AN IMPROVED ENVIRONMENTAL MANAGEMENT MODEL FOR ASSURING ENERGY AND ECONOMIC PROSPERITY

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Highlight

Environmental management model for assuring energy and economic prosperity.

Abstract

Energy efficiency contributes almost 40% of the potential for lowering greenhouse gas emissions. Addressing climate change while sustaining economic development is a crucial and complex task. The research examined energy efficiency's influence on economic growth and environmental sustainability in the top 10 nations with the highest energy efficiency levels between 1990 and 2019. The analysis used energy availability, security, and depletion as moderating factors. A comprehensive empirical investigation, including sophisticated econometric approaches, was conducted to achieve this objective. The findings of the Westerlund panel co-integration test imply long-term linkages among the variables under consideration. The research indicates a positive correlation between energy intensity, availability, and safety, as well as the levels of carbon dioxide emissions, ecological impact, and economic development. The decrease in energy availability was shown to have a detrimental effect on economic growth while positively correlated with both carbon dioxide emissions and the environmental impact. The results indicate that energy magnitude, availability, and security have an excellent effect on economic development but affect the surroundings. The empirical data suggests that economies must attempt to meet economic and ecological goals by separating energy use from economic growth. This task is performed via enhancements in energy utilization.

Keywords

energy; economy; management; environment.

Introduction to a Sustainable Economy

Sustainable development has long been recognized as crucial for maintaining the long-term viability of the global economy and addressing its many difficulties [1]. The dynamics of international development indicate the need to broaden the range of strategies for promoting environmental sustainability in the economy at the macro-, meso-, and micro-levels. The shift from the industrial to a circular economy should be facilitated by implementing creative strategies and adopting new technology, emphasizing eco-innovation and resource optimization. Evidence has shown that promoting ethical behavior and boosting investment in sustainable products and technology increases efficiency in expediting the move to the circular economy. Technological preparedness is a crucial need for developing an economy that shares. Ensuring the long-term growth of areas is vital. The process of trade liberalization has led to an improvement in the environmental quality of nations, notwithstanding their varying degrees of economic development.

Maintaining a well-rounded approach to inventive development is the key to achieving economic growth and long-term stability in a nation. Empirical evidence confirms that green investments successfully promote energy conservation [2]. Green investments have grown prevalent in this environment. Efficient energy management strategies in enterprises are the key driver for increasing expenditures in reducing greenhouse gases from energy generation [21]. However, managerial considerations play a vital role in guaranteeing the sustained growth of

organizations. The considerable efficacy is validated for environmentally friendly human resources and sustainability marketing strategies. Although several practical tools are available for managing the environmental impact of industrial firms, macroeconomic tools, including investment assistance, are the most efficient in promoting equitable development and encouraging the growth of a sustainable economy [20]. The history of European nations indicates that in the face of ecological and economic challenges, the energy industry's efforts to maintain equilibrium eventually result in establishing specific patterns in its transition and advancing renewable energy sources [3]. This reaffirms the significance of balancing the ecological, financial, and energy impacts in the growth of national economies [4]. It also highlights the importance of finding effective strategies to address these impacts simultaneously.

The research is predicated on the concept that identical environmental taxes might yield disparate impacts on various environmental, financial, and energy safety indicators [17]. Consequently, this results in the neutralization of the total impact obtained inside the intricate system. Therefore, it is necessary to consider the overall effect of environmental charges on each aspect of environmental, financial, and energy safety to assess the overall efficacy of these taxes. Pooled impacts refer to the combined effectiveness of ecological levies. To evaluate the effects of environmental taxes, it is necessary to examine their influence on specific ecological, financial, and energy safety measures and identify their overall impact.

Literature Review

Developing cost-effective energy savings upgrades regularly enhances economic activities, often leading to additional employment. Enhancements in efficiency decrease the expenses related to providing services like wireless communication, illumination, heating, and cooling. Improvements in energy use have both direct and indirect effects on business activity. Energy efficiency directly helps individuals as it fulfills their energy demands [6]. Better energy efficiency means less energy is required to supply the same utilities since energy is used to manufacture and consume other products and services. Assuming all other factors remain constant, increasing energy efficiency reduces the need for energy, which is crucial in combating global warming from human activities. The main aim of this research was to find enhancements in energy efficiency and assess their ecological consequences.

