%. Renewable energy includes hydro, solid biofuels, liquid biofuels, biogases, modern biomass, wind, solar, geothermal, tide/wave/oceans, and renewable municipal waste. It does not include traditional biomass, e.g., Wood, charcoal, drugs, and agriculture residues that are used in low-income households that do not have access to modern cooking fuels or technologies (SDG report, 2024)

5.3.1 Outlook for Access to Electricity

The International Energy Agency (IEA) predicts a global increase in electricity access by 2022, primarily in Sub-Saharan Africa. This is largely due to supply chain disruptions and the energy crisis following the COVID-19 pandemic. The pandemic has led to higher costs for electricity systems and financing new projects. The IEA's Net Zero Emissions by 2050 scenario suggests that over half of the population will gain access by 2050 using off-grid solutions. However, achieving universal access by 2030 remains unlikely due to lack of official electrification plans and financing challenges (tracking SDG7 the progress report, 2023).

5.3.2 Outlook for Renewable Energy

The outlook for renewables remains positive in all regions, with IEA's Stated Policies Scenario predicting an increase from 18.5% to 23% in 2030, and modern renewables from 12% to 18%. Power-sector renewables remain the fastest-growing source of energy globally, with solar PV and wind driving growth. Hydropower remains the largest low-emission source, and modern bioenergy is the most significant growth share in end-use renewables (tracking SDG7, the progress report, 2023).

5.3.3 Outlook for Energy Efficiency

Global energy intensity is expected to improve by 2% in 2022 due to the ongoing energy crisis, rising costs, and supply disruptions. Governments worldwide are focusing on efficiency improvement to protect consumers from rising prices and secure supply. The COVID-19 pandemic has caused a slowdown in energy consumption, but increased attention to energy efficiency policies in Europe, Northern America, and Eastern Asia has

improved the outlook to 2.4% by 2030. The crisis has 118 also led to a 16 percent increase in energy efficiency-related investments to USD 560 billion (tracking SDG7, the progress report, 2023).

5.3.4 Investments Needed to Achieve SDG 7

Annual clean energy investments increased by 15% in 2021 to reach SDG 7, reaching almost USD 1.2 trillion. These investments are crucial for renewables and energy efficiency, and offset increased coal and oil use. However, financial resources are inadequate for achieving full energy access and clean cooking access in developing economies. International support and comprehensive policies are needed to address structural challenges and create new jobs. Investments in renewables, efficiency, electricity infrastructure, and hydrogen supply are also needed (tracking SDG7 the progress report, 2023).

CHAPTER 6

CONCLUSION

India's energy policy has evolved from direct state control to partially hybrid power markets. The logic of partial reform is critical to understanding India's energy policy today. During phase II of the energy policy, the government tried to have control over the primary energy supply sector and attempted to decentralize the power sector; following the oil shock, India emphasized energy conservation, usage of petroleum was reduced, the government regulated the coal mining industry and made the necessary investment in it, during the 2nd phase mandated conservation, the energy administration didn't take a step to transit to sustainable energy. Still, it forced to meet the basic needs of the people. The power sector reorganized power generation transmission and distribution across the nation from 1948 to 1991; during phase three finally, sustainable energy gained importance, and the government started to recognize energy policies that were responsible for climatic change; perform Achieve and Trade (PAT) instilled energy efficiency and energy saving practices in the industries. Schemes were introduced to electrify areas that are traditionally disconnected, policy initiatives, modified subsidy loads, and some other schemes like Ujjwala Yojana provided LPG, PM KUSUM scheme provided energy security for the farmers, PLI was introduced in 2020 to enhance manufacturing competitiveness and attract investment. This shows that India has a market-oriented approach to creating a dynamic market for RE transition from long-term manufacturing competitiveness & attract investment.

The government has introduced key policies encompassing support for the creation of ultra-mega and mega solar parks, implemented purchase obligation (RPOs), PLI, and Green Energy Corridor are some of the schemes to reach its target of solar and wind capacity there is a need for investment of $223 billion between 2022 and 2029 and extra $26 billion for battery storage projects.

Emerging technologies, including offshore wind, biofuels, agri photovoltaic (AgriPV), and floating solar, are gaining prominence as strategies to increase the share of RE in the energy mix, showcasing potential with ambitious targets and innovative solutions. In the biofuel sector, the government is encouraging sugar mills and distilleries to produce ethanol; AgriPV technology seamlessly integrates solar panels within agricultural land, offering a win-win situation for farmers to enjoy increased income from both crop cultivation and solar energy generation, balancing agricultural needs while managing its initial cost and developing effective business models remain a key challenge.

