

Forecasting Renewable Electricity Generation in Algeria Using Cobb-Douglas Model

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Abstract:

This study employs the Cobb-Douglas model to analyze and forecast renewable electricity generation in Algeria, using data from 1990 to 2022. The model estimates the impact of gross capital formation, labor productivity, and annual precipitation on renewable energy output. The results indicate that both capital formation and labor productivity have a significant and positive effect on renewable electricity generation, with labor productivity exhibiting the strongest impact. Precipitation also shows a positive but marginally significant influence. The model also forecasts renewable electricity generation until 2030, helping policymakers in planning the Algeria's electricity generation mix.

Keywords: Renewable Energy, Electricity Generation, Cobb-Douglas, Prediction Model.

Jel Classification Codes: Q42, Q47, C51, C53.

Introduction:

In the global context, characterized by the structural drop in oil prices and the increasing acknowledgment of environmental problems, energy diversification became a strategic imperative for most countries, and especially for those whose economies mostly hinge on hydrocarbon exports.

In Algeria, public finances have been heavily impacted by fluctuation in oil and gas prices over the past two decades. After recording a significant budget surplus between 2000 and 2008, the country saw its budget tip into deficit following the fall in oil prices during the 2009 recession, a deficit that widened further after the price collapse in 2014-2015 (Despots, 2024). Faced with this situation, Algeria faces a dual challenge: ensuring its energy security in the face of the gradual depletion of its fossil resources, on the one hand, and meeting the imperatives of sustainable

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development, on the other the transition to renewable energies, and in particular renewable electricity, therefore appears to be an inescapable solution for diversifying the country's energy mix and reducing its dependence on hydrocarbons.

Despite Algeria's exceptional solar potential, with between 2 600 and 3 500 hours of sunshine a year (Mefti and Bouroubi, 1999), the transition to renewable energies remains insufficiently implemented. Despite the ambitions set out in the national renewable energy and energy efficiency program, the country still faces major obstacles to the effective deployment of these resources. These include high initial costs, lack of suitable infrastructure, and slow implementation of public policies.

Against this backdrop, Algeria faces the challenge of adapting to this new energy order while meeting its growing domestic electricity needs.

So, what are the determining factors in the development of renewable electricity in Algeria, and what is its projected value in 2030?

In this article, we propose to answer this question by examining the main factors influencing the development of renewable electricity in Algeria under the following assumptions:

- The development of renewable electricity in Algeria is significantly influenced by capital accumulation, labor productivity, and climatic conditions.
- The installed renewable energy capacity in Algeria will increase significantly by 2030, reaching ambitious levels thanks to the implementation of the national renewable energy program.

1- Brief Literature Review

The transition to renewable electricity generation in Algeria has gained significant attention in recent years, due to country's growing energy demand, high dependence on fossil fuels, and ambitious national targets for clean energy. Various studies have explored the determinants of renewable electricity deployment, assessing economic, environmental, technological, and policy-related factors. This section presents a brief literature review on Algeria's renewable energy transition.

Recent studies highlight that Algeria's energy mix remains dominated by fossil fuels, but with increased policy support, the share of renewable electricity could significantly rise by 2030 and beyond. Mokhtara et al. (2021) assessed Algeria's geographic suitability for wind and solar power plants, finding that while 97% of the territory is unsuitable, several regions have high potential for renewable energy deployment. However, despite ambitious national plans, renewable energy still represents a small fraction of the country's total electricity generation. The government has set targets to expand its renewable energy mix through large-scale solar and wind projects, as well as emerging technologies such as biomass and geothermal energy (Himri et al., 2022). Research assessing spatial complementarity between solar and wind resources suggests that certain regions exhibit higher synergy, allowing for more efficient energy production (Guezgouz et al., 2021). Furthermore, expansion of the national electricity grid is necessary to integrate more renewable sources and reduce dependency on localized fossil fuel generation. Multi-objective optimization studies suggest that achieving a 75% renewable energy share by 2050 is technically feasible but requires significant policy-driven investments and

structural reforms (Makhloufi et al., 2022). Additionally, Algeria's potential as an exporter of solar electricity to Europe is being explored, with scenarios for high-voltage direct current (HVDC) links under discussion (Benasla et al., 2024).

