RISAD
REVISTA INTERNACIONAL
DE SALARIOS DIGNOS

Clean energies in Mexico: projections for solar energy

Rocco Petrarca [1]

Recepción: 10/11/2020

Aceptación: 03/02/2021

Abstract

In this research we analyze the current situation and prospects for solar energy generation in Mexico in order to identify areas of opportunity for both investment for private initiative and intervention for public policies. Methodology. Based on the official data provided by the Ministry of Energy, a forecasting model is built from an autoregressive time series model (AR1). The main results indicate that the generation of energy from clean sources such as solar has a negative trend in Mexico, so it is urgent that the government incentivize the sector so that it is attractive to investors and the country can eventually transition from a model from combustion energy to green energy. One of the main limitations was access to updated data, so information was only available until December 2017. However, the resulting model fit is quite reliable to forecast the behavior of the following years. The results give sufficient evidence of the urgency of intervention in the renewable energy sector in Mexico, abandoned in the most recent energy reform. Originality / value of the paper. The paper places the accent on the green energy sector in the midst of a great global economic crisis that collapsed oil prices to negative values and called into question the continuity of the rentier model for producing countries. It is an alert to initiate the transition of the energy paradigm.

Key Words

Investment opportunities; Time Series Forecasting; Renewable energy; Solar energy.

Introduction

Energy resources can be classified into three categories: fossil fuels, renewable resources and nuclear resources (US Energy Information Administration's report, 2011). Fossil fuels' reserves are limited, and their wide use is an issue connected with the deterioration of the environment. In fact, according to Kalogirou (2004), three international environmental problems exist: acid precipitation, stratospheric ozone depletion, and global climate change. The term acid precipitation includes any form of

1 Student, Master Universitario di Primo Livello", Universitá di Bologna (Italia) and ICN Business School de Nancy (France). roccopretarca@gmail.com

precipitation with acidic components, like sulfuric or nitric acid that drop to the ground from the atmosphere in wet or dry forms. The stratospheric ozone depletion is about the gradual thinning of Earth's ozone layer in the upper atmosphere because of the release of chemical compounds which contains gaseous chlorine or bromine from industry and other human activities (Santoyo-Castelazo, et.al., 2014). Regarding the global climate change, it involves all the changes recorded throughout history. Almost all the climate changes recorded until today are due to very small variations in Earth's orbit that affect the amount of solar energy our planet receives.

The problems listed above are rapidly increasing and this is a serious issue for humans. For example, the rate of skin cancer, eye cataracts, and genetic and immune system damage is increasing (Ruiz-Mendoza & Sheimbaum-Pardo, 2010). This is one of the reasons why starting to use renewable energy represents an urgent and important issue. Renewable energy sources (RES) can be defined as "sustainable resources available over the long term at a reasonable cost that can be used without negative effects" (Dincer, 1999: 845). RES include biomass, hydropower, geothermal, solar, wind and marine energies (Fridleifsson, 2001). Figure 1 shows the renewable energy consumption worldwide since 1990. Overall, the consumption of renewable energy has increased since 1990 by around 1%. The highest percentage of renewable energy consumption can be seen in 1999. From 1999, there was a decrease to about 16.91% of renewable energy utilization. This was the lowest rate of the period considered. From this point, except for 2010 and 2011, the graph illustrates an increasing trend as the average growth is 1%. These data result to be really important for showing the future projections of the RES sector.

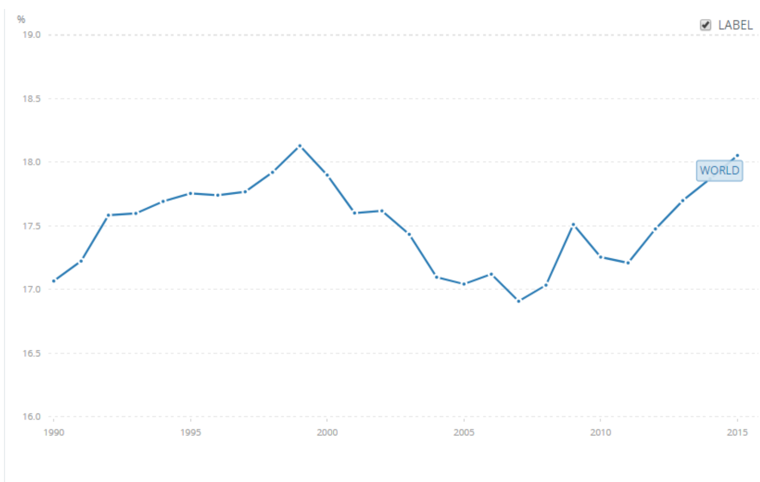

Figure 1: Renewable energy consumption (% of total final energy consumption). (Source: World Bank, 2019)

