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Climate and fundamentals of the energy offer in Cape Verde

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Abstract

In Cape Verde, despite the existence of an exceptional renewable potential, namely wind and solar photovoltaic, estimated, by Gesto (2011), at 258 MW and 315 MW respectively, in 2017 82.2% of the electric energy was generated using fossil fuels. In this work, we propose to explore the fundamentals of energy offer and the relationship with climate change, taking Cape Verde as a case study, analyzing the determinant aspects for the diversification of the energy offer, taking into account an augmented role of renewable resources and the main market mechanisms and exploring aspects such as the energy infrastructures. It is also proposed to create an ARIMA model based on the available data to evaluate the behavior of the Capeverdean energy system in terms of consumption of fossil fuels.

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Keywords: Climate; Energy; Sustainability; ARIMA

1. Introduction

The growing demand for goods and services, coupled with the increased population growth, has led to changes in the industrialization process, with direct repercussions on the rate of economic and social development in the countries. To promote fair and equitable development among populations it is important to develop local economy and provide goods and services (in quantity and quality) but at same time to protect natural resources. For this purpose, economic infrastructures, particularly those in the energy sector, must be sustainable at all levels, as the energy sector has become the engine of economic development in the countries and constitutes one of the most important industries of the modern economy. The economic development of a country is, to a certain extent, conditioned by the quantity and quality of energy it makes available to consumers and economic activities and its associated value. In the case of Cape Verde, this is a critical point, because despite having a great potential in terms of renewable sources, in 2017, 82.2% of the electricity was generated through thermal power plants, thus contributing

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to the degradation of the environment through greenhouse gas emissions (*GHG*) and other air pollutants. Moreover, this form of generating electricity has very negative repercussions in the commercial balance of the archipelago, because, unlike with renewable energy sources, there are no local oil reserves or refining capacity which means that all fuels should be imported. Therefore, oil crises have direct impacts on the economy. Fluctuations in fuel prices imply frequent changes on the price of electricity. According to Electra [1], the average electricity price in 2017 was € 0.26/kWh, well above the European average (€ 0.2113/kWh, for the second semester of 2018, according to Eurostat [2]). According to the ARIMA model, this trend could be maintained during the next five years.

2. Literature review

The supply and demand analysis is a way to evaluate and to solve several problems, allowing structural measures to be taken in order to solve them. In the energy industry, where waste of resources can translate into significant losses for the economy, it is important to establish a balance between these two parameters [3]. In this regard, we intent to provide a brief overview behind the offer and the demand of energy in Cape Verde, particularly in terms of production, distribution, losses and consumption of fossil fuel.

The objective of the present literature review is to search for theoretical arguments that support the development of this work and, on the other hand, to collect data from institutions with energy responsibilities, to assist in the development of the ARIMA model that provides the fluctuation of fuel prices, classifying the electricity market, and finally to evaluate the environmental impact inherent to the consumption of fossil fuels in Cape Verde.

2.1. Production and distribution of electricity in Cape Verde

The generation and distribution of electricity in Cape Verde is basically guaranteed by Electra, SA, which covers all the islands, with the exception of Boa Vista, where electrical production and distribution is ensured by Águas e Energia da Boa Vista (AEB). Electra also acquires part of the electricity from two private companies, Cabeólica (which generated in 2017 about 31 GWh of wind power energy) and Electric Wind (which produced 761 MWh of wind power electricity) [1]. Table 1 shows the production and consumption of electricity in 2017, in the two regions (South and North) of the archipelago. In terms of electricity distribution, the market can be considered as a monopoly type, with two companies independently controlling the markets, thus constituting the extreme form of imperfect competition. However, the market is regulated by the Economic Regulatory Agency (ARE) that sets the prices in order to establish the economic balance in this sector. This failure in the market, characterized by the inexistence of competition or imperfect competition, provokes an unintended result from the point of view of the general well-being. In energy, the large capital intensity that characterizes this sector leads to the existence of large investments in facilities or infrastructures, which tend to assume, individually or jointly, a large dimension. The high scale of operation is compatible with the existence of few players operating on the supply side, which is the perfect scenario for the exercise of market power [4].

Table 1. Energy produced by type of technology in 2017.

Source: Adapted from [1].

