Effectiveness of Replacing Fossil Energy Consumption with Renewable Energy in Algeria from 1990 to 2023

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Summary: In order to integrate renewable energy into the national energy policy, the Algerian government signed the National Program for the Development and Expansion of Renewable Energy in March 2011. This program aims to encourage the production of renewable energy from various sources. To assess the current situation of energy consumption patterns in the Algerian economy, a model was estimated to study the causal relationship between per capita renewable energy consumption and per capita consumption of non-renewable energy for the period 1990-2023.

During the mentioned period, the results confirmed the absence of a causal relationship in both the long and short terms. Therefore, the same model was estimated for the period 2000-2023, and then for the period 2010-2023, where a unidirectional causal relationship from per capita renewable energy consumption to per capita non-renewable energy consumption emerged. This relationship was influenced by the results of the National Program for the Development and Expansion of Renewable Energy, which was initiated by the government starting in 2011. In general, the Algerian economy is still in a phase of almost complete dependence on non-renewable energy and needs to make significant efforts to transition to the second stage of energy transformation.

Keywords: Renewable Energy; Non-renewable Energy; Causal Relationship; Energy Transformation.

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I- Introduction :

Algeria possesses vast reserves of diverse energy sources, holding more than a quarter of Africa's natural gas reserves, ranking 10th globally, and 16th globally in oil reserves. This has enabled the country to increase production and exports, considering it as a reservoir of fossil fuel resources. This situation has resulted in a rentier economy reliant on oil resources, where in 2021, oil revenue contributed 14.5% of the GDP, while oil exports covered more than 96% of total exports. This dependence extends to energy consumption, where over 99% of total energy comes from fossil fuel sources.

I-1 Research Problem:

Due to the growing impact on the continuity of production and increasing export of traditional energy sources, Algeria has shifted towards generating and consuming renewable energy, which is more efficient and less harmful, especially with the availability of several resources for energy generation from diverse sources within Algeria. The Algerian government has adopted practical plans for transitioning towards sustainable growth by replacing traditional energy consumption with renewable energy. The question arises: have these renewable energy sources become viable alternatives to fossil energy?

I-2 Research Hypotheses:

To answer the question above and understand the status of the Algerian economy during its energy transition stages, the following hypothesis is tested:

- There is no causal relationship in the long term between per capita renewable energy consumption and per capita non-renewable energy consumption.
- There is no causal relationship in the short term between per capita renewable energy consumption and per capita non-renewable energy consumption.

I-3 Importance of the Study:

This study addresses an important area in the relationship between renewable energy consumption and traditional energy consumption by Algerian individuals. This relationship helps to evaluate policy trends and encourage investment in renewable energies. It also reveals the extent to which the Algerian citizen is willing to consume new types of energy, thus reflecting the level of awareness within the community. Additionally, it contributes to understanding the effectiveness of energy transition programs and policies.

I-4 Study Structure:

To address the research problem, the following sections are presented:

- First: Energy Transition as a Necessity for Sustainable Growth
- Second: The Status of Renewable Energy in Algeria
- Third: The Reality of Renewable Energy Substitution in Algeria

II - Energy Transition as a Necessity for Sustainable Growth

The process of generating energy from conventional fossil fuel resources has proven incapable of sustaining production based on growth functions in recent years, on the one hand, and its compounded impacts on climate, the environment, and various natural activities, on the other. This has stimulated countries to search for new combinations that ensure continued sustainable growth, achieved through replacing conventional energy sources with renewable energy sources.

II-1 Stages of Transition to Renewable Energy Substitution:

Jean-Pierre Amigues et al. (2015) proposed transition scenarios, either involving high initial investment followed by a decrease with continued consumption of non-renewable resources, or low investment that gradually increases with resource depletion. According to Powell and Oren, or Wirl, the transition towards the use of renewable energy sources can take three successive stages (Amigues & All, 2015):

- **Stage One:** Full exploitation of non-renewable resources, where they are low-cost and available in unlimited quantities. However, continuing at this stage creates the need for the subsequent stage.

- **Stage Two:** A simultaneous use of both renewable and non-renewable energy sources, with greater focus on conventional energy due to ease of generation and available production channels. As non-renewable sources continue to be consumed, they will eventually deplete, leading to the next stage.