In 2017, the shares of the RES market in the world were characterized as follows (IEA, 2018): 50% of Bioenergy, 31% of hydropower, 9% of wind, 4% of solar PV (photovoltaic). The RES sector is expected to continue growing in the future, especially in solar and wind equipment production. According to International Energy Agency (IEA, 2018), which takes into account prevailing market and policy framework, renewable capacity is expected to increase by over 1 TW (Terawatt), which results in 46% growth over the period from 2018 to 2023. The weight of PV (Solar Photovoltaics) in this expansion exceeds more than 50%, thanks to the supportive government policies and market improvements across most regions. According to this forecast, wind represents the second biggest contributor to renewable capacity growth, followed by hydropower and bioenergy. The projection for the expansion of the wind capacity is about 60 %, with offshore wind accounting for 10% of that growth. Growth projections for hydropower and bioenergy are both moderately more positive than last year, mostly due to developments in China (IEA, 2018).

Solar energy refers to the conversion of sunlight into other forms of energy that humans can use to satisfy their needs such as electricity to light up our homes, streets, and businesses, and power our machines as well. The term solar power can be used to indicate the same concept. Solar PV will be the driving force in the renewable capacity growth in the next six years, with 575 GW of new capacity expected to become operational over that period (IEA, 2018). At the same time, technologies for the RES will also show a decrease in production costs thanks to the fast development and the degree of investment in new technologies worldwide (REN21, 2013). The trend of investments in new technologies was already increasing before 2013. Figure 2 illustrates how global new investments in renewable energy were made from 2004 to 2012.

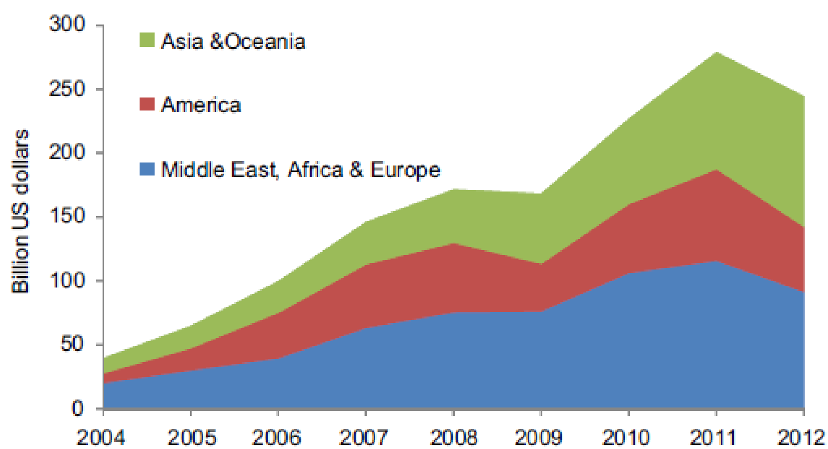

Figure 2: Global new investment in renewable energy by region, 2004–2012. (Source: Network R. Renewables 2013 - Global Status Report 2013).

Renewable energies are not a new topic for Mexico. In fact, since the Rio Conference of 1992, Mexico has been taking initiatives in policies to promote the utilization of this kind of energy (Alemán-Nava et al., 2014). Figure 3 shows all the initiatives which have been taken from Mexico right after the Rio Conference, from 1994 to 2012. The main instrument governing the renewable energy sector in Mexico is the Law for the Development of Renewable Energy and Energy Transition Financing (LAERFTE), enacted in 2008. Under this law, Mexico implemented the Estrategia Nacional de Energía 2013–2027, which establishes that 35 per cent of energy should derive from renewable sources by 2024 (i.e. wind, solar, mini hydro, biomass, geothermal and wave power, large hydroelectric plants and, more controversially, nuclear energy). Although many initiatives have been prepared (adopted), several reasons to boost the use of RES in Mexico can be indicated. The increasing dependence on fossil fuels represents a big problem. In 2007 the national reserves of hydrocarbon were regarded to be sufficient to support the yearly oil and gas production only for 9.6 and 8.9 years respectively (Alemán-Nava et al., 2014). On the other side, RES are likely to become an essential part of a sustainable energy system, contributing both to a country's energy diversification strategy and the appropriation of emerging energy technologies (Ruiz-Mendoza & Sheimbaum-Pardo, 2010).