Region	Technology		
	Diesel and fuel oil (GWh)	Wind (GWh)	Solar (GWh)
South	226.7	31.4	4.1
North	154.6	44.8	2.4
Total	381.3	76.2	6.5

Increasing the use of clean and renewable sources of energy production (namely electricity) is urgent in view of rising prices of oil and the need to avoid environmental degradation. The Government of Cape Verde has defined, in its program for the IX Legislature [5], the use, as far as is technically and economically possible, of alternative energies, particularly renewable and clean energies. In 2017, 464 GWh of energy was produced in the Cape Verde archipelago, 82.2% through the diesel technology, 16.4% from wind power and 1.4% from solar sources, which shows an underutilization of the renewable potential estimated at 257.6 MW and 314.5 MW for wind and solar photovoltaic respectively [6]. Despite the intentions of successive Governments, investment in this sector are practically inexistent. The installed capacity of wind power generation was 25.5 MW in 2011 and in 2018 the capacity is 26 MW. There was no increase in solar technology production capability.

2.2. Consumption and cost of fuel in electricity generation in Cape verde

The cost associated with production through the oil derivatives in 2017, with fuel consumption alone, was 41.4 million Euros (Table 2) [1]. The absence of sources of fossil fuels in Cape Verde leads to a 100% import of oil products, so prices are posted by ARE in line with international price trends. Thus, the prices of the products and the quantity of the products will be subject to the specific characteristics of supply and demand. Therefore, prices and quantities will vary over time due to the way the supply/demand binomial responds to other economic parameters.

Table 2. Fuel consumption and cost in electricity production.

Source: Adapted from [1].

Year	Diesel oil (10 ⁶ L)	Fuel oil 180 (10 ⁶ L)	Fuel oil 380 (10 ⁶ L)	Total (10 ⁶ L)	Cost (million €)
2011	20.5	42.8	10.3	73.6	40.4
2012	15.4	40.2	7.9	63.5	34.5
2013	17.7	38.2	3.7	59.6	33.2
2014	20.9	44.6	4.1	69.7	38.9
2015	21.5	40.6	9.7	71.8	39.6
2016	20.3	40.5	11.8	72.6	39.7
2017	21.5	41.5	12.6	75.6	41.4

2.3. Production, sale and losses of electricity

The data presented in Table 3 [1], show a high rate of losses (technical and non-technical) of electricity, especially in the island of Santiago, with a loss of approximately 36%. Despite some improvement in the quality of service provided to the customer in 2017, as compared with previous years, energy losses, to some extent, condition the operation of Electra. The losses, mainly the non-technical ones, are translated into financial constraints for the company and contribute strongly to the increase of the price of electricity in the Archipelago.

Table 3. Production, sale and losses of electricity.

Source: Adapted from [1].

Island	Production (GWh)	Auto consumption (GWh)	Sale (GWh)	Losses (%)
Maio	3.44	0.01	2.81	18.0
Santiago	241.80	29.09	124.93	36.3
Fogo	14.18	0.32	11.15	19.1
Brava	2.79	0.01	2.37	14.5
S. Antão	15.37	0.32	12.04	19.6
S. Vicente	79.09	12.40	54.38	15.6
S. Nicolau	6.78	0.12	5.54	16.4
Sal	61.36	11.59	48.62	1.9
Total ^a	424.80	53.87	261.85	25.6

^aWithout the island of Boa Vista.

Another factor that does not benefit the energy sector and therefore the national economy is the variation of fuel prices. Table 4 shows the average fuel oil price, in Cape Verde Escudo (ECV), from 2011 to 2017 [7]. Based on the data represented in Table 4, obtained from the ARE reports, the forecast model of fuel price fluctuation for a period of five years is created in section four of this paper.

3. Methodology and method

The data collected during the literature review was treated. In order to create the model that describes the variation of fossil fuel prices in the period from 2011 to 2017, Gretl software – a cross-platform software for econometric analysis written in C language – was used. The Gretl software is free and open source and can be redistributed and/or modified according to the terms of the GNU General Public License (GPL) published by the Free Software Foundation (FSF) [9]. The results achieved through this model give indications on the evolution of fuel prices and enable decision-making on the strategies to be adopted to reduce the consumption of such fuels. Henceforth one

Table 4. Variation in fuel price (ECV)^a between 2011 and 2017.

Source: Adapted from [7].