- **Stage Three:** This is the final stage, where energy production from clean renewable sources expands, far removed from non-renewable fossil fuel sources.

Thus, the importance of renewable energy emerges within the future growth outlook, as its presence is linked to the establishment of sustainable growth principles. This energy is offered under the following concepts:

II-2 What is Renewable Energy: The concept of renewable energy emerged as an alternative to traditional energy, as the latter was characterized by various impacts, which became clearer with the increasing production and consumption of energy from traditional sources. Additionally, traditional sources are finite, and their formation takes hundreds of thousands of years. Moreover, their combustion causes very high emissions of greenhouse gases. In contrast, the demand for energy from various sources can be met by non-depleting sources with lower emissions and lower costs compared to traditional sources. These are renewable energy sources.

II-3 Definition of Renewable Energy:
The United Nations classifies any energy derived from natural sources that renews at a rate greater than it is consumed as renewable energy (United Nations, 2025). Meanwhile, the World Meteorological Organization defines it as "any energy whose source is solar, geophysical, or biological, which renews naturally at a rate equal to or greater than its usage, and is generated from continuous and uninterrupted natural flows, such as biomass energy, solar energy, and geothermal energy, where these sources are converted into primary energies such as heat and electrical energy, and into kinetic energy using various technologies that provide energy services such as fuel and electricity" (Bouatli, 2019).

Renewable energy, or as it is called, "clean or friendly energy," because it is safer for the Earth, derives its continuity and renewal from the ongoing availability of the sources it depends on, which are distinguished by unlimited quantitative and qualitative availability. It is classified based on its sources into:

- **Solar Energy:** This is the energy derived from sunlight, which is captured in the form of heat or light and then converted into chemical energy through natural or artificial photosynthesis (Bouatli, 2019). Solar energy is the most abundant among all renewable energy sources, as all countries can use solar energy, with the only difference being the scale and capacity of its use (Suleiman, 2024).

- **Wind Energy:** Wind energy is extracted from the kinetic energy of the wind using large wind turbines located on land (terrestrial) or at sea and freshwater (marine). The wind first strikes the turbine blade, causing it to spin, and the turbine connected to it rotates, converting kinetic energy into rotational energy by moving a shaft connected to a generator (Bouatli, 2019). According to the International Renewable Energy Agency, wind energy is among the most widespread and used renewable sources due to its low production costs.

- **Hydropower:** Hydropower uses the energy of flowing water from top to bottom, and it can be generated from reservoirs and rivers. Hydropower plants rely on stored water in reservoirs, while river flow plants utilize the energy from river currents. Hydropower reservoirs provide drinking water, irrigation water, flood and drought control, navigation services, and energy supply. Hydropower is the largest renewable energy source in the electricity sector (United Nations, 2025).

- **Geothermal Energy:** Geothermal energy uses heat available within the Earth's crust. Heat is extracted from geothermal reservoirs using wells and other methods. Geothermal reservoirs, which are naturally hot and permeable, are known as geothermal aquifers (United Nations, 2025). Geothermal energy is used for heating, cooling, or harnessed for generating clean electricity (Bouatli, 2019).

- **Biomass Energy:** According to the Ministry of Energy and Mines in Algeria, biomass consists of organic materials of plant or animal origin from the natural environment, including wood, its secondary materials, as well as by-products from industries (such as leaves, food industries), agricultural by-products, animal by-products, and urban waste (Bouatli, 2019).

II-4 Previous Studies:

In-depth studies on renewable energy have confirmed that its development is very slow in industrialized countries, despite considerable investments by governments. However, a study by Habi Abdel Latif and Ben Amer Yahiya (2022) on the relationship between renewable energy consumption and economic growth in Algeria revealed a causal relationship from economic growth towards renewable energy consumption. On the other hand, renewable energy consumption in the Maghreb countries is not linked to oil prices due to high investment costs (Azazi Feryda, 2018).

Moreover, renewable energy consumption positively impacts economic growth and the environmental situation, making the expansion of renewable energy sources essential for sustainable growth (Fateh Belaïd, Maha Harbaoui Zrelli, 2019). These findings were also observed in Arab countries, as revealed by a study by Maïssa Roubi, Ahmed Hadrout, (2022).

As for the relationship between renewable and non-renewable energy consumption, a study by Nicholas Apergis and James E. Payne (2012), applied to 80 industrialized countries for the period 1990-2007, found a bidirectional causal relationship only in the short term.