MoPNRE has said that besides 180GW of RE already installed, 130GW of RE capacity is under various stages of implementation, and 70GW is under bidding; this shows that the Government of India's target to achieve 500GW of renewable energy capacity by 2013 is achievable. To achieve this, new and emergent technologies are posed to play a Pivotal role in this ambitious, and here, embracing cutting-edge innovations such as advanced solar photovoltaic, offshore wind, energy storage solutions, biofuels, and green hydrogen production holds the key to realizing this goal, these technologies offer enhanced efficiency, scalability taking India towards a cleaner and greener energy future.

The country has a sizeable Solar energy potential, benefiting millions of Indians. NISE assessed 748GW as its solar potential. Wind energy's indigenous industry has grown significantly with a strong ecosystem, and the government is promoting it. India's target for the green hydrogen mission is 5 million tons annually, which is essential for achieving energy independence.

Modern bioenergy is used as a domestically available RE alternative; energy from biomass and agriculture waste has reduced waste, created jobs, and reduced import bills. Central financial assistance will be given for biogas, bio-CNG, and power plant projects.

India's energy transition offers enormous opportunities to boost the country's economy, including social development. The country's concern over pollution, air quality, environmental degradation, and climate change is leading to energy transition with RE sources gaining momentum. India's investments in green hydrogen are making the country the global hub for the production and usage, and export of green hydrogen aiming to make India self-reliant on clean energy; it will also benefit economically in the production of fertilizers domestically reducing imports and in steel production, GH will be used in the transport sector as zero emission cruel fuel.

Renewable energy technologies have great opportunities in India, providing promising solutions to meet energy demand and tackle environmental effects; its goal of "Make in India" encourages domestic technology development and leverages private actors' RD&D skills through public-private partnerships. India's innovation-specific policy support and National mission have played a significant role in promoting the development of critical

energy technologies, e.g., NSM and wind energy promotion, by providing generation-based incentives (GBIs)

Undoubtedly, about 50 million Indians get access to free LPG connections but still use non-connection sources for cooking. The reason behind this could be the high price of the LPG cylinder, which rural people cannot afford, and also, the refilling stations of LPG are located far away in the city areas.

Energy diplomacy is crucial for energy transition for a country like India, which imports 41% of its energy from foreign countries; India is exploring new destinations for RE installation equipment. India’s energy is tailoring itself according to the situation, importing and exporting energy resources and technology, and competing and cooperating with other actors when and how it is considered fit.

India sees SA as a region in its domain of influence. This region is dependent on imports of traditional fuels but also has potential in the RE sector. India is engaged in discussions with Southeast Asian countries to facilitate cross-border trade of RE. India has actively invested in Africa, primarily in the energy sector, infrastructure, health, agriculture, and industry. Natural resources, particularly crude oil and minerals, have dominated African imports, with about one-fifth of India's imports coming from Africa. India launched the 'Team-9 Initiative' in 2004 to diversify sources of energy security in the Francophone West Africa region and has extended concessional credit facilities for various projects and schemes.

The US-India Strategic Clean Energy Partnership (SCEP) aims to enhance energy security, promote trade, and facilitate clean energy technologies. India's relationship with

Latin America is growing due to its proximity to oil-rich nations like Trinidad and Tobago and Guyana. India is exploring investment in renewable energy (RE) in the region, with total energy trade reaching $12.32 billion in 2022. India and Israel focus on energy cooperation to strengthen their ties, and a Memorandum of Understanding was signed in 2018.

India and the UAE have formed a significant partnership in the renewable energy sector, focusing on sustainable and greener futures. The partnership has led to a surge in solar energy projects, with India investing in the Mohammed bin Rashid Al Maktoum Solar Park in Dubai.

India and Saudi Arabia have signed a Memorandum of Understanding (MoU) in New Delhi, focusing on cooperation in renewable energy, energy efficiency, hydrogen, electricity, grid interconnection, petroleum, natural gas, strategic petroleum reserves, and energy security.

The Ukraine crisis has led to Western oil and gas companies halting joint projects with Russia in the Arctic due to economic sanctions and opposition. Major energy giants like BP, Equinor, ExxonMobil, and Shell are exiting Russian energy projects.

India and the EU are collaborating on clean energy and climate goals, with India being the third-largest energy consumer globally. The EU-India Clean Energy and Climate Partnership (CECP) support the research and distribution of clean energy and climate-friendly technologies.

The country has signed MoUs with countries like Finland, Germany, and the International Renewable Energy Agency (IRENA). India is also engaging with the International Solar Alliance (ISA) to increase global solar growth and reduce financing costs. The country is

also collaborating with France on solar projects in developing regions, particularly Africa, and green hydrogen to achieve carbon neutrality targets.