Month	Year						
	2011	2012	2013	2014	2015	2016	2017
January	71.27	86.80	91.87	86.30	76.17	53.80	56.30
February	76.97	89.37	89.33	85.23	58.53	43.30	62.60
March	84.53	89.40	89.30	85.20	58.50	43.30	62.60
April	84.53	84.77	91.47	84.43	64.70	44.27	61.57
May	84.50	94.80	91.50	84.40	64.70	44.30	60.07
June	85.80	92.50	86.93	84.20	69.00	48.23	57.97
July	85.80	92.50	86.90	84.20	69.00	48.20	57.97
August	83.37	87.20	88.33	85.37	65.47	52.70	56.73
September	83.40	87.20	88.30	85.40	65.50	52.70	58.00
October	83.77	93.70	89.03	84.43	55.53	52.70	62.43
November	83.70	93.70	89.00	84.40	55.50	52.70	62.43
December	86.77	87.87	86.30	75.87	54.03	56.30	65.40

^a1€ = 110 ECV.

might expect that the conducted analysis might be of assistance to future efforts aimed at reducing the electricity tariff and CO_{2e} emissions.

According Rodríguez et al. [10] the ARIMA model is based on the adjustment of the observed data, aiming to reduce the difference between the data produced in the model and the observed ones to values close to zero. The collected data are discrete with equally spaced time interns, so the ARIMA Model can be applied for the intended study [11]. Fig. 1 shows the schematic diagram of the estimation process of the ARIMA model. The procedures for each of the phases are essentially as follows [8]:

- Data preparation step: Reduce observed variance in the data and find series of series;
- Model identification stage: Evaluate the autocorrelation and partial autocorrelation of the data within the critical values and distinguish which patterns are random (white noise);
- Step of estimating the parameters: Estimate the parameters of the potential models and select the best model using the decision criteria;
- Diagnostic phase (verification, adjustments and validation): to evaluate the autocorrelation and the partial autocorrelation of the residues and to evaluate the existence of seasonality in the series;

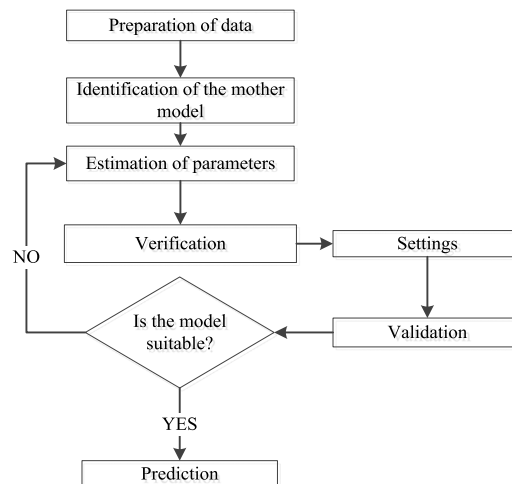


Fig. 1. Schematic diagram of the estimation process of the ARIMA model.

Source: Adapted from [8].

- Prediction phase: use the model to predict the variation in fuel prices and evaluate the adequacy of the model.

4. ARIMA model proposal for the fluctuation of fuel price

The modeling first step was to plot the curve that represents the time series of the fuel price variation as referenced in Table 4. Thus, Fig. 2 represents the time series curve of price variation of fossil fuels, determined by ARE during the period 2011 to 2017 [7]. It is a non-stationary series, that is, it tends to increase in certain time intervals and decreases in other periods of time [12].

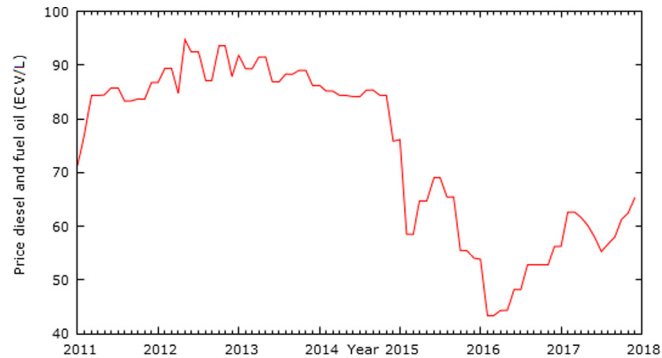


Fig. 2. Variation in fuel price 2011–2017.