III- The Status of Renewable Energy in Algeria

In recognition of the importance of promoting and developing the renewable energy sector, Algeria established the National Program for Renewable Energy Development.

III-1 The National Program for the Development and Expansion of Renewable Energy To integrate renewable energy into Algeria's economic energy policy, the Algerian government signed the National Program for Renewable Energy Development in March 2011. This was further supported by the amended and supplemented National Program for Renewable Energy Development (2013-2020), along with a financial and legal framework that facilitates the exploitation of various renewable resources in the country.

The first program focused on establishing renewable energy capacities estimated at about 22,000 MW during the period 2011-2013, including 12,000 MW to cover domestic electricity demand and 10,000 MW for export. According to the program, relying on solar energy in both photovoltaic and thermal forms, along with wind energy, will allow the Algerian economy to enter a sustainable movement, aiming to produce 40% of electricity from renewable sources by 2030. This is divided into stages: 2015, 2020, and 2030 (as stated in the amended and supplemented law of 2015). Regarding renewable electricity production, the following targets were set:

Table 1: Targets of the National Renewable Energy Development Program

| Year	2015	2020	2030
Share of renewable energy in total actual needs	4.6%	15.9%	37.7%
Share of renewable energy in total electricity production	3%	11%	27%

Source: Renewable Energy Development Program 134/2015, January 2015

The law-based plans focus on the optimal use of solar energy in both forms, along with wind energy, which are especially available in southern areas and the Sahara. A "Guaranteed Purchase Pricing" mechanism was introduced to encourage individuals to participate in the transition to renewable energy, guaranteeing renewable energy producers a pricing system that ensures a reasonable return on their investments over a 20-year period for both solar and wind energy.

Additionally, the "National Renewable Energy Fund (FNER)" was created to provide financial support for investments in renewable energy projects, such as solar energy projects using solar panels (Jadi S., Jadi T., 2015).

III-2 Renewable Energy Sources in Algeria

Hydropower usage appeared early in Algeria. Since the second half of the last century, Algeria has exploited water energy, particularly since it possesses ample resources for this energy. Hydropower generation reached its peak in 2012 with a production capacity of (0.62 TWh). With the growing spread of other types of energy generation and following governmental encouragement programs, a new mix of renewable energies was formed, primarily relying on solar energy, followed by wind energy, and then hydropower.

Figure 1: Renewable Energy Generation by Source

Modern renewable energy generation by source, Algeria
Measured in terawatt-hours[1].
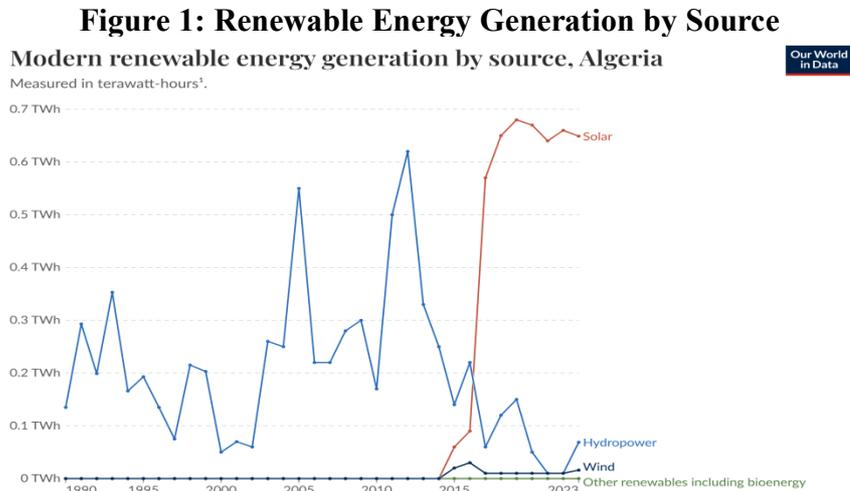
Source: Energy Institute Website, 2025

Due to the availability of vast areas within the dry desert climate, investment projects have achieved clear results in solar energy generation. This is evident in the positive growth surge achieved over five years since the beginning of solar energy generation, reaching 0.65 terawatt-hours (TWh) by 2023. This occurred alongside a decline in hydropower generation values (0.07 TWh). As for wind energy, its emergence coincided with the start of solar energy generation and use, but it remained at very low values compared to solar energy (0.01 TWh).