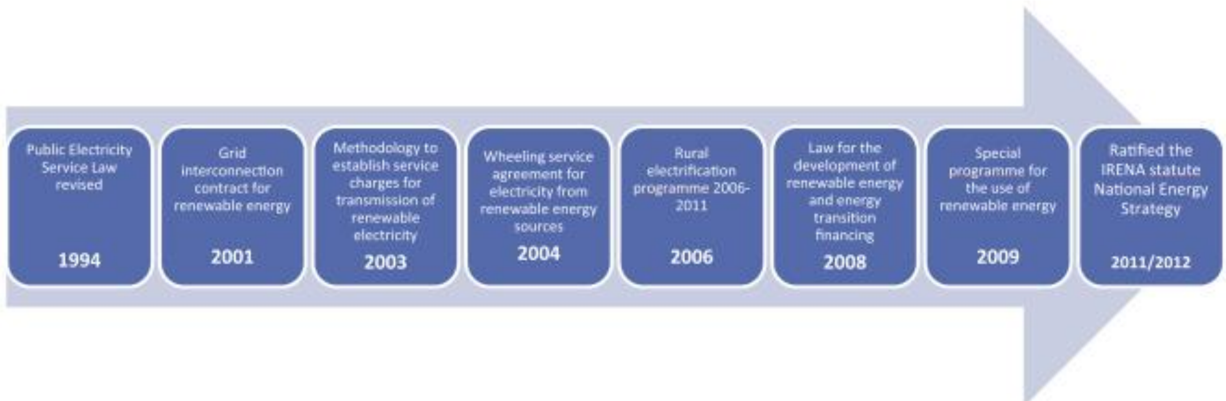

Figure 3: Policies timeline about power generation from RES progress (source: RENA. Renewable energy country profile: Mexico. 2012).

The geographical distribution of solar radiation is graded into 4 categories or sun belts according to their intensity worldwide (Romero et al., 2012). The most favourable belt lies between latitudes 15°N and 35°N, and between 15°S and 35°S. Mexico is completely within latitudes 15°N to 35°N, with an estimation of solar radiation levels of 5.35 kW h/m2. Exactly for this reason, there is a huge potential to generate power through solar energy, as shown below (Figure 4). Studies have been conducted to test the feasibility of the use of renewables and it is possible to generate power through them (Resch et al., 2008). These studies have demonstrated that in Mexico there is a potential to generate 16,351 GW h/year through solar energy and only taking in consideration the states of Chihuahua and Sonora. These two states account for 45% of the generation, as shown in Figure 4.

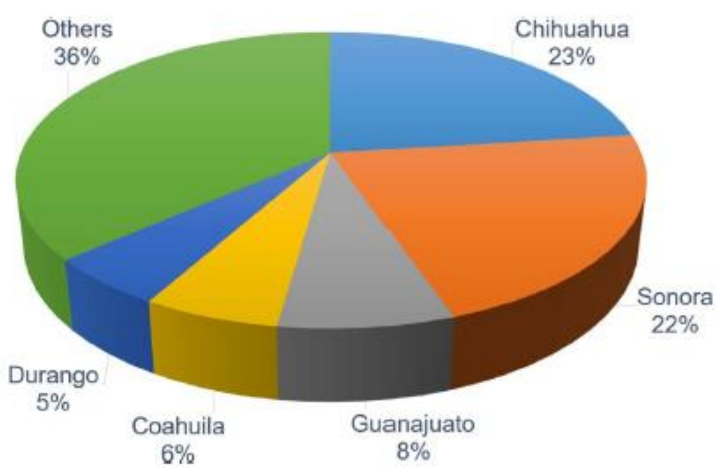

Figure 4: Proven potential for power generation using solar energy in Mexico.

The main problem in Mexico is represented by the fact that despite the enormous potential to generate power using solar energy, this kind of energy is not widely used. As stated above, in 2017 solar energy accounted for only 4% of the total renewable energy market in Mexico (IEA, 2018). Nowadays, it is indispensable to find the most appropriate alternatives to promote public policies and obtaining an absolute advantage.

