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Critical Analysis of the Renewable Energy Policies in India

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***Abstract*: This research thoroughly investigates the progress of energy adoption in various states of India from 2010 to 2020. It examines how energy policies and initiatives promoting power have influenced the development of renewable energy in India. Over the past decade consistent policy support from the Indian Renewable Energy Development Agency (IREDA) and subsequent frameworks have played a role in driving the growth of renewable electricity generation. As a result, India has positioned itself favourably compared to countries when it comes to achieving international targets for renewable energy. Despite the increasing popularity of power initiatives driven by consumer demand their tangible impact remains relatively modest up until now. This study explores the benefits that such initiatives may bring and considers potential future paths for this emerging sector's evolution. In conclusion it offers insights gained from India's journey towards renewable energy. These findings can serve as lessons for policymakers and stakeholders in fostering effective strategies and fostering market growth across different states ultimately enabling a more widespread shift towards sustainable and renewable energy sources. The study also provides a comparison of progress among various Indian states offering a nuanced perspective, on India's overall renewable energy landscape.**

***Keywords*: Consumer demand, Effective policies, Energy policies, Green power initiatives, Indian Renewable Energy Development Agency (IREDA), Indian states, Market growth, Policy support, Renewable electricity generation, Renewable energy, Sustainable energy sources.**

1. Introduction

In the ten years India has seen a rise, in the share of renewable electricity in its energy combination. This impressive development has established India as a contributor to the advancement of energy. However, with these strides coal continues to play a significant role in India's power production making up a considerable portion (67.4%) of its overall generation. Nonetheless India's unrivaled progress in expanding its capacity, for energy in solar and wind power sectors is recognised worldwide.

India's remarkable progress, in the field of energy is a success story that warrants thorough exploration. The main purpose of this research paper is to gain an understanding of the factors and dynamics that have propelled this growth. By analysing the elements that have played a role, in India's advancement in energy we can gather valuable insights to inform future policy making and develop sustainable energy strategies.

To achieve this the paper starts by giving a summary of the events and milestones that have shaped the state of the market. Understanding the background is crucial, in order to grasp how renewable energy has developed in India and lays down the groundwork, for analysis. By examining the policies, initiatives and market conditions that have impacted energy growth we can get an understanding of how the market functions.

One specific area that we are focusing on in our research is the examination of public policy measures that have played a role, in promoting the supply of energy in India. In particular our study delves into the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyaan (PM KUSUM) program. By conducting an analysis of this policy initiative, including its objectives, implementation strategies and outcomes our paper aims to provide insights into how impactful these public policy measures have been in fostering the growth of renewable energy, in India.

Through this research we aim to gain insights, into how policy frameworks, market dynamics and technological advancements have worked together to drive India's energy sector forward. The findings will not enhance our understanding of the factors that have shaped India's energy market but also offer valuable lessons and recommendations for other countries looking to embark on a similar journey, towards sustainable energy development.

To summarise the main objective of this research paper is to conduct an analysis of the factors driving the expansion of India's energy market. By delving into the background policy measures and specifically focusing on the PM KUSUM program we aim to gain an understanding of how renewable energy has evolved in India. This research will provide insights and recommendations, for policymakers, industry players and researchers working towards advancing energy transitions globally.

A. Objectives

1) To identify the challenges and barriers faced in the implementation of green energy policies.
2) To analyse the effectiveness of current green energy policies in promoting renewable energy adoption and potential in different states of India.
3) To propose recommendations for improving the

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implementation of green energy policies in India.