III-3 Clean Electricity Production in Algeria

The success of clean energy diversification projects and encouraging their consumption is one of the key pillars of sustainable development challenges in Algeria at various levels. In addition to government decisions and development trends aimed at transitioning to a clean economy, efforts have been made to promote and encourage consumption through the integration of private investors in renewable energy generation projects from various sources, as well as promoting the consumption of this type of energy and prioritizing local citizens over export operations. The following figure reflects the actual results of the renewable energy status in Algeria.

Figure 2: Share of Electricity Generation from Renewable Sources Since 1990
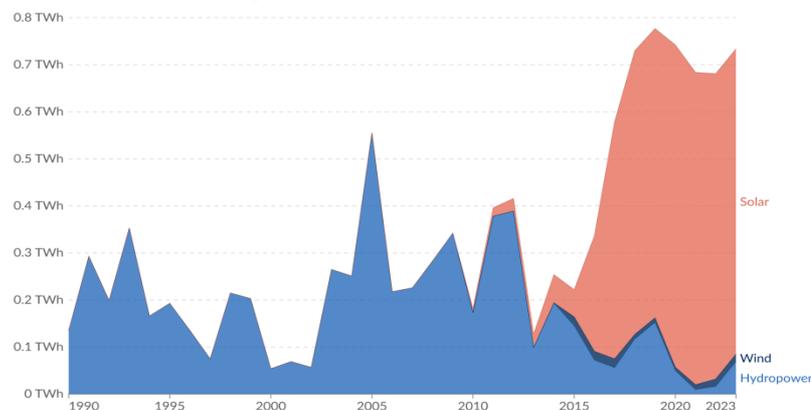
Source: Energy Institute Website, 2025

Despite the fluctuations in the field of electricity generation from renewable sources, it has witnessed a significant qualitative shift since 2015. The capacity of electricity generated from solar energy surpassed that generated from hydropower, in addition to growing from 0.13 terawatt-hours (TWh) in 2013 to over 0.7 TWh in 2019. This highlights the success of the National Renewable Energy Development Program launched in 2011.

This growth in the use of renewable energy, despite its relatively low value, comes at the expense of energy sources derived from fossil fuels, which signifies a transition towards clean and sustainable energy.

Figure 3: Share of Primary Energy Consumption from Renewable Sources
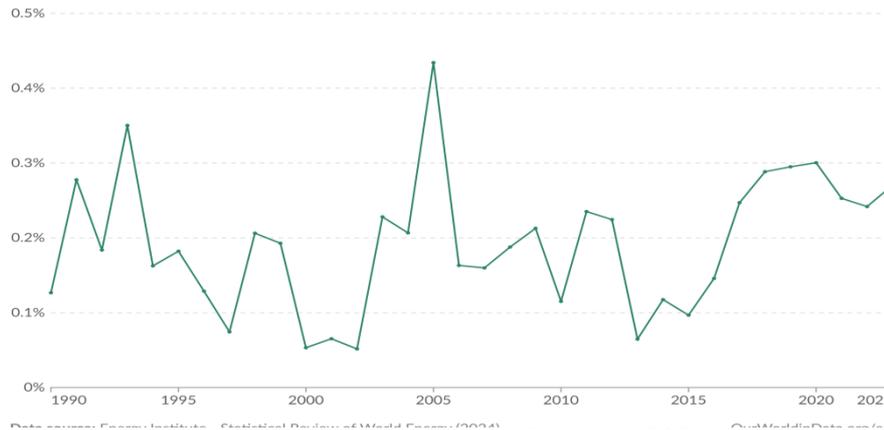
Source: Energy Institute Website, 2025

The reality of Algeria's energy policy demonstrates its heavy reliance on fossil fuel sources for energy generation, exceeding 96%. However, recent trends toward encouraging renewable energy have yielded positive results, albeit modest, as seen in the increase recorded starting from 2016. The growth in renewable energy consumption is shown in the following figure:

Per Capita Renewable Energy Consumption

Source: Website of the Energy Institute, 2025

To activate these results, the Algerian governments aim for a real and effective transition towards renewable energy, which is achieved by replacing these energies with depleting traditional energies. To understand this impact, a model must be constructed linking the consumption of renewable energy with the consumption of depleting energy.