In this paper, it is going to be analyzed the current situation, the prospects and the investment opportunities for solar energy. The analysis will be especially focused on actual data provided by Secretaría de Energía (SENER, 2017) and future projections of solar energy in order to understand, analyze and release the large potential in Mexico.

Can the economics aspect match the ethics side of people?

The way we live, the places we visit, the air we breathe and everything we do are affected by the behaviours of all human beings. What does it mean? That the way in which people act is fundamental for the current situation and the future developments of our society and the most important thing that all people share every day is the environment. Nowadays, our planet is suffering a lot for environmental pollution so, switching to a society based on a sustainable culture should be the priority. In a sense, it is the ethical side of each one which considers important to contribute to this important cause. But, the “simplest” way to switch to a “clean society” is investing in renewable energy and the investment required for this kind of transition is often huge; for families, this could mean spending a huge amount of their income to make this kind of investment.

Thus, the question is the following: when people have to spend a significant amount of money, for example for renewable energy equipment, are still considering “appealing” or a priority this kind of investment? Can the economics aspect match the ethics side of people and could we accept that the advantages are often limited to people who can afford some expenses?

To better answer to this question, a good idea could be starting from an example. In the United Kingdom, the transition to the use of renewable technologies has been well supported by economics. Several users of clean energy have taken a decision by mixing two aspects at the same time: the desire to obtain energy independence and the willingness to make a decision based on the respect of the environment which is, in other words, an ethically driven environmental decision. However, for other users, the transition to the new clean energies has been driven only by economic reasons such as lucrative government incentives aimed to allow users to make an important financial return on the installation of clean systems.

Why acting in a ethical way whilst making a return on investment should be not considered a good thing? The creation of investment aimed to the use and development of renewable energy system could actually be seen as a positive thing.

But what happens when the economic incentive disappears? In this case, the question shifts to consumer’s personal opinion on sustainability and on renewable energy. It is exactly from this point that this issue can become a problem. Before we were talking about the important investment that a person should face for the transition from fossil fuels to renewables which is still prohibitive for many people, even with the advantages coming from the competitive financing payback periods which are starting to get close to the lifespan of the equipment. In effect, this is not a simple and easy choice financially even for family or firms who have both the means and the desire to change.

We are confident that people already strongly believe and have an ethics and long term view that fossil fuels are finite and that we need to develop systems for the future. Unfortunately, this is not the best way for large scale adoption of renewable technologies so we must look for a balance between the long term need for energy security and the simple economics of affordability. The two should have a mix of finance and fundamentals, so which is the best way to reach the optimal mix?

It is important that, at the beginning, the first issue to be studied is the economic one. Later, we can focus on the ethical issue. As in any market, also in this case consumers need to be persuaded of the cost benefits or efficient solutions ready to decrease disruption to their lifestyle. For this reason, the first thing to be done is the improvement of investment strategy focusing on the development of products which are cost effective and deliver the best return for the money both in financial and usage terms. A good example can be the car industry. In many ways the real estate industry should be inspired from the car industry, hybrid and efficient engines are now perceived as normal within the market place, therefore customers are adopting a more environmentally friendly position by simply purchasing a car.

The private sector must consider the development of CSR (Corporate Social Responsibility) and ethical practices as the main pillar of its future strategies. “Corporate social responsibility (CSR) is a company's commitment to manage the social, environmental and economic effects of its operations responsibly and in line with public expectations. CRS activities may include: Company policies that insist on working with partners who follow ethical business practices”.

Government and public sector must take a both an economic and ethical view as well. It is important they follow ethical lines of action because they create the macro environment through policy and financial incentives. They should make legislation which encourages consideration of the ethical basis for renewables whilst providing financial support for those who adopt these solutions.

There is a way to apply legislation and, at the same time, maintaining the market forces? Taking into consideration the example of the United Kingdom, the standards have been set via planning and building regulation. Developers and designers work by following these frameworks and are used to the changing demands of policy and develop the financial case accordingly.

In order to support more stringent targets economic support to offset costs should be available with the main objective decreasing the initial cost to the consumer, in a way that sustainable options could be attractive both in terms of economics and ethics. In order to reach this, the solutions do not have to be related just with hard cash subsidy but, for example, with the reduction of contributions which real estate developers and investors are asked to pay for public infrastructure, with government contributing to the gap. A public-private partnership in the real sense rather than a financing mechanism. Also the technology should be consider a pillar in the ethical issues. Indeed, technology is transferrable on an international level and by creating an economy of scale, we can also support developing nations to adopt renewables.

