

Non Conventional Energy Sources Gd Rai

Non Conventional Energy Sources Gd Rai Non-Conventional Energy Sources GD Rai Non-conventional energy sources GD Rai refer to alternative forms of energy that are harnessed from natural resources, which are abundant, renewable, and environmentally friendly, contrasting with conventional energy sources like coal, oil, and natural gas. These energy sources have gained global prominence due to the increasing demand for sustainable development, the depletion of fossil fuels, and the urgent need to reduce greenhouse gas emissions. GD Rai, an advocate for sustainable development, emphasizes the importance of adopting non-conventional energy solutions to ensure energy security, environmental protection, and economic growth. --- Introduction to Non-Conventional Energy Sources Non-conventional energy sources, also known as renewable energy sources, are derived from natural phenomena that are replenished naturally and continuously. Unlike traditional fossil fuels, these sources produce little to no pollution, making them crucial in combating climate change and ensuring a sustainable future. Their utilization is increasingly becoming a priority for governments, industries, and individuals worldwide. --- Types of Non-Conventional Energy Sources There are several types of non-conventional energy sources, each with unique features and applications. The most prominent among them include solar energy, wind energy, biomass, small hydroelectric power, geothermal energy, and tidal energy. Solar Energy Solar energy is harnessed from the sun's rays using solar panels or collectors. It is the most abundant and accessible renewable energy source. - Advantages: - Infinite supply - Reduces electricity bills - Low operating costs - Can be installed at various scales - Applications: - Solar photovoltaic panels for electricity generation - Solar thermal collectors for heating water - Solar-powered devices and street lighting Wind Energy Wind energy is generated by converting kinetic energy from wind into electrical energy using wind turbines. - Advantages: - No emissions during operation - Cost-effective in windy areas - Large-scale power generation possible - Applications: - Wind farms for electricity supply - Small wind turbines for individual use 2 Biomass Energy Biomass energy involves burning organic materials such as crop residues, wood, and animal waste to produce heat or electricity. - Advantages: - Utilizes waste materials - Reduces reliance on fossil fuels - Can be used locally - Applications: - Biogas plants - Biomass power plants - Charcoal and biofuels production Small Hydroelectric Power Small hydro refers to hydroelectric projects with a capacity of up to 10 MW, utilizing flowing water from rivers or streams. - Advantages: - Reliable and consistent - Environmentally friendly - Can serve local communities - Applications: - Rural electrification - Micro-hydro schemes Geothermal Energy Geothermal energy is derived from heat stored beneath the Earth's surface. - Advantages: - Stable and reliable - Low emissions - Suitable for heating and power generation - Applications: - Geothermal power plants - Direct heating systems Tidal and Wave Energy These energy sources capitalize on the movement of ocean tides and waves. - Advantages: - Predictable and

consistent - High energy density - Applications: - Tidal barrages - Wave energy converters --- Importance of Non-Conventional Energy Sources The shift toward non-conventional energy sources is driven by multiple factors: - Environmental Benefits: Significantly reduces carbon footprint and air pollution. - Energy Security: Decreases dependence on imported fossil fuels. - Economic Growth: Promotes new industries and job creation. - Rural Development: Provides decentralized power solutions, especially in remote areas. - Sustainable Development: Ensures energy availability for future generations. --- Challenges in Adopting Non-Conventional Energy Sources Despite their advantages, several hurdles hinder widespread adoption: High Initial Investment: Capital cost for infrastructure can be substantial. 1. Intermittency: Solar and wind energy depend on weather conditions, affecting reliability. 2. Storage Issues: Efficient energy storage solutions are still evolving. 3. Technological Limitations: Need for advanced technology to optimize efficiency. 4. Environmental and Social Impact: Certain projects may disrupt local ecosystems or communities. --- Government Initiatives and Policies Governments worldwide, including India, have implemented policies to promote non-conventional energy sources: - India's GD Rai and Renewable Energy Policies: - Setting ambitious targets for renewable capacity addition. - Providing subsidies and incentives for solar and wind projects. - Establishing institutions like the Indian Renewable Energy Development Agency (IREDA). - Promoting research and development in emerging technologies. - Global Commitments: - Paris Agreement - Sustainable Development Goals (SDGs), particularly Goal 7: Affordable and Clean Energy Future Prospects of Non-Conventional Energy Sources The future of renewable energy is promising, with technological advancements reducing costs and improving efficiency. Emerging trends include: - Hybrid Systems: Combining multiple renewable sources for reliable power. - Smart Grids: Enhanced energy management and distribution. - Energy Storage: Breakthroughs in battery technology to tackle intermittency. - Decentralized Generation: Empowering local communities with their energy solutions. - Artificial Intelligence: Optimizing energy production and consumption. --- Role of Individuals and Industries The transition to non-conventional energy sources requires collective effort: - Individuals: - Installing solar panels at homes - Using energy-efficient appliances - Supporting policies promoting renewable energy - Industries: - Incorporating renewable energy in operations - Investing in research and development - Promoting sustainable practices --- Conclusion Non-conventional energy sources GD Rai symbolize the pathway to a sustainable, clean, and resilient energy future. Their adoption is essential to address the pressing challenges of climate change, energy scarcity, and environmental degradation. While there are hurdles to overcome, technological innovations, supportive policies, and collective responsibility can accelerate their integration into our daily lives. Embracing renewable energy not only benefits the environment but also paves the way for economic growth and energy security, ensuring a healthier planet for future generations.