B. Limitations

1) *Limited Data Availability:* One of the drawbacks of this research paper is the possibility of data availability. Although the study endeavours to analyse state data regarding energy potential, capacity and generation there might be cases where information, for specific states or time periods is incomplete or unavailable. This could potentially affect the thoroughness of the analysis and our ability to reach conclusions.
2) *Reliance on Official Data Sources:* The research is based on information acquired from the Ministry of New and Renewable Energy which might have its restrictions. There is a chance that the data provided by the ministry may contain errors or discrepancies leading to uncertainties, in the conclusions drawn and potentially compromising the reliability of the analysis.
3) *Lack of Granularity in Non-Quantifiable Benefits:* Examining the quantifiable advantages of green power initiatives can pose difficulties, in accurately measuring and quantifying them. Factors, like acceptance enhanced air quality and job opportunities can have interpretations making it challenging to comprehensively capture these benefits within the study's framework. Consequently, the analysis of quantifiable benefits may have certain limitations to consider.
4) *Absence of Long-term Analysis:* The research paper focuses on the years, between 2010 and 2020 offering insights into how renewable energy has progressed in Indian states over the last ten years. However, it's important to note that this specific time frame might not fully reflect the long-term impacts and trends of energy policies and initiatives. Conducting an analysis over a longer period would be beneficial, in order to accurately assess the ongoing effects of these policies identify any potential challenges and gain a more comprehensive understanding of the trajectory of India's renewable energy sector.

2. Methodology

A. Literature Review

Firstly, the paper extensively examines the existing literature, on energy policy in India from 2010 to 2020. This review of studies provides a basis, for comprehending the historical background, policy frameworks and significant advancements in the renewable energy sector during that period. It relies on a range of papers, reports, government publications and industry sources to ensure an inclusive and impartial analysis.

B. Quantitative Analysis

In order to better understand the aspects of both the supply and demand, for electricity the researchers have put together a comprehensive database that includes time series data on renewable energy development from 2010 onwards. This database allows them to analyse and calculate growth rates, market shares and make comparisons with areas. Through the use of techniques and thorough checks for plausibility this paper aims to offer precise and trustworthy insights into the trends and patterns of renewable energy adoption, in India.

C. Market Development

Furthermore, the research paper recognises the significance of market growth and integrates summarised information to present a comprehension of the progressing energy market, in India. The condensed data, obtained from a database and empirical research discoveries provides perspectives on market dynamics, trends and potential future opportunities.

D. Rigorous Methodology

It is important to highlight that the approach used in this paper for conducting research guarantees an extensive examination of the growth of the green energy market in India. By combining a review of existing literature, data compilation and conducting our own empirical research this paper provides valuable insights into renewable energy policies, market patterns and the overall sustainability scenario, in India.

E. Research Design

In this research paper we have chosen to use a combination of quantitative research methods to thoroughly investigate the implementation of renewable energy policies, in the Indian market. By employing techniques, we aim to gain a comprehensive understanding of how these policies are put into action in the actual renewable energy sector.

F. Secondary Data Analysis

An examination of various literature, reports and case studies that explore the implementation of renewable energy policies in the Indian market is conducted. This review of existing research serves as a groundwork and offers support for our research findings. Furthermore, we have analysed relevant documents such as reports on renewable energy projects, impact assessments and other related materials. These secondary sources of data provide insights into the achievements and innovative methods utilised to promote sustainable development, in the renewable energy sector.

3. Literature Review

1) In the year 1982 the Ministry of Energy established a department called DNES (Department of Non-Conventional Energy Sources) to oversee all energy related matters. Later in 1992 this department underwent a transformation. Became MNES (Ministry of Non-Conventional Energy Sources). Then in October 2006 it was further renamed as MNRE (Ministry of New and Renewable Energy).
2) The Ministry receives support from five institutions. These include IREDA (Renewable Energy Development Agency) and SECI (Solar Energy Corporation of India). Additionally, there are research institutes such, as NISE (National Institute of Solar Energy) NIWE (National Institute of Wind Energy) and SSS NIBE (Sardar Swarn Singh National Institute of Bioenergy). NISE, located in Gurugram Haryana serves as a center for energy research and development. On the hand NIWE is based in Chennai

Tamil Nadu. Focuses on conducting research specifically within the wind energy sector. SSS NIBE specialises in bioenergy research. Is situated in Kapurthala, Punjab.