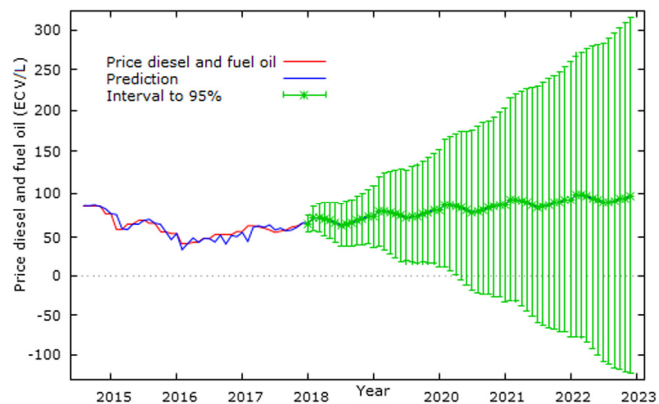


Fig. 3. Model proposed for average variation of fuel price.

In order to evaluate the behavior of the Capeverdean energy system in relation to fluctuations in fossil fuel prices as well as fossil fuel consumption during the next five years and to estimate the economic and environmental impacts of this trend, a model was proposed. Thus, in compliance with the procedures listed in Section 3, to estimate such a model, the SARIMA (19, 1, 1) (1, 1, 1)₁₂ model was used as the “mother model”, constructed by counting the peaks outside the confidence intervals defined in the correlograms autocorrelation function (ACF) and partial autocorrelation function (PACF) of the non-seasonal (p and q) and seasonal (P and Q). With the help of Gretl software, based on the data released by ARE, several models were tested, and the model which best meets the requirements according to methodology of Box Jenkins was ARIMA (1, 1, 1) (0, 1, 0), represented in Fig. 3.

The prediction shows an increasing trend in the period considered (2018 to 2023), occurring several oscillations characteristic of the oil market. This rising trend in fuel prices and the progressive increase in fossil fuel consumption, together with the poor progress in clean energy production, continues to have negative consequences in for the national economy and the environment. According to the data provided by ARE in 2017, the average price of diesel was 74.03 ECV/L (€ 0.673/L), Fuel 180 was 56.70 ECV/L (€ 0.515/L) and Fuel 380 was 48.58 ECV/L (€ 0.4141/L). The average electricity tariff was posted at € 0.23, € 0.25 and € 0.26 in the years 2016, 2017 and 2018 respectively.

The proposed ARIMA model is adequate to predict the data, since, as shown in Fig. 3, the curves of the read and predicted data are practically collinear. In addition, the average default error for the first five predictions from 2018 is small and stands at 7.9%.

5. Classification of the Capeverdean electricity market

According to economic theories market equilibrium occurs when the price and quantity of the good desired by demand and supply equals. That is, there is no excess or lack of demand or supply. Fig. 4 represents the market equilibrium point proposed by Pindyck and Rubinfeld in 1994.

The point (Q_0, P_0) represents the equilibrium point, S_0 is the supply curve and D_0 is the demand curve. According to Pindyck and Rubinfeld [3], one of the ways to calculate the equilibrium conditions of a company with simple x production is by means of the formula: $C(x) = C_f + C_v(x)$, where C_f represents the fixed cost and $C_v(x)$ represents the variable cost of production of x .

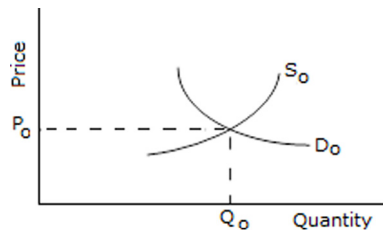


Fig. 4. Market equilibrium.

As previously mentioned, the electricity tariff is readjusted periodically in order to establish the market equilibrium. Thus, the market price of the product will be constant and equal to P during the period of validity of the price update, in this case, the electricity tariff. However, the $Q(x)$ profit of the producing company is highly affected by the volatility of the fuel price as the proposed model demonstrates, and by the high rate of electricity losses in the system, calculated at 25.6% at national level and at 36.3% at the largest production center - island of Santiago, and by the fluctuation of fuel prices, having registered, in 2017, eight updates with variations in the range of $[-10.1\%, +4.2\%]$ in relation to the average value. Consequently, the electricity market in reference becomes unbalanced.