The most important consideration is that the ethical argument needs to move on and become part of the consumers' minds which consider the long term energy viability of their property as they do with their cars, and understand that they support long term development of an industry which will guarantee the security of energy for future generations long after we, the pioneers, are gone.

Materials and Methods

To study the prospects of energy production by solar energy in the next years, it is necessary to make forecasts. The methodology which is going to be used to base these forecasts is the time series analysis. The statistical forecasts are a method widely used in the analysis of time series to predict a response variable for a specific period (Minitab, 2019). Time series analysis is a statistical technique that consider time-series data. With time series data we refer to the fact that data is in series of particular time periods or intervals (Statistic Solutions, 2019).

The analysis uses data from Secretaría de Energía (SENER, 2017), which conducts the energy policy in Mexico to guarantee the high quality and the competitive supply of energy sources required in the country. The data which are going to be analysed describe the production of primary energy. With primary energy source, we refer to all the form of energy naturally available before being converted or transformed. This kind of energy later requires to be transformed into a secondary power source to be used. One of the best-known forms of consumption of energy is electricity (APPA, 2019). The primary energy sources considered in the research are coal, crude oil, gas condensate, natural gas and wood, nuclear energy, the sun, the wind, the geothermal energy, the hydroelectric energy, the biogas and the biomass.

There are two main goals of time series analysis: 1) identifying the nature of the phenomenon represented by the sequence of observations, and 2) forecasting (predicting future values of the time series variable) (Statsoft, 2019). We are going to use this method to achieve the second goal. Both of these goals require that the pattern of observed time series data is identified (Statsoft, 2019). To be more specific, for this time series forecasting, Autoregressive model ARp is the model which will be used, and this kind of model is frequently used in economic projections. Why is it called Autoregressive model? The following sentence gives us an idea. “An autoregressive model relates a time series variable to its past values” (Hanck et al., 2019). This is why this model is called autoregressive. In this paper we assume that the autoregressive model has no lags, so it is considered type 1. The number 1 represents the lag in the time. To obtain a more accurate result from this methodology, monthly statistical series will be necessary, both for energy obtained by carbon and for energy obtained by solar energy. The focus is on monthly data so that the time series can be more efficient in the forecast.

The variables which are taken into consideration are the growth rate of the energy produced by carbon and the growth rate of energy produced by solar energy. Since in an autoregressive model the variable of interest depends linearly on its previous values, time is assumed to be fundamental. From these data, an analysis of a time series can be done and to make a forecast will be possible. Seasonality, trends and cycle are going to be measured. By seasonality, we mean periodic fluctuations. For example, retail sales are about to increase for the Christmas period and then falling after the holidays. So, time series of retail sales will normally show growing sales from September through December and declining sales in January and February. Seasonality is common in economic time series. If seasonality is present, it must be incorporated into the time series model (Allen, 2019).

Table 1. Variables and Data

Variables	*Data*
Y_α= Coal energy	Mwts/hour(months) Jan 2013-Dec 2017 (INEGI, 2019)
Y_γ= Solar energy	Mwts/hour(months) Jan 2013-Dec 2017 (INEGI, 2019)
X_α= Time with respect Y_α	Jan 2013-Dec 2017
X_γ= Time with respect Y_γ	Jan 2013-Dec 2017

Source: Own Elaboration

Our time series model is composed by trend, cycle, seasonality, and irregular variations, as showed in the equation (1).

$$Y_t = (Tt * Ct * St) + \varepsilon$$

where Tt is the trend, Ct is the cycle, St is the seasonality and Tt is composed as showed in the equation (2):

$$Tt = \beta_0 + \beta_1 X_1 + \varepsilon$$

where β_0 is the intercept of the equation, β_1 is the coefficient of the variable with respect to time X_1 is the time with respect to own variable and ε is the error.

In this analysis, we assume the absence of irregular variations (elements not depending on the three variables) and we are going to build two autoregressive models. The first one is the autoregressive model AR1 α, which is going to be adjusted with a second one AR1 β. The second model is obtained from the monthly series related to carbon source. The model will suggest to us that the production of energy from solar energy is going to increase and it is going to predict up to when this growth is going to stop. The adjustment of the model AR1 α with AR1 β is useful to observe the marginal changes. “A marginal change is a proportionally very small addition or subtraction to the total quantity of some variable” (Johnson, 2019). The main result we want to find out is the marginal change with respect to the time t.