3) IREDA functions as a banking institution under the supervision of this ministry. Its primary role is to provide term loans for projects related to energy and energy efficiency. SECI takes responsibility for implementing and executing initiatives associated with the National Solar Mission, as wind energy on behalf of the ministry.
4) At the Indian Institute of Technology Roorkee there is a department called the Department of Hydro and Renewable Energy (DHRE) formerly known as the Alternate Hydro Energy Centre (AHEC). They offer support, for the development of large-scale projects. It's worth mentioning that the Ministry does not have jurisdiction, over DHRE.

4. Related Government Schemes

A. PM Kusum Yojana (Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan)

- The Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM KUSUM) is a program that the Indian Government has launched to encourage the use of power at a level, in agriculture. The main goal of PM KUSUM is to increase farmers income improve irrigation systems and ensure energy stability all while supporting the nation's energy objectives.
- Under the PM KUSUM program farmers are being incentivised to set up power installations on their idle or unused lands. This allows them to produce electricity for their energy needs, such as running irrigation pumps and other agricultural activities. Moreover, any excess electricity can be supplied back, to the grid enabling farmers to earn an income through feed in tariffs.
- The government's program offers assistance to farmers for different aspects of solar power implementation. These include installing solar pumps connecting solar power plants to the grid and converting existing agricultural pumps to run on solar energy. By providing subsidies and capital support the government aims to make solar installations more affordable and accessible, for farmers.
- The PM KUSUM initiative serves two purposes. Firstly, it encourages the use of energy while also tackling the problems caused by relying on diesel and the high costs of traditional farming methods. By replacing diesel pumps with solar pumps farmers can decrease their reliance on non-renewable energy sources cut operational expenses and reduce carbon emissions significantly.
- This research paper seeks to investigate the influence and efficacy of the PM KUSUM scheme in promoting solar power within the agricultural sector. It will analyse how the program is implemented its policy framework, financial incentives and the advantages it brings to farmers in terms of generating income, accessing energy and ensuring sustainability. The results of this study will enhance our understanding of how government driven initiatives can foster energy adoption and sustainable development, in India's agricultural domain.
- As of December 31, 2022, the Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan (PM KUSUM) initiative has made strides in promoting decentralised solar power. Component A of the program has successfully installed a capacity of 88.45 MW in solar power plants. Additionally, Component B has facilitated the installation of 181,000 standalone solar pumps allowing farmers to utilise clean energy for irrigation and agricultural needs. Furthermore, Component Cs individual pump solarisation variant has resulted in the conversion of 1,174 pumps to solar power. These accomplishments demonstrate progress, in fostering renewable energy adoption and empowering farmers with sustainable energy solutions.

B. Roof Top Solar (RTS) Programme Phase-II

The second phase of India's Roof Top Solar (RTS) Programme has made progress in promoting the installation of solar panels on rooftops. As of December 31, 2022, the program has successfully achieved an installed capacity of 1.66 GW, which is part of the targeted 4 GW. Additionally, the overall capacity of grid connected RTS plants across the country has now reached 7.6 GW. To support growth Phase II of the Rooftop Solar Programmes has extended its timelines until March 31 2026. These accomplishments not showcase advancements in encouraging the adoption of solar energy on rooftops but also contribute to a deeper understanding and acceptance of renewable energy, in India.

C. Central Public Sector Undertaking (CPSU) Scheme for Grid-Connected Solar Photovoltaic (PV) Power Projects

- The CPSU Scheme, also referred to as the Scheme has played a role, in India's efforts to promote energy usage. As of December 31, 2022, a total of 8.2 GW of PV power projects have been granted through this scheme. Among these awards 1.5 GW have already been successfully implemented, highlighting India's progress in embracing energy. The primary objective of the CPSU scheme is to encourage the involvement of public sector undertakings (CPSUs) in power project development. This initiative supports the growth of energy within government entities. Demonstrates India's commitment to practices. These projects not contribute to India's energy capacity but also foster self-reliance and reduce dependence on fossil fuels. By commissioning 1.5 GW of PV power projects and effectively implementing the remaining awarded projects the CPSU scheme plays a role, in driving India's energy agenda and shaping a greener and more resilient future for our energy needs.
- The CPSU scheme plays a role in India's renewable

energy policy framework by driving the adoption of clean and sustainable energy sources. It involves CPSUs in promoting power projects, which helps speed up the country's shift, towards a greener and more sustainable energy landscape. As India continues to expand its power generation capacity the contribution of the CPSU scheme becomes essential in meeting the nations renewable energy goals and creating a more sustainable and resilient energy ecosystem.