Regarding the determinants of renewable electricity generation, Tayeb & Bougueroua (2021) showed that rising oil prices positively influence renewable energy deployment, by making investment in alternative energies more attractive. Similarly, Cherifi et al. (2024) found that GDP per capita has a significant unidirectional causal relationship with renewable electricity generation, highlighting the role of economic growth in the expansion of the energy sector. The gross capital formation has been shown to have a statistically significant and positive impact on renewable electricity production, with a 1% increase in capital investment leading to a 0.55% increase in renewable energy production (Makhloufi et al., 2022).

Furthermore, government policies and regulatory frameworks heavily influence renewable electricity deployment in Algeria. Legal frameworks, such as Law No. 02-01, govern electricity distribution and transmission, yet further reforms are needed to accelerate renewable energy development (Rahmouni, 2022). Implementing the National Renewable Energy and Energy Efficiency Program has been a central policy instrument, but its effectiveness remains debated (Cherifi et al., 2024).

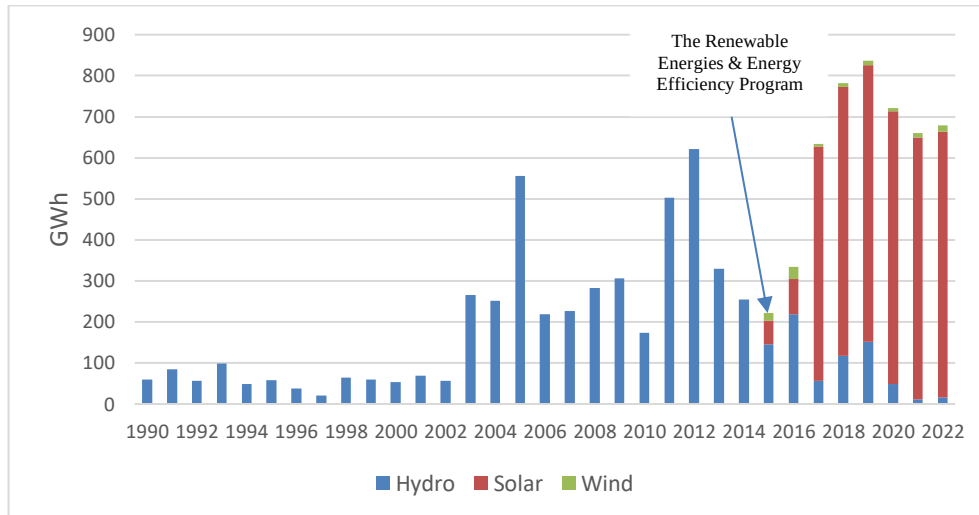
According to Makhloufi et al. (2022), climate-related factors, such as precipitation variability, also have a marginal yet notable impact on renewable electricity output, particularly in hydropower generation. Empirical findings suggest that a 1% increase in annual precipitation can lead to a 0.87% rise in renewable electricity generation.

In this paper, we propose an appropriate model for forecasting renewable electricity generation in Algeria, based on available data, for the period 1999-2022.

2- Data and Method:

The data used in this study includes three explanatory variables to analyze economic and environmental factors, over the period 1990 to 2022: Gross capital formation (in constant units of account) represents investment in fixed assets such as land improvements, infrastructure, machinery, and buildings, as well as changes in inventory levels. These data come from the national accounts of the World Bank and the OECD. Another important variable is GDP per person employed which measures economic productivity by dividing GDP by total employment, adjusted using purchasing power parity (PPP) in constant 2021 international dollars. In addition, the annual rainfall observed in Algeria is included as a climate factor, taken from the World Bank's Climate Knowledge Portal. The dependent variable represents the production of renewable electricity (non-combustible source), measured in GWh, and collected by the International Energy Agency (IEA). Figure 1 shows the evolution of this variable from 1990 to 2022.

Figure 1. Evolution of renewable electricity generation in Algeria (1990-2022)



Source: Author using AIE date (<https://www.iea.org/data-and-statistics>)

The total electricity production in Algeria reached 91 231 GWh in 2022, marking 259% increase since 2000, according to the IEA. This sharp increase is driven by economic expansion, population growth, and industrialization, leading to higher energy demand. However, natural gas was the dominant source of electricity generation, accounting for a staggering 99% of total electricity production in 2022. For this purpose, Algeria has set ambitious renewable energy targets to diversify its energy toward a more sustainable energy future. Despite the launch of an ambitious program for the development of renewable energies (RE&EEP), which was adopted by the government in February 2011, revised in May 2015, and made a national priority in February 2016 (*cf.* Table 1), the use of renewable energies in Algeria remains modest.