QuestionAnswer 4 What are non-conventional energy sources according to GD Rai? Non-conventional energy sources, as explained by GD Rai, are renewable and environmentally friendly energy sources like solar, wind, biomass, geothermal, and small hydro that are alternative to traditional fossil fuels. Why is GD Rai emphasizing non-conventional energy sources for sustainable development? GD Rai highlights that non-conventional energy sources are essential for sustainable development because they reduce pollution, decrease dependence on fossil fuels, and ensure long-term energy security. How does GD Rai describe the potential of solar energy among non-conventional sources? GD Rai considers solar energy to be one of the most

promising non-conventional sources due to its abundance, cost-effectiveness, and technological advancements making it accessible for widespread use. What role does GD Rai see for wind energy in India's energy future? GD Rai views wind energy as a vital component of India's clean energy portfolio, emphasizing its capacity to generate large-scale power in suitable regions and contribute significantly to the national grid. According to GD Rai, what are the main challenges in harnessing non-conventional energy sources? GD Rai mentions challenges such as high initial investment, technological limitations, intermittency issues, and lack of adequate infrastructure as hurdles in fully exploiting non-conventional energy sources. How does GD Rai suggest promoting non-conventional energy sources in developing nations? GD Rai advocates for government incentives, technological innovation, awareness campaigns, and international cooperation to promote the adoption and integration of non-conventional energy sources. What is GD Rai's perspective on biomass energy as a non-conventional source? GD Rai considers biomass energy a viable renewable resource that can help manage agricultural waste, reduce pollution, and provide decentralized power solutions, especially in rural areas. According to GD Rai, what is the future outlook for non-conventional energy sources globally? GD Rai envisions a future where non-conventional energy sources will dominate the global energy mix, driven by technological advancements, decreasing costs, and the urgent need to combat climate change.

Non-Conventional Energy Sources: An Expert Review of G.D. Rai's Perspective

In an era marked by escalating environmental concerns and the urgent need for sustainable development, energy production has become a pivotal focus worldwide. Traditional fossil fuels—coal, oil, and natural gas—have powered economies for centuries but at significant environmental and geopolitical costs. Enter non-conventional energy sources: innovative, renewable, and environmentally friendly alternatives that promise a cleaner, more sustainable future. Among the leading voices in this domain is G.D. Rai, whose insights and analyses provide a comprehensive understanding of these emerging energy options.

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This article delves deeply into non-conventional energy sources, exploring their types, advantages, challenges, and the critical role they play in shaping a sustainable energy landscape, all through the lens of expert commentary inspired by Rai's perspective.

--- Understanding Non-Conventional Energy Sources

Non-conventional energy sources, also known as renewable or alternative energy sources, are those that are naturally replenished on a human timescale and have minimal environmental impact compared to conventional fossil fuels. These sources harness natural phenomena such as sunlight, wind, water flow, and geothermal heat to generate power. G.D. Rai emphasizes that embracing these sources is not merely an environmental imperative but also an economic opportunity, fostering energy security, technological innovation, and job creation. Key characteristics of non-conventional energy sources include:

- **Renewability:** They are replenished naturally and sustainably.
- **Environmental friendliness:** They produce little or no greenhouse gases.
- **Distributed generation potential:** They can be harnessed locally, reducing transmission losses.
- **Supplementarity:** They complement traditional energy systems, enhancing resilience.