Energy efficiency is a vital component in the suggestions of the Climate Action Program concerning the European Union's (EU) climate change objectives [7]. The US Senate in 2020 clearly emphasized the significance of energy conservation in tackling difficulties connected to climate change. Several critical studies have examined the aspects that impact energy usage and the economy. A study revealed that in the Middle East, there is a direct correlation between economic development (measured by Gross Domestic Product (GDP)) and an increase in oil consumption [19]. Real GDP growth positively correlates with electrical consumption in Korea, Iceland, Finland, Hungary, and the Netherlands. An argument has been made that there is a positive correlation between the increase in real GDP and CO_2 emission levels and the growth in the use of renewable energy. The rise in oil costs affects renewable energy usage.

The concept of energy security exhibits significant variability, and several explanations are offered to explain this phenomenon. Energy security refers to the consistent availability of various energy sources at reasonable costs [9]. There has been a significant focus on energy safety in recent years, particularly with the accessibility, availability, price, and environmental tolerance of energy supplies. Energy insecurity does not directly indicate energy security but rather arises from several circumstances that stem from a lack of available energy. Diversification, equilibrium, and inequality contribute to the attainment of energy security. Energy security has been described in several research, taking into account the viewpoints of both emerging and industrialized nations. Energy security guarantees a consistent and affordable primary power supply for households and businesses. This ensures that the economy is enhanced and poverty is reduced while minimizing any negative impact on the surroundings. Developed nations see energy security as the guarantee of obtaining reasonably priced energy and implementing efficient industrial methods. Energy security is a complex matter that requires a comprehensive and universal approach to assessment [10]. Examining energy security posed difficulties due to its many characteristics, theoretical considerations, and the impact of national and regional variations. Some studies use an excessive number of indicators, therefore complicating analysis and reducing its emphasis. Many nations are now making efforts to attain energy safety to have a dependable, cost-effective, and easily accessible energy supply and to prevent any disruptions to their industries.

Sustainability is crucial in the analysis of energy sources [18]. Exergy is an energy analysis tool that focuses on achieving environmental protection goals and promoting economic development by improving the efficiency and effectiveness of energy sources. Utilizing energy conservation to achieve sustainability in energy provides the chance to use environmentally friendly technology and renewable energy sources to encourage energy preservation [11]. This contradictory predicament highlights the need to have enough energy supply. Comprehending energy sustainability requires a thorough awareness of several technological aspects and the consideration of non-technical elements such as governance, culture, education, and morality.

For an energy system to ensure its long-term viability, it must exhibit high efficiency, effectiveness, and reliability while recovering all losses and wastage. The research introduced a framework to evaluate the sustainability of European energy, such as elements related to environmental stability. This research argues that no energy measure can fully include the many dimensions of energy efficiency [12].

This research demonstrated that sustainability is influenced by a diverse range of elements that work together harmoniously [13]. Therefore, composite energy efficiency metrics are more suited to assess its efficacy. Another research also examined the connection between achieving emission neutrality and ensuring environmental sustainability [14]. An exhaustive evaluation of energy viability was conducted using a multimodal methodology to study energy sustainability via a quantitative context.

As mentioned earlier, the research examined facets of energy security, efficiency, and ecology. Yet they should have acknowledged the connections between these vital energy-related factors and the principles of ecological responsibility and healthy economic development. The research sought to address this gap by examining the influence of conflicts between the preservation of the environment and economic growth on energy availability, security, and longevity. The research used the ten most resource-efficient nations as a sample for the analysis.

Materials and Methods

Data Source

This research utilizes yearly data from 1970 to 2020 to examine the relationship between natural resources, economic development, and environmental impact. The ecological impact refers to the use of producing biological areas by individuals, specifically the biocapacity of a region. Biocapacity is the ecosystem's capacity to supply nutrients and assimilate human-generated waste. National account footprints are the data source for collecting information on environmental and biocapacity impacts. The GDP per capita quantifies economic development.

In contrast, natural assets are assessed using an index of composite variables, including gas rentals, oil leases, coal leases, mineral leases, and forestry rents per person. Urbanization is quantified by calculating the yearly increase in the proportion of people living in urban areas. The statistics on natural resources, urbanization numbers, and economic expansion are gathered from the World Statistics Indicator. Human capital refers to people's collective skills, schooling, talents, and traits that directly impact their ability to be productive and their capacity to produce income. The information on human resources is gathered from the Penn World Table, specifically version 9.0 [15].