Results

In order to describe the main findings and goals achieved in this research, it is important to describe all the steps we followed. The analysis of the current situation was the first and most important step. The data taken into consideration were from "Sistema de Información Energética" and they represented the "gross energy production by technology". The focus was on the energy produced by the two relevant sources for our investigation, carbon and solar energy, and we considered 60 periods (monthly data for the period which goes from January 2013 to December 2017).

In Figure 5, the blue line represents the growth rate of the production of primary energy from solar energy and the red line represents the growth rate of the production of primary energy from carbon (SENER, 2017). The growth rate of production of solar energy increased more than the growth rate of production from carbon even though in 2005 there was a significant fall of the growth rate of production of energy from solar energy.

Figure 5: Growth Rate. National Primary Energy, 1991-2017. Sistema de Información Energética. Secretaría de Energía - Dirección General de Planeación e Información Energéticas

Both for the carbon and the solar energy, data have been ordered by months and the arithmetic mean has been obtained for each year (from 2013 to 2017). The calculation of the arithmetic mean has been necessary to obtain the seasonal index, useful to obtain the seasonally adjusted series. The seasonal adjustment was necessary to remove the seasonal component of our time series and the goal was to obtain data comparable among the different months. All the steps described so far were necessary to obtain data to build the autoregressive model which considers two relevant moments for our research: the current situation and the future predictions. By starting with the analysis of the output that we obtained for the energy produced by carbon, we can find out that the production of energy has a positive slope, as represented in the equation (3).

$$T_\alpha = 1{,}193{,}512.21 + 31{,}132.55X_1 + \varepsilon$$

$$p = 0.00; \quad R^2 = 0.58$$

where p=0.00 represents the statistical significance of the model. It means that the reliability of this model is 99%. In other words, this model is robust, predictable and it has a high level of reliability. R^2 is the coefficient of determination which is used in statistical analysis to assess how well a model explains and predicts future outcomes. This means that the energy produced by carbon source increases over time (positive sign) and it grows by 31,132.55 Megawatts/hour each month. The fitting level of the model (R^2) is 58%. The equation (4) represents the time series regarding the production of energy from carbon source.

$$Y_\alpha = (1{,}193{,}512.21 + 31{,}132.55X_1) * Ct * St$$

The analysis of the production of energy by solar source gives us important insights as well, as represented by the equations (5) and (6):

$$T_\beta = 1{,}129.92 - 3.28\, X_1 + \varepsilon \qquad (5)$$

$$p = 0.00; \quad R^2 = 0.37$$

$$Y_\beta = (1129{,}92 - 3{,}28) * Ct * St \qquad (6)$$

The production of energy by solar energy has a negative slope with a decrease of 3.28 Megawatts/hour each month. The fitting level of the model is 37% which is quite low if we compare it with the ideal value > 0.5 (50%). Our low value is due to the fact that this time series had many variations, so it does not fit the model as in the first case (carbon source). To better explain, a high R^(2)means that the data are very adjusted to the line which went out from our data. R^2 is low because we have small size of the time series the more historical data we have, the higher is R^2. If the data do not adjust to the line, as in the second case (37% of the data fitting the model), we need a Hypothesis Test. This is a mean to verify if the data are statistically significantly similar or different than a specific value. It indicates how the model works in general terms. To validate a model, we need to take into consideration the Hypothesis Test F described in the equation (7). Normally, a value F > 10 is an acceptable value.

$$F = \frac{\mathrm{N1} * \mathrm{S1}^2 / (\mathrm{N1} - 1) * \sigma 1^2}{\mathrm{N2} * \mathrm{S2}^2 / (\mathrm{N2} - 1) * \sigma 2^2}$$

where N1: N of sample data 1, S1^2: sampling variance of group 1, σ1^2: variance of group 1, N2: N of sample data 2, S2^2: sampling variance of group 2, σ2^2: variance of group 2.

From the Hypothesis Test F, we obtain the results showed in Table 2.

Table 2: Hypothesis Test F results

Model	Result (F_{value})
Y_α	81.46
Y_β	34.84

Regarding the forecasts, Figure 6 and Figure 7 represent the future values regarding the production of energy from both the solar energy and the carbon. These results come from the two equations (4) and (6) seen before.