According to the “Report on the Results of the National Energy Balance for the Year 2023” (Ministry of Energy, Mines and Renewable Energies, 2023), Algeria’s renewable electricity generation reached 723 GWh in 2023, marking a 6.1% increase compared to 2022. This growth was primarily driven by a 77% rise in hydropower generation, which increased from 16 GWh to 29 GWh, benefiting from improved rainfall conditions. Additionally, solar photovoltaic (PV) production grew by 4.8%, reaching 700 GWh.

Despite this progress, renewables accounted for less than 1% of Algeria’s electricity mix in 2023, as the country remains overwhelmingly dependent on natural gas, which still contributed 99% of total electricity production.

Table 1. Summary of RE&EE Program (2015-2023)

Energy source	Program Objectives (MW)		Generate 22000 MW of renewable energy by 2030.
	2015-2020	2021-2030	
Photovoltaic	3 000	10 575	13 575
Wind	1 010	4 000	5 010
Concentrated solar power	0	2 000	2 000
Biomass	360	640	1 000
Cogeneration	150	250	400
Geothermal	5	10	15
Total	4 525	17 475	22 000

Source: Author using Algerian Ministry of Energy and Mines (<https://www.energy.gov.dz/>)

To analyze the determinants of renewable electricity generation in Algeria, over the period 1990-2022, we propose the Cobb-Douglas production function. This economic model is widely used to study the relationship between inputs (factors of production) and outputs (level of production) (Greene, 2008). The model is specified as follows:

$$REG = A \cdot K^{\beta_1} \cdot LP^{\beta_2} \cdot PREC^{\beta_3} \cdot e^{\epsilon}$$

Where:

- **REG:** Renewable electricity generation (output),
- **A:** A constant term representing total factor productivity (baseline level of production),
- **K:** Gross capital formation (capital input),
- **LP:** Labor productivity (Labor input),
- **PREC:** Annual precipitation (climate input),
- **$\beta_1, \beta_2, \beta_3$:** Elasticities of output with respect to capital, labor productivity, and precipitation, respectively,
- **e^{ϵ} :** Multiplicative error term capturing random shocks or unexplained variations.

To convert the Cobb-Douglas model into a log-linear form, we take the natural logarithm of both sides. This simplifies the equation, making it suitable linear regression analysis as follows:

$$\ln(REG) = \ln(A) + \beta_1 \ln(K) + \beta_2 \ln(LP) + \beta_3 \ln(PREC) + \epsilon$$

We can write:

$$LREG = \beta_0 + \beta_1 LK + \beta_2 LLP + \beta_3 LPREC + \epsilon$$

Where:

- $LREC = \ln(REG)$: log of renewable electricity generation,
- $LK = \ln(K)$: log of gross capital formation,
- $LLP = \ln(LP)$: log of labor productivity,
- $LPREC = \ln(PREC)$: log of annual precipitation,
- $\beta_0 = \ln(A)$: constant term (intercept),
- $\beta_1, \beta_2, \beta_3$: elasticities of **REG** with respect to **K**, **LP**, and **PREC**, respectively,
- ϵ : Additive error term.

In the log-linear model, the coefficients $\beta_1, \beta_2, \beta_3$ indicate the percentage change in **REG** for a 1% change in the respective input.

3- Results and discussion:

The Cobb-Douglas model used in this study helps to explain the factors influencing renewable electricity generation (LREG) in Algeria from 1990 to 2022. The results of the model estimation are very satisfactory, with an R-squared value of 0.6168, meaning that around 61.68% of the variations in renewable electricity generation can be attributed to capital formation, labor productivity, and rainfall.

In addition, the F-statistic (15.5569) is highly significant at the 1% level, confirming that the model is statistically reliable and provides meaningful information. Table 2 presents the summary result of the estimates of the Cobb-Douglas model.

Table 2. Summary of results of the estimates model

Variable	Coefficient	Std.Error	t-Statistics	Prob.
C	-79.46679	19.14261	-4.151305	0.0003
LK	0.554082	0.162306	3.413802	0.0019
LLP	5.945475	1.859599	3.197182	0.0033
LPERC	1.028651	0.514676	1.998636	0.0551

R-squared	0.616760	Mean dependent var	5.566341
Adjusted R-squared	0.577114	S.D. dependent var	0.747251
F-statistic	15.55686	Durbin-Watson stat	1.244866
Prob(F-statistic)	0.000003		