--- Major Types of Non-Conventional Energy Sources

G.D. Rai categorizes non-conventional energy sources into several primary types, each with unique mechanisms, advantages, and developmental considerations.

- 1. Solar Energy Overview:** Solar energy is harnessed from sunlight using photovoltaic (PV) cells or solar thermal collectors. It is the most abundant and accessible renewable resource globally. **Applications:**

 - Solar panels for electricity generation
 - Solar water heaters
 - Solar cookers
 - Solar farms for large-scale

power production Advantages: - Abundant and universally available - Declining costs due to technological advancements - Low operational and maintenance costs - Suitable for decentralized power generation Challenges: - Intermittency due to weather and day-night cycles - Storage requirements for 24/7 supply - Land use considerations for large installations Expert insight: G.D. Rai highlights the rapid technological improvements and decreasing costs of photovoltaic systems, making solar energy a pivotal component of future energy strategies. --- 2. Wind Energy Overview: Wind energy is captured through turbines that convert kinetic energy from wind into electricity. Applications: - Onshore wind farms - Offshore wind farms (particularly in coastal regions) Advantages: - Cost-effective in suitable locations - No emissions during operation - Rapid deployment potential Challenges: - Variability of wind speeds - Noise Non Conventional Energy Sources Gd Rai 6 and aesthetic concerns - Impact on bird and bat populations - Need for suitable sites with consistent wind patterns Expert insight: Rai points out that offshore wind has enormous potential, especially in countries with extensive coastlines, but technological and environmental considerations must be addressed. --- 3. Hydropower (Water-Based Energy) Overview: Hydropower utilizes flowing or falling water to generate electricity, predominantly through dams or run-of-river systems. Applications: - Large dams for grid-scale power - Small hydro projects for localized needs - Pumped-storage systems for grid balancing Advantages: - Reliable and controllable - Capable of meeting large energy demands - Long lifespan of infrastructure Challenges: - Environmental impact on aquatic ecosystems - Displacement of communities - High capital costs - Dependency on water availability, which can be affected by climate change Expert insight: Rai emphasizes the importance of sustainable hydropower practices, advocating for environmentally sensitive designs that balance energy needs and ecological preservation. --- 4. Geothermal Energy Overview: Geothermal energy taps into heat stored beneath the Earth's surface to produce electricity or provide direct heating. Applications: - Geothermal power plants - District heating systems - Geothermal heat pumps for heating and cooling Advantages: - Stable and reliable source - Low emissions - Small land footprint Challenges: - Geographically limited to tectonic activity zones - High initial exploration and drilling costs - Potential for induced seismicity Expert insight: G.D. Rai highlights geothermal's potential in specific regions, especially volcanic zones, and underscores ongoing technological improvements to reduce costs. --- 5. Biomass and Waste-to-Energy Overview: Biomass involves converting organic materials such as crop residues, animal manure, and waste into energy through combustion, fermentation, or gasification. Applications: - Power generation from biomass plants - Biogas production - Biofuels for transportation Advantages: - Utilizes waste materials, reducing landfill - Can provide decentralized energy solutions - Renewable when managed sustainably Challenges: - Land and water resource requirements - Emissions from combustion processes - Competition with food production Expert insight: Rai advocates for sustainable biomass management, emphasizing innovations in biofuel technology and waste processing for cleaner energy. --- Non Conventional Energy Sources Gd Rai 7 Emerging and Innovative Non-Conventional Energy Technologies Beyond the mainstream sources, several innovative technologies are emerging, promising to further diversify the renewable energy portfolio. 1. Tidal and Wave Energy Harnessing the kinetic energy of ocean tides and waves offers a predictable energy source, especially in coastal regions. Advantages: - Highly predictable - Environmentally benign Challenges: - High infrastructure costs - Marine ecosystem impacts - Technological infancy 2. Hydrogen Economy Hydrogen, especially green hydrogen