D. Development of Solar Parks and Ultra Mega Solar Power Projects

The Solar Parks and Ultra Mega Solar Power Projects initiative has been instrumental in promoting the growth of energy infrastructure in India. As of December 31, 2022, a total of 57 Solar Parks have been given the light in 13 states under this program with a combined capacity of 39.28 GW. These designated areas serve as hubs for large scale solar power projects that are connected to the grid enabling development, optimal resource usage and increased generation of renewable energy. The creation of these Solar Parks significantly contributes to India's energy goals. Supports the country's journey, towards a cleaner and more sustainable energy future.

E. Green Energy Corridor

- The Green Energy Corridor project has made strides in improving the transmission infrastructure for renewable energy within states in India. By December 31, 2022, a total of 8,759 circuit kilometers of transmission lines have been built, along with the commissioning of 19,868 MVA of substations. Currently seven states including Gujarat, Himachal Pradesh, Karnataka, Kerala, Rajasthan, Tamil Nadu and Uttar Pradesh are in the process of issuing tenders for projects aimed at accommodating 20 GW of renewable energy capacity. This initiative is crucial in bolstering the transmission infrastructure and facilitating the integration of renewable energy into the grid—an essential step, towards India's sustainable energy transition.
- The Ministry recently introduced a National Portal for Rooftop Solar (solarrooftop.gov.in) on July 30, 2022. This portal allows residential consumers across India to independently apply for rooftop solar installations without having to wait for the Discom (Distribution Company) to finalise tenders and select vendors. Since its launch the portal has received applications totaling a capacity of 117 MW. Out of these over 18 MW of projects have already been. Granted. This initiative aims to make it easier, for individuals interested in adopting rooftop power thereby contributing to the nations shift towards renewable energy and decentralised power generation.

F. PLI Scheme - National Programme on High Efficiency Solar PV Module

The Indian government has introduced the Production Linked Incentive (PLI) Scheme specifically targeting the National Programme on High Efficiency Solar PV Modules. This initiative aims to promote the manufacturing of high efficiency solar PV modules. With a budget of Rs. 24,000 crores allocated to this scheme it offers incentives to selected manufacturers for a period of five years. The objective is to encourage production and sales of these modules in alignment, with India's energy objectives. By supporting manufacturing, the PLI scheme contributes to enhancing energy security and promoting clean and sustainable energy sources thereby reinforcing India's commitment to renewable energy generation.

5. Status of Renewable Energy Sources in India

A. Wind Energy

- Until the 30th of April 2023 India had installed a capacity of 42,868 MW aiming to reach a target of 500 GW by 2030. During the period from January to October 2022 India achieved a capacity of 1761.28 MW in wind energy. Currently India ranks fourth globally in terms of installed wind power capacity. The government plans to invite bids for energy projects totaling 50 GW annually over the next five years starting from the financial year 2023 24 until the financial year 2027 28. As of February 28, 2023, India's renewable energy capacity stands at a total of 168.96 GW with 82 GW in various stages of implementation and around 41 GW currently, under tendering stage.
- Significant progress has been made in India's energy policies. There have been some changes to the "Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Solar Hybrid Projects." It is worth noting that starting from March 9th, 2022 authorised representatives are now allowed to participate in bidding on behalf of buyers. Additionally, the timeline for completing projects has been extended from 18 to 24 months. Another amendment, dated November 2nd, 2022 has streamlined provisions related to delays caused by the operationalisation of Late Transmission Agreements (LTA). Based on recommendations from the Ministry of New and Renewable Energy (MNRE) the Ministry of Finance has also extended the custom duty benefit (CCDC) for various wind turbine components until March 31st, 2023. This initiative aims to enhance accessibility and affordability, in this sector.
- Furthermore, there has been a development in the form of a draft National Repowering Policy for Wind Power Projects in 2022. This policy highlights the importance of utilising wind energy resources maximising the energy output per square kilometre and adopting