Source: Author using Eviews 10 software outputs

Table 2 indicates that the capital formation coefficient (0.5541) is positive and statistically significant at the 1% level ($p=0.0019$), indicating that a 1% increase in investment leads to a 0.55% rise in renewable electricity generation. This underscores the importance of infrastructure and technology investments in expanding Algeria's renewable energy capacity. Similarly, labor productivity (5.9455) has a strong positive impact and is also significant at the 1% level ($p=0.0033$). A 1% increase in labor productivity results in a 5.95% rise in renewable

electricity generation, emphasizing the need for a skilled and efficient workforce to drive the energy transition. Precipitation (1.0287), although marginally significant at the 10% level ($p=0.0551$), also plays a role, with a 1% increase in annual rainfall leading to a 1.03% increase in renewable electricity generation. This highlights the climate-related impact on hydropower generation, suggesting that renewable energy planning must account for weather variability.

The Durbin-Watson statistic ($DW=1.2449$) is used to detect first-order autocorrelation in the residuals of a regression model. For $n = 33$ and $k = 3$, the critical values at the 5% significance level are $dL = 1.24$ (lower limit) and $dU=1.65$ (upper limit). As $DW = 1.2449$ is very close to dL , there is a risk of positive autocorrelation in the residuals. However, as the value is close to the lower limit, the result is borderline, marking the conclusion uncertain.

For the purpose, we used the Breusch-Godfrey (BG) test, which is more robust and general test than the Durbin-Watson test for detecting autocorrelation in residuals. It allows us to test for autocorrelation at higher order (not just order 1, like the Durbin-Watson test). Table 3 shows the results of this test.

Table 3. Breusch-Godfrey Serial Correlation LM test

F-statistic	2.861904	Prob. F(2,27)	0.0746
Obs*R-squared	5.772117	Prob. Chi-Square(2)	0.0558

Source: Author using Eviews 10 software outputs

The results of the Breusch-Godfrey test indicate that the autocorrelation of residuals is not statistically significant at the 5% threshold. Although the p-values are near to 0.05 (0.0746 for the F-statistic and 0.0558 for Obs*R-squared), they do not allow us to reject the null hypothesis of no autocorrelation.

According to the table below (Table 4), the results of the normality and heteroscedasticity tests confirm the validity of the regression model used to analyze the determinants of renewable electricity generation in Algeria. The Jarque-Bera test gives a statistic of 0.1305 with a p-value of 0.9368, well above the 5% threshold. This means that the null hypothesis (the residuals follow a normal distribution) cannot be rejected.

The Breusch-Pagan-Godfrey test does not detect any significant presence of heteroscedasticity. Indeed, the p-value associated with the F-statistic is 0.0865, slightly above the 5% threshold, and the other statistic (Obs*R-squared and Scaled explained SS) also display p-values above 0.05. These results suggest that the variance of the residuals is constant, reinforcing the reliability of the standard errors and hypothesis tests applied to the model.

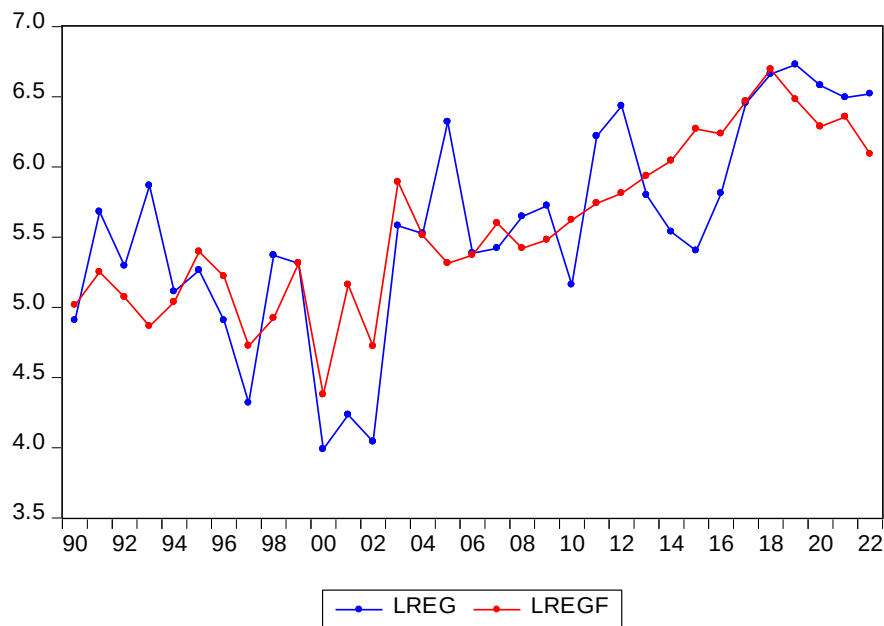
Table 4. Normality and Heteroskedasticity Tests