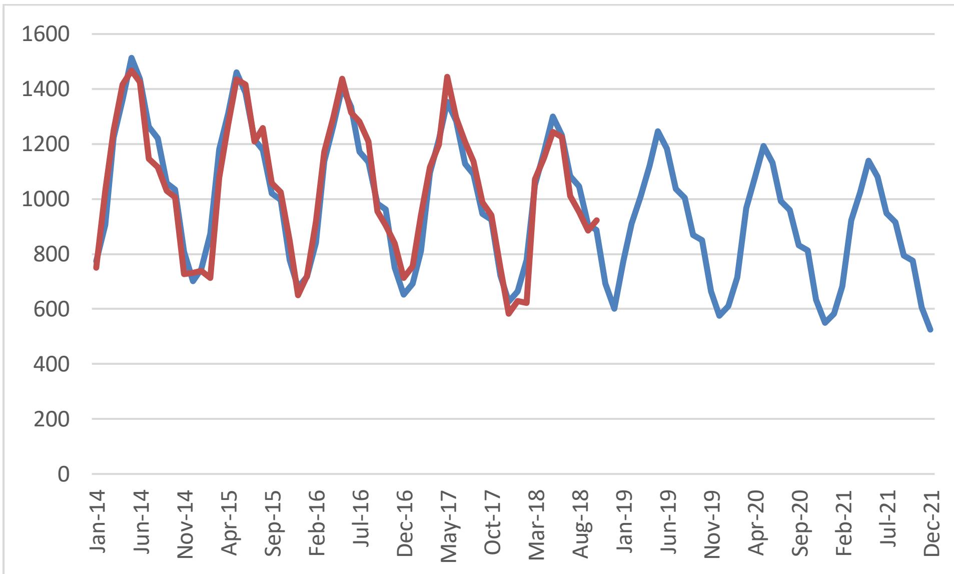

Figure 6: Energy production from solar energy. Real data and projections.

In Figure 6, referring to the energy production from solar energy, both the actual and the future trends can be seen. The red line represents the original data from “Sistema de Información Energética” and the blue line represents our time series which refers to the production of energy from solar energy for 94 periods. These 94 periods represent the 94 months included in the period starting from January 2014 to December 2020, on a monthly basis. On the Y axis, the values are expressed in Megawatt/hour and they represent the energy production.

Therefore, Ceteris Paribus, based on our projections, in the long term the production of energy from solar energy is going to show a decreasing trend with peaks and drops increasing and decreasing. These results may be worrying considering that we are talking about a renewable source of energy which is slowing its growth. With the information we have nowadays, it seems impossible to establish which are the causes of the forecast decrease. It may depend from the lack of governmental policies aimed to invest in solar energy or from the increasing cost of the production of the energy from solar energy. But these are just assumptions. The two lines result to be very close due to the fitting level of our time series model of around 93%. Figure 7 shows the production of energy from carbon source, taking into consideration 94 periods (94 months), from January 2013 to December 2020.

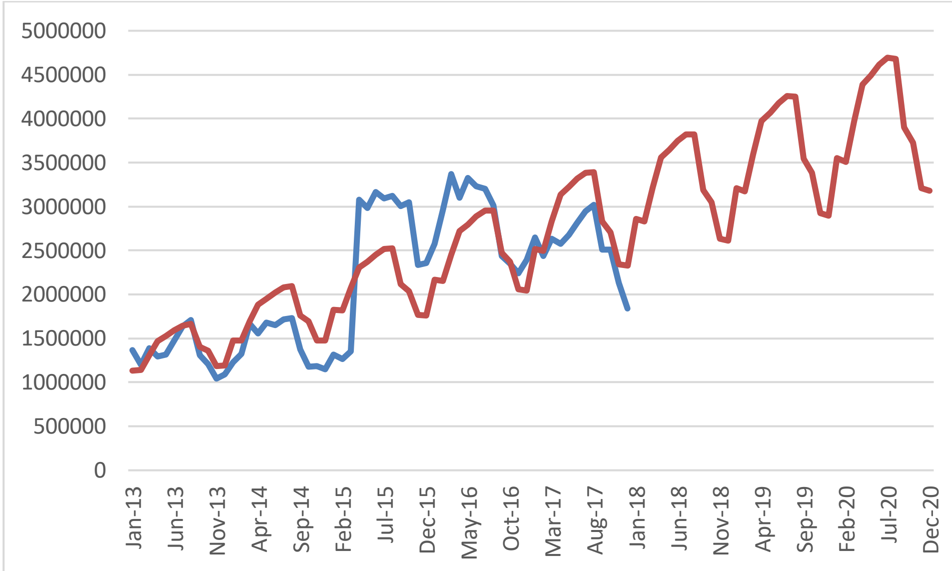

Figure 7. Energy production from Carbon source. Real data and projections.