advanced onshore wind turbine technologies. The offshore wind sector has also made progress with a strategy paper outlining various business models to achieve a target of 30 GW by 2030. A concept note proposing a Viability Gap Funding (VGF) scheme worth Rs 14,283 crore for the 3 GW of offshore wind energy projects has been sent for 'in principle' approval to the Department of Expenditure in the Ministry of Finance. Additionally, there is now an established trajectory for bidding on offshore wind energy blocks with a capacity of 37 GW until fiscal year 2029 30. The finalisation process is currently underway for the draft Offshore Wind Energy Lease Rules for 2022 and the circulation of draft documents for offshore wind energy projects after completing necessary evaluations. These accomplishments demonstrate India's dedication to energy development and establishing a strong market, for renewable energy sources.

B. Solar Energy

- As of December 31, 2022 India, has made progress in utilising solar energy with a total installed capacity of 63.30 GW. This includes 53 GW from ground mounted installations 8.08 GW from rooftop panels and 2.22 GW from off grid systems. Moreover, there are currently projects amounting to 51.13 GW and an additional 31.4 GW, in the tendering phase. It is anticipated that 15 GW of solar power projects will be finalised during the financial year of 2022-23.
- To support the development of scale projects that are connected to the grid a scheme called "Development of Solar Parks and Ultra Mega Solar Power Projects" is currently being implemented. The main goal of this initiative is to achieve a capacity target of 40 gigawatts (GW) by March 2024. Solar Parks play a role, in this endeavor as they offer developers a plug and play" model by providing essential infrastructure like land, power evacuation facilities, road connectivity, water facilities and necessary clearances. As of October 31, 2022, a total of 56 Solar Parks spanning across 14 states have been given approval with a capacity of 39.28 GW. Among these parks 10 GW worth of projects have already been completed and are operational in 17 parks. The remaining parks are currently at stages of implementation. Between January and October 2022 alone solar projects, with a capacity totaling at around 832 megawatts (MW) were successfully commissioned within Solar Parks.
- Looking ahead, it is anticipated that around 15,000 MW of solar capacity will be installed through various solar programmes by March 31, 2023.

C. Biomass Energy

The Indian Ministry has been actively promoting the generation of power from biomass sources such, as residues and wood waste. They are aiming to tap into the energy potential of these biomass sources. India has an estimated biomass power potential, with around 42,312 MW split between residue (28,446 MW) and bagasse cogeneration in sugar mills (13,866 MW). To further enhance the utilisation of biomass the Ministry has launched the Biomass Programme as part of the National Bioenergy Programme. They have allocated Rs. 158 crores for 2021 26 to support the establishment of biomass briquette/pellet manufacturing plants and cogeneration projects. As of December 2022 India, has successfully installed over 800 biomass power plants and cogeneration-based power plants with a combined capacity of 10,209 MW. Additionally, several bioenergy schemes have been implemented alongside these initiatives. Notably there has been progress in waste to energy projects with an increase in capacity by 61.12 MWeq during 2022. These efforts demonstrate India's commitment to translating energy policies into action, within its energy market.

D. National Green Hydrogen Mission

The National Green Hydrogen Mission has received approval, from the Union Cabinet with a budget of Rs. 19,744 crores. By 2030 the mission aims to establish a capacity to produce 5 million tons of hydrogen per year and add around 125 GW of renewable energy capacity. This initiative is expected to attract investments of over Rs. 8 lakh crores create than 600,000 job opportunities reduce fossil fuel imports by over Rs. 1 lakh crore and mitigate 50 million metric tons of greenhouse gas emissions annually.