IV - Reality of Renewable Energy Substitution in Algeria

The success of Algeria's energy policy depends on two main factors: the first is working on generating types of renewable energy based on the available natural resources, and the second is encouraging the consumption of clean energy and replacing depleting traditional energy. The nature of this effect can be understood by examining the causal relationship between renewable energy consumption and depleting energy consumption during a certain period.

Therefore, a model was constructed between two variables: per capita renewable energy consumption (REN) and per capita depleting energy consumption (FOS) during the period 1990-2023, based on the data published on the website of the Energy Institute, according to the following model:

$$\text{FOS}_t = \sum_{i=1}^{n} \alpha_i \text{REN}_{t-i} + \sum_{j=1}^{n} \beta_{1j} \text{FOS}_{t-j} + u_t$$

IV-1 Stationarity Test:
To understand the causal relationship between the variables under study, the stationarity level of each of them must be determined first. The results of the ADF and PP tests were as follows:

Table 02: Stationarity Level of Variables

Variable		test	value	prob		test	value	Prob
FOS	level	ADF	0.09	0.95	First difference	ADF	6.69	0.03
		PP	0.25	0.88		PP	24.5	0.00
REN	level	ADF	2.24	0.32	First difference	ADF	62.9	0.00
		PP	1.34	0.51		PP	103.1	0.00

Source: Prepared by the researchers based on EVIEWS program outputs

The results of the ADF & PP unit root tests indicate that both variables (per capita renewable energy consumption and per capita depleting energy consumption) are stationary at first difference, as they could not be stabilized at the level.

The similarity in the degree of stationarity of the studied variables indicates the possibility of establishing a long-term relationship between them, which should be tested for, along with testing for long-term causality using the Toda-Yamamoto test and short-term causality using the Granger test.

IV-2 Determining the Optimal Lag Period:
The optimal lag period is obtained by estimating the VAR model for the variables at their original levels I(0), based on basic statistical criteria: Akaike AIC, Schwarz SIC, Hannan HQ, etc. The results were as follows:

Table 3: Results of Lag Period Determination Tests

Lag	LogL	LR	FPE	AIC	SC	HQ
1	-330.8597	NA	36706239*	23.09377*	23.28237*	23.15284*
2	-330.1016	1.307159	46045185	23.31735	23.69453	23.43548
3	-328.3825	2.726788	54353632	23.47465	24.04043	23.65185

Source: **Prepared by the researchers based on EVIEWS program outputs**

The results above show that the optimal lag is one period based on all tests used, and the values of these lags are statistically significant according to the Chi-squared test shown in the table.

Table 4: Chi-Squared Test

	FOS	REN
Lag 1	26.40131	3.314025
	[1.85e-07]	[0.1]

Source: Prepared by the researchers based on EVIEWS program outputs

IV-3 Cointegration Test:
The Johansen cointegration test aims to detect the number of equations that can be generated from the relationship between the concerned variables. After estimating the cointegration relationship between FOS and REN, the following results appeared:

Table 5: Johansen Cointegration Test Results

	Eigenvalue	Trace Statistic	prob	Max-igen Statistic	Prob
None	0.25	0.59	0.31	9.46	0.24
At most 1	0.00	0.12	0.72	0.12	0.72

Source: **Prepared by the researchers based on EVIEWS program outputs**

The absence of statistical significance in the values of both Max-Eigen and Trace means there is no cointegration relationship between the variables in the long term, which leads to the acceptance of the null hypothesis.

Since the causal relationship is not linked to a cointegration relationship, we can search for the existence of the causal relationship between the variables in both the long and short terms.

IV-4 Long-Term Causality Test: Toda-Yamamoto

The Toda-Yamamoto (TYM) test looks for causal relationships between variables that are stationary at the level or at the first difference, based on the Wald test statistic, which aims to test the restrictions imposed on the parameters of the VAR model. K represents the maximum degree of integration plus the optimal lag period K = Dmax + P, following the Chi-squared test with p degrees of freedom. In this case, k = 1 + 1.