Materials

This research aimed to analyze the influence of energy conservation on the economic development and sustainable development of the ten most resource-efficient nations. This analysis used energy availability, security, and shortages as moderator factors. The study covered the period from 1990 to 2020. Germany achieved the maximum level of energy efficiency with a score of 65 out of 100. Ireland has achieved a commendable performance in sustainability, consistently decreasing its carbon footprint by 15% each year in recent times. Due to its relatively tiny population and low energy usage, Denmark consumes less energy than New York City.

The country's primary banking industry uses comparatively little energy. Environmentally friendly hydroelectric dams produce the majority of Norway's energy. If it were not for its very high energy usage per capita, this nation would have achieved an even higher place in this ranking. France is at the forefront of promoting energy savings.

In 2021, the French economy achieved a 19% improvement in effectiveness in the manufacturing industry and a 12% rise in transportation. This progress is attributed to substantial tax credits provided to energy-efficient firms. Austria's economy has a notable level of energy efficiency since 23% of the nation's energy supply is derived from renewable sources. Italy's railway system is characterized by a high level of energy efficiency, which has significantly contributed to its favorable rating. However, the nation's industrial sector has seen a decline of almost 25% in energy conservation. Despite the relative youth of Mexico's finances, it has demonstrated much promise in energy conservation. Mexico is now making significant endeavors to establish itself as one of the most environmentally friendly nations globally and is expected to ascend in this position shortly. Australia has made notable advancements in energy conservation. However, transportation remains a significant contributor to pollution [16].

An ecological footprint refers to the competition of individuals, regions, the global population, or activities to exert control over ecologically productive land and water areas. In this situation, renewable energy is generated, city infrastructure is supplied, and waste goods are decomposed or assimilated, including greenhouse gas emissions from fossil fuels. They determined land and ocean areas by comparing the footprints to the land and ocean regions. In nature, productive places, as defined by the Global Footprint Network, include land use, forests, waters for fishing, and seas. Emissions of greenhouse gases are the primary driver of global warming, and it is imperative to decrease them to avoid negative consequences immediately. The study used ecological impact and carbon dioxide emissions as measures to evaluate the level of sustainable development. The former was quantified based on per capita worldwide hectare use using the Worldwide Footprint Network (GFN) data. According to statistics from the International Energy Agency (IEA), the measurement of carbon dioxide emissions per person was done in metric tons [5] [8].

By prior research, the research used GDP as a metric to quantify economic expansion. The GDP was computed by determining the yearly percentage increase using constant regional currency pricing in 2010 US dollars. Every individual in the market contributes their gross value to merchandise taxation and deducts any benefits not accounted for in the product's worth. The information on energy use was used to compute energy utilization by dividing the gross inland energy consumption by the GDP. GIEC is the total energy sources used inside a country's borders, including petroleum, coal, gases, nuclear power, and alternative energy sources. The measurement of access to electricity was determined based on the proportion of the population. The primary power availability, a proxy indicator of energy security, included factors like energy output, net imports, international buildings, and stock movements.

The rate of energy degradation was calculated by calculating the amount saved as a proportion of the GDP. Energy depletion is determined by the stock of fossil fuels, limited to a maximum of twenty-five years, and the remainder of the resources' lifespan, including petroleum, coal, natural gas, and crude oil. The World Development Indicators (WDI) were used to gather information regarding economic progress, energy accessibility, and energy scarcity. The figures for the essential supply of primary energy were obtained from the IEA and measured in kilotonnes of oil equivalent.

Since the 1970s, environmental rules and advocacy have been focused on IPAT formulas (Impact = People Affluence Technologies) and other theories that revolve around population and shortages of resources. Ehrlich's theories preceded these by a significant number of years. Thomas Robert Malthus, an academic and preacher from the latter part of the 18th century, first made the arguments. In his 1798 study, it is said that despite the rapid expansion of the human race, resources from nature can only develop linearly. Without population regulation, starvation, illness, and population catastrophe ensue. The IPAT equation elucidates the correlation between human beings and their environmental effect. The impact of affluence, gadgets, and population expansion on ecosystems is significant.

Method

During the first phase of the research, it is necessary to establish a comprehensive list of environmental levies that substantially influence the concurrent supply of ecological power and financial stability. The information on taxes on the environment was gathered from the Database on Economic Instruments for the Environment. To do this, a Granger causality analysis was conducted, which enables the determination of the link between indications

and the characterization of the relationship between signals about single or dual causative connections. The Granger test, widely used in economic research, diagnoses the links between various events.