To promote the manufacturing of electrolysis and green hydrogen production the Strategic Interventions for Green Hydrogen Transition (SIGHT) program will provide incentives. The mission also highlights the importance of pilot projects developing hydrogen hubs implementing policy frameworks and regulations investing in research and development initiatives as providing skill development programs.

The Ministry of New and Renewable Energy (MNRE) will lead the implementation of this mission in collaboration with partners through initiatives like the Quad Workshop on Regulations, Codes and Standards, for Clean Hydrogen and the Indo German Green Hydrogen Task Force to further advance its objectives.

6. Research and Development

A. Introduction

The Ministry of New & Renewable Energy (MNRE) places importance on research, design, technology advancement and showcasing in the field of energy through its Renewable Energy Research and Technology Development Programme. This initiative aims to foster the growth of sustainable energy technologies, processes, materials, components and products. The ultimate goal is to promote manufacturing and make the industry globally competitive. The programme strives to increase the share of energy, in the country's energy mix while ensuring self-sufficiency and profitability in renewable energy generation. The policy framework provides guidelines for project identification, formulation, monitoring, evaluation and financial support. MNRE supports research and development

activities that focus on reducing costs improving reliability and enhancing efficiency for energy systems including components and Balance of System (BOS). The programme gives priority to areas such, as solar thermal power generation systems, solar photovoltaic (SPV) systems,bio gas systems,wind power generation systems hydro power plants, hydrogen fuel cells and more. The aim is to promote development, demonstration, testings standardisation and validation of these technologies. Industry participation is highly encouraged to foster research & development efforts that lead to development as well as manufacturing of renewable energy solutions.

B. R&D Focus in Wind Energy

In the pursuit of expanding renewable energy sources, the Ministry of New & Renewable Energy (MNRE) in India has initiated two pivotal projects aimed at harnessing wind energy.

- The initial project focuses on collecting met ocean data in the Gulf of Khambhat and Gulf of Mannar. This includes evaluating wind resources, environmental conditions and oceanographic factors to support the development of offshore wind energy.
- The project has resulted in an achievement, by creating a floating buoy LiDAR system, which is a groundbreaking initiative in India. This technology enables the cost assessment of wind resources along the country's extensive coastline. Our ongoing focus is on identifying areas, with a higher capacity utilisation factor (CUF) to maximise the efficiency of installations.
- The second initiative, known as the Integrated Wind and Solar Resource Assessment through Mapping and Measurements (IWSRA) aims to create maps that assess the wind potential and viability of wind hybrid projects. These maps are resources, for stakeholders looking to implement grid connected wind hybrid projects in the most efficient and effective manner possible.
- Moreover, the project focuses on developing the skills of developers and investigating the use of sensing tools, like SODARs and LiDARs to ensure measurements. Detailed data analysis reports, from wind monitoring stations have been diligently submitted to the ministry with efforts to improve the accuracy and reliability of the produced maps.
- These impressive initiatives make an impact, on improving energy policies and identifying key locations necessary to achieve India's ambitious goals, for renewable energy.

C. R&D Focus in Hydrogen

Significant progress has been made in the field of research and development (R&D) for hydrogen. One notable project, led by the Indian Institute of Science (IISc) focuses on generating hydrogen through biomass gasification for fuel cell applications. The IISc team has achieved a breakthrough by developing an efficient Pressure Swing Absorption (PSA) system that separates gases effectively. In news they have successfully produced hydrogen from biomass using an innovative two-step process. First the biomass is converted into syngas. Then a low-pressure gas separation unit is used to obtain pure hydrogen. This groundbreaking approach shows promise for hydrogen production.

Another noteworthy project funded by NTPC Ltd. involves green hydrogen mobility initiatives in Leh, where solar power is utilised to produce 80 kg of green hydrogen per day. This renewable resource is compressed, stored safely and then dispensed into Fuel Cell Buses. These eco-friendly buses are planned to operate within Leh and Ladakh offering an sustainable transportation solution for intra city routes. These projects represent advancements in R&D for green hydrogen with potential implications for renewable energy technologies advancement and efforts, towards decarbonisation.