Jarque-Bera Test		
Statistics	0.130480	
Prob.	0.936843	
Breusch-Pagan-Godfrey Test		
F-statistic	2.418031	0.0865
Obs*R-squared	6.602980	0.0857
Scaled explained SS	4.787337	0.1880

Source: Author using Eviews 10 software outputs

The robustness of the Cobb-Douglas model makes it possible to anticipate the evolution of renewable electricity production in Algeria, taking into account the explanatory variables chosen in this study. Figure 2 shows the actual and predicted renewable electricity generation in Algeria (1990-2022).

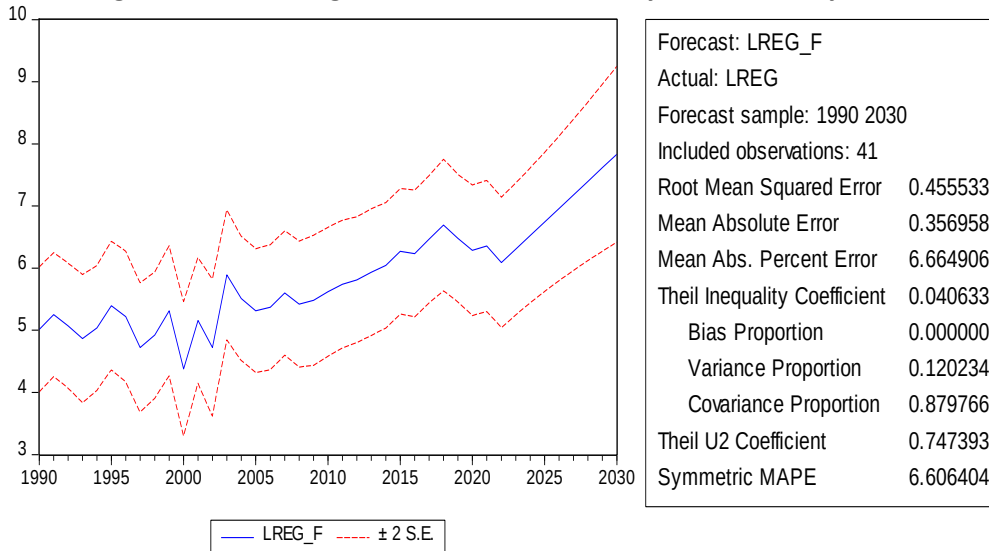
Figure 2. Actual and predicted renewable electricity generation in Algeria (1990-2022), using the Cobb-Douglas Model.



Source: Author using Eviews 10 software outputs

The following graph shows the forecasts, which covers the period from 1990 to 2030.

Figure 3. Forecasting the Renewable Electricity Generation by 2030



Source: Author using Eviews 10 software outputs

The forecast analysis of LREG_F compared to the actual values of LREG reveals an upward trend over the period from 1990 to 2030. The Root Mean Squared Error (RMSE = 0.4555) and the Mean Absolute Percentage Error (MAPE = 6.66%) indicate a moderate level of accuracy.

Theil's Inequality Coefficient (0.4040) suggests that the forecast follows the general trend of, (0.8798) dominates, confirming that the model effectively captures the variations in the data. However, the confidence intervals widen over time, indicating increasing uncertainty in long-term forecasts. Overall, the model provides reliable short-term predictions, but caution is needed for long-term projections due to growing variability.

Conclusion:

Faced with volatile oil prices and growing environmental concerns, Algeria urgently needs to diversify its energy mix to ensure long-term energy security and sustainable development. This study examined the main determinants of renewable electricity generation in Algeria using the Cobb-Douglas production function, analyzing data from 1990 to 2022 and projecting trends to 2030.

The empirical results confirm that capital formation and labor productivity significantly boost renewable electricity production. Precipitation also plays a positive but marginally significant role, underlining the influence of climatic conditions, particularly on hydropower.

However, despite Algeria's vast solar potential, its renewable energy transition remains sluggish, hindered by financial, infrastructural, and policy barriers. However, the findings suggest that targeted investments in renewable

infrastructure, workforce development, and adaptive policies could accelerate progress. While projections indicate growth in renewable electricity generation by 2030, achieving national energy goals demands stronger institutional commitment and policy implementation.

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