A comprehensive indicator of ecological, energy, and financial stability was established during the second stage. In this step, the task is to choose an extensive list of three security sectors susceptible to environmental taxes' impacts. A causal relationship, in most instances, often defines these areas. The selected metrics were normalized using natural standardization for amphetamine and Savage standardization for de-stimulants, considering their various dimensions.

At this step, the task is to build a comprehensive indicator that combines and summarizes the three degrees of security. Creating an integral indication representing the connected categories must be based on describing every component's degree of integration and considering the links between each part. The combined economy, finance, and energy safety indicator was created using the Kolmogorov-Gabor approach, which involves linear additive-multiplicative inversion.

During the third phase of the research, it simulated the effect of environmental charges on the overall degree of ecological, financial, and energy security. Before the computations, a Dickey-Fuller test was conducted to see whether the time series data was stationary. Due to the varying levels of environmental taxes across various countries, the evaluation was carried out individually for each nation, using the basic specifications of the least squares method. The models included revenues generated from each of the ecological levies as variables. Therefore, a collection of models has been constructed for each country, which aligns with the specific number of green charges that have been chosen and are now in existence. To accurately assess the influence of environmental charges on the combined indicator of ecological, financial, and energy safety, it is essential to include the specific operating circumstances in the nation. This suggests that it would be beneficial to incorporate certain control elements into the framework.

- Inflation

Inflation is expected to reduce the effects of environmental taxes, as some of the indicators included in the integrated ecological, economic, and energy security indicators have monetary measures.

- Trade openness

This indicator reflects the intensity of the state's foreign economic relations, which, on the one hand, can identify threats to national security and, on the other, increase its level for export-oriented countries.

- Control of corruption

An indicator that reflects public relations within the country regarding perceptions of corruption. It is expected that the growth of this indicator will strengthen national security and, accordingly, be a prerequisite for increasing the multiplex efficiency of environmental taxes.

- Government effectiveness

It is traditionally believed that the growth of this indicator increases the efficiency of all processes in the state, so in the models, it is considered an enhancer of the impact of environmental taxes on the integrated dictator of ecological, economic, and energy security.

- Regulation quality

Like previous indicators, this indicator is a prerequisite for increasing the effectiveness of regulatory instruments, which include environmental taxation.

Results

The different power produced by different nations using the RES are shown in Figure 1.

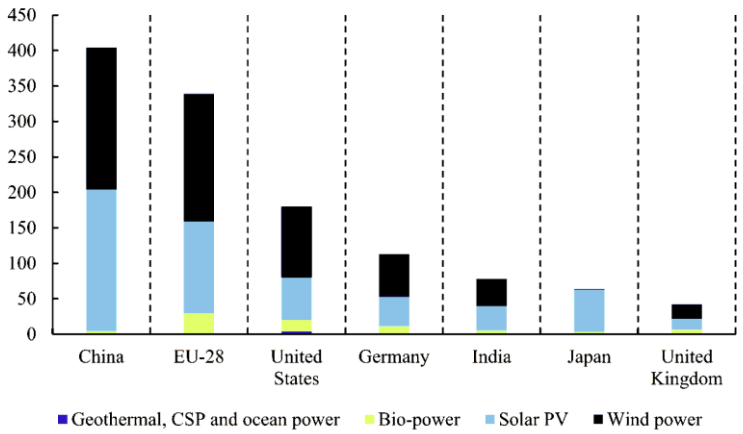

Figure 1. Power generation by RES

- Descriptive statistic

The variability of every factor from the average value is relatively low. A strong link is detected among the fundamental aspects.

- Unit root analysis

Before examining cointegration among financial variables, assessing the amount of stationarity is essential to prevent significant regression. It is necessary to evaluate whether any factor is incorporated in order 2. For instance, any second-order integrated factor would prevent us from using the ARDL approach. The Ng and Perron unit root analysis is employed to assess the stationarity level of the factors. The test findings indicate that none of the parameters are incorporated at order 2, confirming the suitability of the approach.

- The bound testing approach

To assess the cointegration among the factors being studied, it is recommended to use the bound testing strategy, which involves examining the order of association at the first level. The outcomes of the bound testing method using an assessment for the environmental footprint modeling and the ecological carbon footprint model. When calculating F statistics, the lag duration is determined before co-integration is used. The Akaike information criteria is employed for lag length selection because of its robust explanatory power supported by empirical evidence. The criterion determines that four lag lengths are chosen for the environmental footprint approach.