produced via electrolysis powered by renewables, is gaining attention as a clean fuel for transportation, industry, and storage. Advantages: - Zero-emission when used - Versatile energy carrier Challenges: - Production costs - Storage and transportation complexities - Infrastructure development needs 3. Piezoelectric and Other Niche Technologies Innovations such as piezoelectric energy harvesting from vibrations or kinetic sources are in experimental stages but could supplement larger systems. --- Advantages of Non-Conventional Energy Sources G.D. Rai emphasizes the multifaceted benefits these sources offer: - Environmental Sustainability: Minimal greenhouse gas emissions and pollution. - Energy Security: Reduced dependence on imported fossil fuels. - Economic Opportunities: Job creation in manufacturing, installation, and maintenance. - Decentralization: Promoting rural electrification and reducing transmission losses. - Resilience: Distributed generation enhances grid stability against outages. --- Challenges and Limitations Despite their promise, non-conventional energy sources face several hurdles: - Intermittency and Variability: Many renewables depend on weather or natural cycles, requiring storage solutions. - High Capital Costs: Initial investments can be substantial, although decreasing over time. - Storage and Grid Integration: Developing efficient energy storage and smart grids is essential. - Environmental and Social Concerns: Land use, ecological impacts, and community acceptance need careful management. - Policy and Regulatory Frameworks: Supportive policies are critical for scaling up deployment. G.D. Rai underscores that overcoming these challenges requires technological innovation, Non Conventional Energy Sources Gd Rai 8 supportive policies, and public-private partnerships. --- The Future of Non-Conventional Energy: Insights from G.D. Rai According to G.D. Rai, the future landscape of energy is poised to be dominated by renewables, driven by technological advances and global commitments to climate change mitigation. Key projections include: - Cost Competitiveness: Continued decline in the costs of solar and wind power will make them the cheapest options in many regions. - Integrated Energy Systems: Hybrid systems combining multiple renewables and storage will enhance reliability. - Decentralized Generation: Increasing adoption of microgrids and rooftop solar to empower consumers. - Policy Support: Governments worldwide are setting ambitious renewable energy targets, incentivizing investments. - Innovation in Storage: Breakthroughs in battery technology and other storage solutions will address intermittency issues. - Global Collaboration: Sharing technology, expertise, and financing to accelerate adoption in developing countries. Rai advocates for a proactive approach, emphasizing the importance of research, policy reforms, and public awareness to harness the full potential of non-conventional energy sources. --- Conclusion: Embracing a Sustainable Energy Future The transition to non-conventional energy sources is not merely an environmental choice but an economic necessity and a strategic imperative for energy security. As G.D. Rai eloquently points out, harnessing these diverse and innovative energy options requires a concerted effort from policymakers, industry stakeholders, scientists, and the public. While challenges remain, the rapid pace of technological innovation, decreasing costs, and global commitment to sustainable development signal a promising future. Embracing non-conventional energy sources will pave the way for a cleaner, resilient, and equitable energy landscape that sustains our planet for generations to come. --- In summary, non-conventional energy sources are transforming the global energy paradigm. Their successful integration depends on addressing technical, environmental, and economic challenges, guided by expert insights such as those offered by G.D. Rai. The future is undeniably renewable, and renewable energy, solar power, wind energy, bioenergy,

hydroelectricity, geothermal energy, sustainable energy, green technology, alternative energy, clean energy

Non-Conventional Energy Sources and Utilisation Non Conventional Energy Resources Non-Conventional Energy Resources Non Conventional Energy Resources Non-Conventional Energy Resources Non-conventional Energy Sources for African Development Conventional Energy in North America Non Conventional and Renewable Energy Sources Non-Conventional Energy in North America Non-Conventional Energy Resources (For UPTU & UTU) NON CONVENTIONAL RESOURCES OF ENERGY Status and Future Challenges for Non-conventional Energy Sources Volume 1 Applied Power and Energy Technology II Renewable Energy Energy Supply and Environmental Impacts UNDP and Energy Efficient Use of Energy Sources in Meeting Heat Demand Energy Supply and Environmental Impacts - Conventional Energy Sources Physics Of Non-conventional Energy Sources And Material Science For Energy - Proceedings Of The International Workshop Investments in Renewable and Conventional Energy RK Rajput Ashish Chandra Bansal N.K. Sobh Nath Singh Dr. D. S. Chauhan Jorge Morales Pedraza S. S. Thipse Jorge Morales Pedraza Navani J.P. & Sapra Sonal G. S. SAWHNEY Sanket J. Joshi Hong Bo Fan Tim Jackson Dr. James McFadden United Nations. Economic Commission for Europe J.H. McFadden Giuseppe Furlan Gurhan Kok