Table 6: Long-Term Causality Test Results

	Chi-sq	Prob	
REN cause FOS	0.08	0.76	Accept h0
FOS cause REN	0.02	0.88	Accept H0

Source: Prepared by the researchers based on EVIEWS program outputs

The estimated results indicate that the Chi-squared test values are 0.08 and 0.02, respectively. However, these values are not statistically significant at the 10% level, meaning the null hypothesis is accepted and the alternative hypothesis is rejected. It is not possible to detect a long-term causal relationship between per capita renewable energy consumption and per capita depleting energy consumption during the period 1990-2023.

IV-5 Short-Term Causality Test

The short-term causal relationship is revealed by the Granger test, and the results are as follows:

Table 7: Short-Term Causality Test Results

	F-Statistic	prob	DECISION
REN does not Granger Cause FOS	0.12	0.78	Accept h0
FOS does not Granger Cause REN	6.81	0.15	Accept H0

Source: Prepared by the researchers based on EVIEWS program outputs

The results of the short-term causality test were consistent with those of the long term, confirming the absence of causal relationships between per capita renewable energy consumption and per capita depleting energy consumption in both directions.

IV-6 Causality Test Between the Variables for the Period 2000-2023

To investigate the relationship between the variables further, the model was re-estimated using data for the current period only, and the estimation results for the period 2000-2023 were as follows:

Table 8: Causality Test Results for the Period 2000-2023

		Chi-sq	prob			F-Statistic	Prob	
REN cause FOS	Long-term	0. 17	0.91	Accept h0	Short-term	0.07	0.73	Accept h0
FOS cause REN		3.9	0.14	Accept H0		2.23	0.01	Reject H0

Source: Prepared by the researchers based on EVIEWS program outputs

The results of the Chi-squared test during the current period were no different from the previous period, confirming the absence of a long-term causal relationship between the variables. However, in the short term, a one-way causal relationship was found: FOS causes REN. This

suggests that depleting energy consumption is related to renewable energy consumption, which could indicate that some types of renewable energy require depleting energy for their operation.

IV-7 Causality Test Between the Variables for the Period 2010-2023

Upon re-estimating the model for the period 2010-2023, it was found that there was a significant long-term relationship from renewable energy consumption to depleting energy consumption. Despite the short estimation period, the results showed that there is a causal relationship between them. This is due to the growth in the generation and consumption of renewable energy in recent years and the efficiency of the programs implemented by the government.

Table 9: Causality Test Results for the Period 2010-2023

		Chi-sq	Prob			F-Statistic	Prob	
REN cause FOS	Long-term	6.23	0.04	Accept h0	Short-term	0.03	0.85	Accept h0
FOS cause REN		0.05	0.97	Accept H0		0.43	0.52	Accept H0

Source: Prepared by the researchers based on EVIEWS program outputs

The absence of a short-term causal relationship between the variables (FOS, REN) may be attributed to the nature of the Granger test, which only examines direct relationships and ignores indirect relationships.

Conclusion

Following the plans aimed at achieving sustainable economic growth, Algeria has started to exploit renewable energy resources. For several decades, water energy was exploited, but the focus shifted to solar energy, utilizing the vast spaces in Algeria's desert due to the low cost and effectiveness of this type of energy in replacing depleting energy in many processes.

The transition to renewable energy was supported by the law for supporting renewable energy utilization enacted in 2011, amended in 2015, which outlined plans for renewable energy utilization and replacing depleting energy. The figures regarding renewable energy utilization confirm the success of this program in generating and utilizing renewable energy. However, the other aspect related to substituting renewable energy for depleting energy was explored through a model that tested the causal relationship between per capita consumption of the two energy types during the period 1990-2023.

The results confirmed the absence of a cointegration and causal relationship in both the short and long terms between the two variables. Therefore, the model was re-estimated for the period 2000-2023, where a relationship was found indicating that per capita consumption of depleting energy causes per capita consumption of renewable energy. This supports the initial direction that renewable energy is generated by consuming depleting energy.

For the period 2010-2023, the model showed a long-term relationship where per capita renewable energy consumption causes per capita depleting energy consumption. These results are attributed to the results of the renewable energy utilization support program, which began to show clear results starting in 2016 and may continue in the upcoming years.

Accordingly, it is recommended to continue supporting projects aimed at promoting the consumption of renewable energy in place of non-renewable energy, with a focus on utilizing various available natural resources. By implementing the strategies developed by the government to enhance the utilization of renewable energy sources, the share is expected to reach 30% by the year 2035.

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