In contrast, a lag length of six is selected for the environmental carbon footprint approach. Both models provide sufficient evidence to reject the null theory of no cointegration, indicating that cointegration is among the studied factors. This research determines the degree of importance by considering the suggested upper and lower boundaries. The results of the boundary testing technique reveal that the F statistic for the environmental footprint is higher than the threshold, indicating the existence of cointegration among the factors being examined.

- Long-run estimates

This research examines the influence of biodiversity on the environmental footprint. The model employed the ecological impact per person as the dependent factor and economic development, resources, human capital, biological resources, and urbanization as distinct factors. This research contributes to the current knowledge base within specific setting. The estimated coefficients of GDP are roughly comparable to the elasticity of the environmental impact concerning economic development, natural assets, urbanization, biological capacity, and human resources, accordingly, due to the conversion of every factor into a logarithmic shape.

Over time, economic growth and the carbon footprint have a clear and meaningful correlation. GDP has an advantageous and considerable influence on the environmental impact. The square of GDP has an adverse and substantial effect on the ecological effects in the long term. The results support the quadratic correlation between revenue growth and the environmental implications, indicating that during the initial phase of economic expansion, pollutants tend to rise compared to the ecological impact. After reaching the optimal level, economic growth reduces pollution, thus verifying the Environmental Kuznets Curve (EKC) theory.

Next, the research uses natural resources. The relationship between the flexibility of the environmental impact and the availability of natural resources is positive, meaning that a rise in natural resource richness leads to an increase in the ecological impact. The favorable coefficient of plenty of natural resources indicates that nations lacking in mineral wealth must import energy from fossil fuels, such as petrol or gas, to stimulate economic growth that impacts the surroundings. These findings indicate that people need to be more efficient in using their mineral wealth and employing ineffective energy methods that cannot decrease their reliance on traditional energy sources. The environmental footprint of people, especially in its mining operations, is attributed to the impact of natural resource richness. People are now facing challenges in establishing ecological footprint criteria for critical sectors of their economy to achieve environmental goals while maintaining the country's economic development.

The urbanization process has a substantial adverse effect on the environment, indicating that urbanization is highly responsive to changes in environmental impact. Urbanization directly correlates with ecological footprint reduction, with a 1% increase resulting in a 1.93% drop. This phenomenon is attributed to converting agricultural land to housing developments, which diminishes the land's ability to absorb waste and pollutants. Urbanization fosters innovation, cutting-edge technology, and ecologically sound devices, including automobiles, communication systems, machinery, and utilities. Both biological capacity and human resources have no substantial statistical impact on the environmental footprint. Given the emphasis of this research on long-term outcomes, the study focuses on something other than immediate or temporary findings.

The research utilizes many diagnostic procedures to assess the presence of heteroscedasticity and hysteresis. The diagnostic test findings validate that the model lacks correlation and heteroscedasticity issues. To guarantee the stability of the approach, the research employs a cumulative sum and the total number of squares.

- Granger causality results

The test estimates provide long-term outcomes but do not indicate the causal relationship. The Granger causality examines the causal relationship between the studied variables. The Granger causation findings show a causal relationship between biological capacity and environmental impact in the long term. There is a bidirectional causal connection between natural resources and the ecological impact. Urbanization and the environmental impact have a reciprocal causal relationship where each causes the other. The cumulative sum results are shown in Figure 2, and the cumulative sum square results are shown in Figure 3.

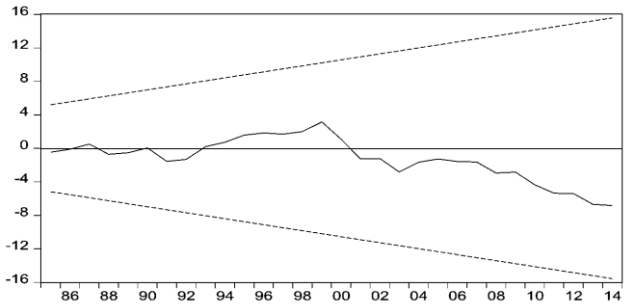

Figure 2. Cumulative sum results of Granger causality

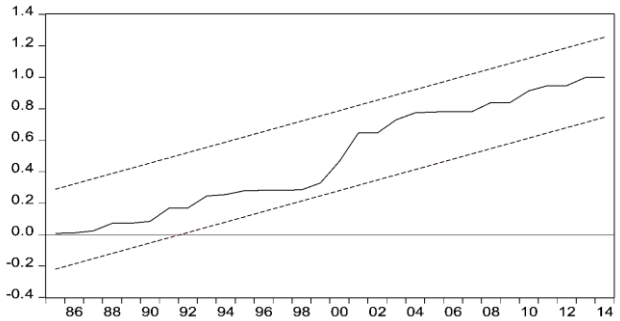

Figure 3. Cumulative sum square results of Granger causality

Nevertheless, the research does not discover any direct relationship between human resources and environmental impact. Nearby, a two-way causal connection between ecological impact and biological capacity exists. However, there is no causal connection between the other variables and the effect on the environment.