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first edition 2012 reprints 2013 second revised edition 2014 i the textbook entitled non conventional energy sources and utilisation has been written especially for the courses of b e b tech for all technical universities of india ii it deals exhaustively and symmetrically various topics on non conventional renewable and conventional energy and systems iii salient features of the book subject matter has been prepared in lucid direct and easily understandable style simple diagrams and worked out examples have been given wherever necessary at the end of each chapter highlights theoretical questions unsolved examples have been added to make this treatise a complete comprehensive book on the subject in this edition the book has been thoroughly revised and a new section on short answer

questions has been added to make the book still more useful to the students

energy is the hottest topic of concern in the world today fast receding stocks of conventional resources impelled governments worldwide to include renewable energy sources in their energy programmes newer non conventional methods need to be developed before the conventional stocks are totally exhausted more and more universities in india are including the studies on renewable non conventional resources in their curricula in the 4th year of their be btech mechanical programmes this book caters to such courses as a full fledged textbook it covers a wide range of topics from the origin of all energy sources their manifestation availability resource assessment to science and technology of renewable energy conversion processes every chapter enunciates its learning objectives before beginning the discussion and offers insightful questions in the end renewable energy is going to be a very important part of the whole energy chain and its know how will be essential at various levels of education especially in science and engineering considering this fact this book will also serve as a knowledge compendium for the seekers in renewal energy sources and technology

with energy sustainability at the forefront of public discussion worldwide there is a vital requirement to foster an understanding of safe alternative sources of energy such as solar and wind power tailored to the requirements of undergraduate students of engineering non conventional energy resources provides a comprehensive coverage of the basic principles working and utilization of all key renewable power sources solar wind hydel biomass hyower and fuel cells the book also consists of several solved and unsolved questions for thorough practice and revision

this book discusses the developments in the field of non conventional energy resources and their applications the topics are fully covered so that the students of b tech may use for their elective courses such as non conventional energy resources renewable energy and solar energy engg the topics are solar radiation solar energy collectors energy resources solar cell mhd power generator wind energy biomass otec tidal and wave energy hydrogen energy micro hydel power and storage of solar energy

conventional energy in north america current and future sources for electricity generation provides in depth information on the current state of conventional energy sources used for electricity generation in the united states and canada as energy is a major force of civilization determining to a high degree the level of economic and social development this book provides relevant information and a deep analysis regarding the main problems associated with the use of fossil fuels for the generation of electricity in both countries finally the book offers guidance for countries seeking to expand their use of conventional energy sources for electricity generation users in government energy experts economists politicians academics scientific institutions and universities international organizations and the private and public power industry will find this book to be a great reference on what type of conventional energy sources should be used for electricity

generation with the aim of reducing the emission of CO₂ and other contaminated gases to the atmosphere includes comprehensive information on the different types of conventional energy sources available in the USA and Canada including their impact on climate level of energy reserves and levels of production and consumption covers the pros and cons of each type of conventional energy source for electricity generation features an analysis of what types of conventional energy sources should be used for future electricity generation in the USA and Canada with the aim of reducing the emission of CO₂ and other contaminated gas to the atmosphere

Non conventional and renewable energy sources are important in this era of fossil fuel depletion and environmental degradation this book covers various alternative and renewable energy sources such as solar energy tidal energy ocean energy geothermal energy biomass energy hydropower and wind energy in detail with their applications the global scenario on renewable energy has been discussed along with the prominent differences one of the challenges faced by the renewable energy is its economic viability and this has been highlighted at length along with examples various applications of renewable energy in rural urban and semi urban areas and for variety of markets like industrial commercial and domestic have also been discussed in great detail the importance of solar energy has been prominently highlighted along with its different manifestations such as solar collectors solar ponds photovoltaics along with detailed thermodynamic analysis nuclear energy which is nowadays very controversial has been reviewed with its pros and cons and several types of nuclear reactors have been discussed with their usage patterns all over the world each renewable energy system has minimal environmental impact and reduces the carbon footprint of the world such as the geothermal systems which have been elaborated in detail along with their applications an additional highlight is the extensive coverage of new energy concepts for future clean mobility such as hybrid electric vehicles and fuel cell vehicles the infrastructure required deployment strategies and emission benefits of the electric hybrids and fuel cell vehicles have been incorporated in this text the importance of hydrogen as a future freedom fuel has been stressed through an in depth review of its storage handling and combustion this book attempts to inform the reader regarding the various renewable energy options