D. Solar R&D

Significant advancements have been made in the field of photovoltaics under the Solar R&D (SPV) projects funded by the Ministry of New and Renewable Energy (MNRE). The National Centre for Photovoltaic Research and Education (NCPRE) at IIT Bombay has achieved milestones in areas such as solar cell efficiencies, education and training international collaboration, patents and spinoffs. They have developed courses spanning an entire semester while also organising short term courses and workshops that have trained numerous participants from both academia and industry. The Photovoltaic Users Mentorship Programme (PUMP) has played a role in facilitating collaboration and implementing research projects. Progress has also been made in enhancing cell efficiencies through the development of Aluminum Back Surface Field (a BSF) cells and Passivated Emitter Rear Contact (PERC) cells. Additionally, notable strides have been made by NCPRE in solar cells achieving impressive efficiencies of up to 23%, for tandem cells composed of silicon and perovskite materials.

In the field of energy storage, the project funded by MNRE, at IIT Bombay has been focused on advancing lithium ion and sodium ion batteries as redox flow batteries. Significant progress has been made in enhancing the energy density, capacity and overall performance of lithium-ion batteries. This includes exploring battery chemistries and experimenting with graphene-based materials. Innovative materials have also been utilised in developing sodium ion batteries while successful demonstrations and scale up efforts have been achieved in research, on redox flow batteries. Moreover, there is a startup called Voltrez Technology Inc. Dedicated to developing lithium batteries specifically for electric vehicles.

The Solar R&D projects have also made progress in power electronics and PV system reliability. The development of Wide Band Gap-based Medium Voltage Converters has resulted in more compact and efficient string solar PV inverters. Research on PV system reliability includes industry collaborations for anti-soiling coatings and data-driven quantification of the impact of hailstorms on PV plants. Furthermore, the establishment of a primary reference solar cell measurement facility at CSIR-NPL has achieved state-of-the-art measurement capabilities with low uncertainty. The facility has

demonstrated the lowest measurement uncertainty for World PV Scale Standard reference solar cells and successfully participated in international intercomparing exercises.

The research and development initiatives, in photovoltaics, energy storage, power electronics and the reliability of PV systems play a role in driving the progress of solar technologies in India. The advancements made in enhancing efficiency, developing materials providing training and education opportunities and establishing testing facilities form the basis for the expansion of the energy industry, in our nation.

7. Data Analysis

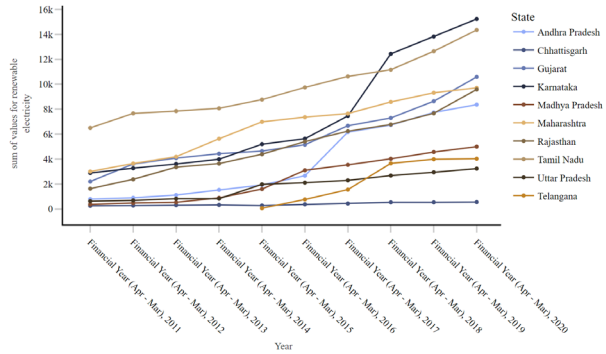

Fig. 1. Energy Capacity (State-wise Yearly Data)

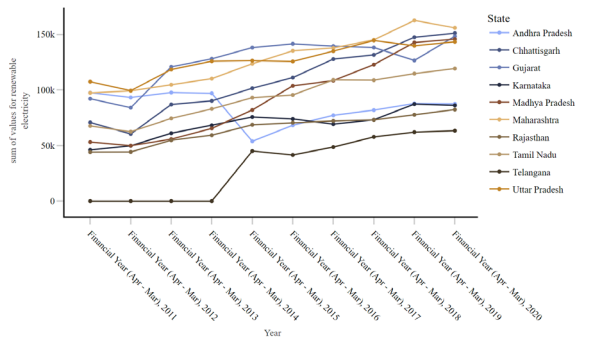

Fig. 2. Energy Generation (State-wise Yearly Data)