6. Climate and energy supply

Cape Verde is located between the parallels $14^{\circ}23'$ and $17^{\circ}12'$ north latitude and the meridians $22^{\circ}40'$ and $25^{\circ}22'$ west of Greenwich [13], a region covered by a dry tropical climate with few natural resources, except for the wind and the sun.

Despite continued global warming, the evidence shows that wind and solar photovoltaic power generation facilities have a reduced or neutral level of vulnerability to climate change. According to the 2011 Cape Verde Energy Plan, the most economical renewable resource is wind power, with a cost of energy production less than half the cost of fuel oil ($\text{€ } 50/\text{MWh}$ vs. $\text{€ } 131/\text{MWh}$). The generation from the solar photovoltaic resource carries a higher cost, since investment is estimated at $\text{€ } 3.25/\text{Wp}$.

With an investment in wind technology equal to the total amount spent on fuel consumption in the year 2017, a total of 829 MWh of wind electricity could have been produced, which would mean avoiding the emission of 546 tons of CO_{2e} into the atmosphere, taking as a factor of emission for the consumption of electricity $0.659 \text{ tCO}_{2e}/\text{MWh}$, a factor determined from the data provided, in 2017, by the National Statistical Institute (NSI) [14], which takes as reference the methodology of the Intergovernmental Panel on Climate Change (IPCC).

7. Results

The most important results are presented in Table 5. The results clearly show an under-utilization of the renewable potential in favor of fossil resources, with consequent GHG emissions. The national average of lost power is well above the world average estimated, by International Agency Energy (IAE), at 14.07% [15]. The loss is most pronounced on the most important island. The electricity market of monopoly type enables the company to control

Table 5. Main results.

Item evaluated	Parameters	Evaluation
Electricity market	Type	Monopoly
Exploitation of renewable potential	Wind	10%
	Solar photovoltaic	2.4%
Consumption of fossil fuels	Annual average	69.4×10^6 L
Average fuel price	Projection until 2023	From € 0.45/L to 0.9/L
Energy produced by type of technology in 2017	Diesel	82.20%
	Wind	16.40%
	Solar photovoltaic	1.40%
Technical and non-technical losses in 2017	National average	25.60%
	Island of Santiago	36.30%
GHG emissions in 2017	Preventable emission	546 ton. de CO_{2e}
Electricity market	Situation	Unabled

the price and quality of service it provides. However, factors such as electricity losses lead to electricity market imbalance.

The projection points to a change in the price of fuel between 2018 and 2023 in the range of 0.45 to 0.9 euros, with the growing trend.

The possible solutions to overcome these situations are the liberalization of the electric sectors, the greater investment in renewable technologies and the improvement in the process of billing the companies.

7.1. Comments on results

In Cape Verde, 82.2% of the total electric energy is generated through diesel technology, which shows an underutilization of the existing renewable potential, estimated at 257.6 MW and 314.5 MW for wind and solar photovoltaic sources, respectively. Divergent decisions or policy options are an important barrier to implementing measures to increase the penetration rate of renewable energy in the grid. However, the trend is towards an increase in fossil fuel consumption for the next five years according to the existing conditions, with negative consequences for the environment and for the national economy. In the year 2017, 75.6×10^6 liters of fuel were consumed, with a cost of 41.4 million Euros, for the generation of energy, equivalent to 2.7% of the Gross Domestic Product of the country estimated by Bank of Cape Verde (BCV), at 1.533 billion Euros [16]. With an investment in wind technology equal to the amount spent on fuel, the emission of 546 tons of CO_{2e} could be avoided. Technical and non-technical losses contribute to the imbalance between energy supply and demand in the archipelago, where the island of Santiago stands out for its importance as well as for the percentage of energy losses in the system, estimated at 36.3%. The sine-qua-non condition for the implementation of renewable energy production infrastructures is the existence of potential sources of this nature. Cape Verde is in a region where the level of vulnerability is low or neutral, compared to wind and solar photovoltaic installations, in the face of climate change.

8. Conclusion

The unbalanced electricity market, the weak use of renewable resources and technologies, the forecast of fluctuations in the price of fuels with increasing tendency, as shown by the ARIMA model, are an obstacle to the reduction of electricity tariffs and the reduction of greenhouse gas emissions. Consequently, they limit the development of the country in question.

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