Conclusion and Findings

The preservation of natural resources and the protection of global ecosystems are crucial for maintaining the well-being and health of humans. Sustainability in the environment is inherently future-oriented since many environmental choices have long-term repercussions. Financial, social, and ecological variables influence sustainability criteria. Practical tools and strategies for sustainable energy management entail organizing and monitoring a complex process as a collection of distinct activities to be executed at precise times and in specified ways. A crucial component of energy administration is the examination, strategizing, supervision, execution, and regulation of all the diverse elements required to attain sustainable and economic advantages. The objective of modern and sustainable energy administration is to enhance energy effectiveness, minimize the use of non-renewable energy sources, and provide both financial and non-economic advantages. This research sought to investigate the influence of energy utilization on economic development and sustainable development in the top ten most resource-efficient nations between 1990 and 2020. The study used energy availability, safety of energy, and energy scarcity as moderating factors.

The research analyzed empirical data using sophisticated economic models, specifically adopting second-generation Westerlund and integration and cross-sectional regression analyses to estimate long-term effects. The findings indicate a positive correlation between energy intensity, access, and security with economic development, CO_2 emissions, and ecological impact. Reducing energy reserves was inversely correlated with economic expansion and directly associated with CO_2 emissions and environmental footprint. In summary, the results indicate that energy intensity, availability, and energy security have a detrimental effect on economic development and the surroundings. Energy depletion affects the environment and hinders economic growth in the top ten most resource-efficient nations.

These results provide evidence that supports the hypothesis of significant policy consequences. Over time, a greater level of energy consumption leads to a rise in economic development but also causes harm to the environment. This discovery corroborates the claim that there is a strong connection between the environment and the economy. The ecosystem acts as a provider of resources for the economy and also as a receptacle for pollutants. Many economic sectors rely on the extraction and use of natural resources, which often leads to the creation of waste and other ecological issues. Low levels of environmental quality harm economic development and human well-being by reducing the amount and quality of resources or causing harm to human health. Implementing green initiatives mitigates the adverse impact of the environment on the economy.

However, there is much controversy around their efficacy and whether they ultimately positively or negatively impact society. It is recommended that policymakers establish energy codes or gasoline consumption requirements and implement compulsory energy-saving initiatives. Driven by economic expansion, the rise in energy generation and use intensifies their impact on the natural world. Governments are advised to pursue economic and ecological goals concurrently by disassociating energy use from economic expansion. They are decoupling accomplished by increasing energy utilization to decrease the need for utilities or enhance the effective use of energy. This discovery implies that total energy consumption influences the overall ecological consequences of energy generation, the choice of fuels, and the technology employed.

Examining long-term results suggests that energy availability promotes economic expansion while also causing harm to the environment. Policymakers are advised to consider energy policies within a socio-technical framework encompassing technological, financial, political, and social variables. Growing research highlights the need for a dependable power supply for industry growth, significantly affecting the income and surplus of rural people and enterprises regarding electrification. An excessive discount rate applied to future benefits or external costs results in the undue exploitation of natural assets since the oversight of the earth's resources involves global and local consequences. Identifying the best suitable solutions and policy measures to tackle these concerns is essential. This research also indicates that planners should create a sustainable energy recovery strategy since it enhances resilience and safety in multiple ways. Investments in power networks and battery storage should be promoted. Implementing these measures will mitigate the likelihood of supply interruption,

enhance the modernity of power systems, and bolster their resilience to endure and recover from unforeseen events.

This will aid in enhancing the economical availability of energy services, facilitating the incorporation of variable-generated renewable power, and enhancing system dependability. To ensure public and ecological security and optimize industrial efficiency, it is necessary to coordinate energy and environmental systems. The government provides opportunities to develop renewable resources and energy sources, improve climate resilience and long-term viability, and assist in making energy-saving choices.

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