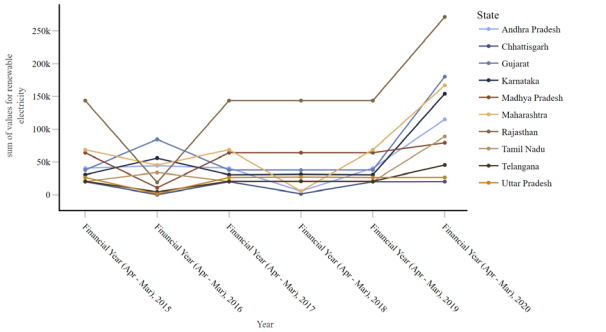

Fig. 3. Energy Potential (State-wise Yearly Data)

8. Data Interpretation

1) When we look at the energy potential, capacity and generation, across states we gain insights. In terms of capacity Tamil Nadu leads the way with 14,352 MW closely followed by Gujarat (10,586 MW), Maharashtra (9,710 MW) and Rajasthan (9,583 MW). However, when we consider the actual generation data of just capacity numbers Maharashtra takes the lead with 155,891 MW. It is followed by Gujarat (148,275 MW), Chhattisgarh (151,119 MW), Uttar Pradesh (143,280 MW) and Tamil Nadu (119,221 MW). These statistics clearly show a discrepancy between installed capacity and actual energy generation within these states. It emphasises the need, for utilisation and equitable distribution of our energy resources.
2) Moreover, Rajasthan exhibits immense untapped potential, with a staggering 271,219 MW, closely followed by Maharashtra (166,743 MW) and Gujarat (180,215 MW). This highlights the opportunity for further capacity expansion and the importance of leveraging this potential through appropriate policies.
3) The data interpretation supports the hypothesis that there's a requirement for increased energy capacity infrastructure in the run as well as more effective energy export policies and distribution in the short term. India has an opportunity to make use of its surplus energy by improving its energy export policies and distribution systems. This will help address the problem of underutilised resources boost revenue generation for specific states decrease reliance, on coal-based electricity and reduce environmental pollution.

9. Conclusion

1) *The Need for Improved Energy Policies and Distribution Systems:* The examination of our findings, based on state-wise data surrounding renewable energy potential, capacity, and generation, bolsters our hypothesis. It is evident that the key to leveraging India's abundant renewable energy sources lies in the implementation of improved energy export policies and distribution systems. It underscores the pressing need to strategically align regulatory frameworks and operational systems to facilitate seamless energy transmission across the country.
2) *Unlocking Untapped Renewable Energy Potential:* Our research sheds light on the potential of energy, in India. We see this as a chance for our nation to harness these resources in a sustainable manner resulting in the production of eco dependable electricity. This will not meet the increasing need for power, in both urban regions but also significantly improve the overall well-being of countless individuals.
3) *Addressing the Capacity-Generation Disparity:* After conducting our research we have discovered that there exists a disparity, between the amount of energy we can generate and the actual amount we are currently producing. This discovery should prompt us to take action and make the most of our resources. These discrepancies emphasise the need, for technology and meticulous planning in order to bridge this gap.
4) *Maximising Renewable Energy Utilisation for Energy Independence:* In our proposal we suggest that India has the potential to achieve energy independence by making the most of its climatic conditions to harness renewable energy resources. By expanding our range of energy sources and decreasing reliance, on imported fuels we can enhance both

our energy security and economic stability.

5) *Converting Commitment into Action:* India has gained recognition, for its dedication to renewable energy. However, it is crucial that we transform this dedication into steps. By implementing policies and establishing frameworks India has the opportunity to solidify its position as a frontrunner, in the renewable energy industry. This will serve as a model for countries to emulate.
6) *Contributing to a Greener, Sustainable Future:* Lastly our research highlights the connection, between the energy industry and a more environmentally friendly sustainable future. By giving priority to and hastening the use of energy sources we have the ability to significantly decrease our carbon emissions address the effects of climate change and protect our surroundings for generations to come. In doing we contribute to a more sustainable planet guaranteeing a brighter future with greener prospects, for everyone.

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