India faces challenges in achieving SDG7, which aims for affordable and clean energy for all. 70% of energy demand is coal-based, and limiting fossil fuel production is crucial. However, more than implementing renewable energy matrices is required to match the increase in fossil fuel usage. Despite the potential for energy efficiency, implementation challenges include more awareness, financing, and enforcement of regulations. The power sector faces challenges such as the availability of power, low quality, and location-dependent resources. Clean cooking access is also a challenge, with global awareness increasing and policy support and capacity building needed.

Thus, India's access to electricity is achieved and is on track; however, in the clean fuel and technology sector, the achievement is 67 percent; renewable energy share in total final energy consumption is increasing at less than 50% of the required rate.

My first research question was to look upon India’s current renewable energy situation; this question is answered in chapter three under India’s renewable energy scenario; the critical analysis shows that India is globally ranked as the 3rd largest producer of renewable energy and 4th largest consumer of electricity, in 2022 its RE capacity was 40% 160 out of 400 GW came from renewable sources. It plans to reach 500 GW capacity by 2030. India’s current RE policies desire to substantially reduce GHG emissions from the power and transport sectors and identify more reliable and long-term energy sources.

The next question was, what is India's renewable energy policy strategy? This question is answered in chapter two under India's Energy Policies and Approach, moving on to India's policy strategy. It plans to develop and implement policies to achieve its goals and objectives. The research finds that India's policy strategy after independence was to offer policy support in the electricity sector; the primary goal of energy policy was to regulate the coal-mining industry for the sake of India's energy security; during this phase, India concentrated its energy demand by controlling primary energy supply sector. Soon, in the 1990s, with the liberalization of our economy, markets were open for foreign investments in the energy sector. Later, policies were created to protect the environment; moreover, in 2008, India's sustainable energy policy received more attention because of its National Action Plan on Climate Change (NAPCC); the NAPCC prioritized integrating renewable energy sources into the primary energy mix. Thus, we can conclude that India's policy strategy is market-oriented.

Moving on to the next question, does India's approach to renewable energy follow a market-driven strategy? This question is also answered in chapter two under India's energy policies and approach; looking at the policy strategy, we can conclude that India's approach towards implementation of energy policy involves a diverse range of techniques and initiatives, partly because it has different needs, priorities, and system of government, these factors make it challenging to analyze the policies or find out its approach but if compared between market or strategic approach, it can be said that India has market-oriented approach as it focuses on promoting energy efficiency, renewable energy and addressing financial challenges. The policies of India create a market for trade and utilization of renewable energy, making it a more flexible and efficient market.

Initiatives like market coupling foster competition and drive innovation in renewable technologies; by adopting a market-driven approach, India seeks to leverage its renewable energy potential, effectively attracting investment to achieve the targets in this sector. The focus is on achieving a more inclusive and sustainable energy system.

The final research question is, how far has India accomplished the SDG 7 objective? This question is answered in chapter five under India's progress towards SDG7**,** India's overall achievement in accomplishing SDG7 objectives. The country has achieved significant progress in areas such as electricity access to its population, to which 99% already have access. Still, the only concern is that the quality of the electricity needs to be improved. Secondly, access to clean fuel: more than 80 million people got access to LPG in 2018 under PMUY; renewable energy share in total final energy consumption is increasing at less than 50% of the required rate.

The study was based on the two Hypotheses:

Firstly, Despite challenges, India's policies and strategies are focused on promoting the development of RE through indigenous design. In chapter three, under domestic manufacturing of RE, we can see that India's government has implemented policies to encourage indigenous manufacturing in the renewable energy industry, focusing on electrolysis, battery energy storage devices, and solar parts. The production-linked incentive program has secured 40 GW of module manufacturing capacity by the end of the 2024-25 fiscal year. The National Green Hydrogen Mission offers domestic electrolysis and green hydrogen production incentives. However, concerns over excessive barriers and the need for low-cost financing remain. India should also invest in R&D,

explore international collaborations, and develop a roadmap for next-generation technology. Hence, this hypothesis is proved.

The second hypothesis was that through effective collaboration between the government, private sector, and research institutions, India's RE sector will foster innovation, technological advancements, and energy solutions, positioning the country as a leader in the clean energy transition.

In chapter three, it was found that the government collaborates with the private sector by giving subsidies to their projects, such as battery storage; this technology will store electricity from intermittent power sources like renewables and can be used later. Secondly, India's private sector has strongly supported government efforts to promote energy transition, like the Reliance group aiming to install 100GW of RE. Moreover, PPP in the clean cooking access initiatives can overcome financial gaps to ensure sustainable funding for clean cooking initiatives; India's national hydrogen energy mission requires PPP in R&D for green hydrogen. Thus, PPP projects have fostered innovation and technological advancement by utilizing private sector expertise, capital, and technology, which lead to knowledge and technology transfer.

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