Non conventional energy in North America current and future perspectives for electricity generation provides an analysis of the current state of non conventional energy sources used in the United States and Canada the book works through all non conventional renewable energy power sources such as solar wind and nuclear considers the associated pros and cons their impact on society the climate and the population and their potential as well as coverage on the amount of power generated from each source this book considers various imposed policies and programs alongside public opinion to provide readers with an understanding of current and future potentials for sustainable energy readers in government energy experts economists academics and scientists will find this book to be a great reference on which types of power generation they would like to develop in their regions to promote economic and social development the book will

equip readers with the knowledge to make future decisions to diversify the energy mix in their respective regions includes information on the different types of non conventional energy sources in the usa and canada analyzing their impact on climate and the population presents the pros and cons of each power generation technology along with public opinion features policy and programs currently in force in the usa and canada on each type of non conventional energy source

this book entitled non conventional energy resources has been written for b e b tech final year students of upto kucknow mtu gbtu and utu dehradun the book uses simple and lucid language to explain fundamentals of this subject

there has been an enormous increase in the demand for energy as a result of industrial development and population growth due to the depletion of fossil fuels at a rapid pace harnessing the power of clean alternative energy resources has become a necessity thus the book aims to increase awareness among readers about the renewable energy resources and the technologies used to harness them written in a lucid and precise manner the text matter is structured in the question answer format supported with numerous examples and illustrations besides discussing various renewable energy sources such as solar wind biogas hydrogen thermoelectric tidal geothermal wave and thermal the book also discusses energy management and environment and outlines kyoto protocol the book caters to the needs of undergraduate engineering students of all branches

this book highlights recent advancements in such an important topic through contribution from experts demonstrating different applications in day to day life both existing and newly emerging non biological technologies and thought provoking approaches from different parts of the world potential future prospects associated with some frontier development in non conventional energy sources it covers different types of natural energy sources such as ocean tidal and wave energy nuclear energy solar cells geothermal energy hydrogen fuel photovoltaic modules gas hydrates hydrate based desalination technology and hydrothermal liquefaction of kraft lignin lignocellulosic biomass to fuels and chemicals this book is a comprehensive and informative compilation for international readers especially undergraduate and post graduate students and researchers

selected peer reviewed papers from the 2014 2nd international conference on advances in energy and environmental science icaees 2014 june 21 22 2014 guangzhou china

renewable energy prospects for implementation contains papers that were originally commissioned by the journal energy policy for a series on renewable energy appearing between january 1991 to september 1992 in view of the fast changing demands on conventional energy supply to meet environmental imperatives it

seemed timely to reproduce here a selection of those papers with a new introduction and a revised concluding chapter by the editor of the series dr tim jackson a research fellow with the stockholm environment institute the book is organized into four parts the papers in part i cover the individual renewable energy technology types from a broad perspective addressing the technological aspects of improved power capture and conversion efficiency but also providing a broad overview of costs environmental aspects and institutional factors for each technology category part ii of this collection examines questions of feasibility and system integration renewables and development is the theme of part iii of the book while part iv is dedicated to policy aspect and the development of strategies for implementation of renewable energy technologies

an up to date account on the advancement in science and technology and the most recent developments on materials used for solar energy devices is presented with detailed description in the following areas selective coating for heating and cooling photovoltaic conversion and comparison among single crystalline silicon concentrating cells and amorphous silicon and advance tendum coating for selective spectrum which can be used for greenhouse homes and in energy conservation

there is an ongoing debate on how providing a subsidy for one energy source affects the investment level of other sources to investigate this issue we study a capacity investment problem for a utility firm that invests in renewable and conventional energy with a consideration of two critical factors first conventional sources have different levels of operational flexibility i e inflexible e g nuclear and coal and flexible e g natural gas second random renewable energy supply and electricity demand are correlated and nonstationary we model this problem as a two stage stochastic program in which a utility firm first determines the capacity investment levels followed by the dispatch quantities of energy sources to minimize the sum of investment and generation related costs we derive the optimal capacity portfolio to characterize the interactions between renewable and conventional sources we find that renewable and inflexible sources are substitutes suggesting that a subsidy for nuclear or coal fired power plants leads to a lower investment level in wind or solar energy on the other hand wind energy and flexible sources are complements thus a subsidy for flexible natural gas fired power plants leads to a higher investment in wind energy this result holds for solar energy if the subsidy for the flexible source is sufficiently high we validate these insights by using real electricity generation and demand data from the state of texas

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