The blue line represents the production of energy until December 2017 and the red line represents our time series model which include forecasts until December 2020. Ceteris Paribus, the production of energy from carbon source in the long term is going to increase with peaks and drops over the period considered. The two lines are not that close as in Figure 6 because of a lower fitting level of our time series model which is around 66%. The growth of the energy production from carbon source in the next years may leave rooms for questioning because carbon is not a renewable energy source. Investing in this kind of energy could be counterproductive for the country and the planet in general.

The forecast model and the validation of this model has been made through a regression of the real value with the projected/forecast value, by taking into consideration the R^2 values. These values suggest us how much our data is adjusted to the reality.

Given:

$$Y1 = B0 + B1(x1)$$

where Y1:Forecast and x1:Real.

Fitting levels of 0.93 and 0.66 mean that the two models are respectively validated for 93% and 66%. In other words, the two models are highly predictive, especially in the first case and, for this reason, we can figure out that our models are quite reliable.

Discussion

The first big issue to be discussed is the different trend of the production of energy by renewable energy between Mexico and the world average, based on the initial data we have. In fact, the consumption of renewable energy (which includes solar energy) has increased since 1990 by around 1% until today on a world scale (World Bank, 2019). The same thing cannot be said for Mexico: we find out that, on the contrary, the production of energy by solar energy has a negative slope with a decrease of 3.28 Megawatts/hour each month. Moreover, based on our projections, the production of energy from solar energy is going to show a decreasing trend in the next years and these results may be worrying considering that we are talking about a renewable source of energy which is slowing its growth faced with an increasingly exhausted development model (Jiménez-Bandala, 2020).

Based on the initial data we have, the RES sector worldwide is expected to continue growing in the future, with a particular development of solar and wind energy sector. More precisely, renewable capacity is expected to increase and the growth will be about 46% over the period from 2018 to 2023. The weight of PV (Solar Photovoltaics) in this increase exceeds more than 50%, thanks to the supportive government policies and market improvements across most region. Solar PV will be the driving force in the renewable capacity growth in the next six years. It is important to consider that these results are the world average and some countries still present decreasing trends, as the case of Mexico.

The results stated above, calculated on a global scale, are in contrast with the results obtained in this research which is only related to Mexico. In Mexico, the use of carbon source for the production of energy is going to increase in the next years and this is questionable because carbon is not a renewable energy source and could affect the health of the planet and the country in general. The dependence on non-renewable energy is a historical problem in Mexico, that is, it is due to structural situations of its condition as a peripheral country (Jiménez-Bandala, 2018). The increasing dependence on fossil fuels is a big problem because already in 2007 the national reserves of hydrocarbon resulted sufficient to support the yearly oil and gas production only for 9.6 and 8.9 years respectively (Alemán-Nava et al., 2014).

Further, our results state the decreasing trend of the Renewable Energy in the next years in Mexico find support in the last study of the International Energy Agency (IEA) “Renewable 2019: analysis and projections to 2024”. In this study, IEA reduced the rate of expansion of renewable energies in Mexico by about four por cent by 2024 due to the suspension of long-term auctions that during the past six years allowed the growth of solar and wind power plants. The new government suspended auctions of clean energy certificates (CEL) in 2019 to review them. Consequently, solar and wind capacity will expand more slowly in 2021 and 2022, based on last IEA study. The administration of Andrés Manuel López Obrador decided to suspend the auctions for the need to review the mechanisms that during the past six years had allowed to commit about $ 8.6 billion of the three long-term auctions, mostly solar and wind. The Agency expects tenders to be retaken in 2021, so that growth rebounds between 2023 and 2024. But the progress of renewables energies could accelerate if the government makes clear its policies the following year, and could expand up to 21% each year, based on IEA. The auctions of the previous administration will allow until 2021 to continue the installation of new capacity of solar and wind energy in Mexico, but, because of this brake, the expectations of the IEA are about an annual growth of 12.3% between 2019 and 2024 compared to the 16% expected in last year's report covering 2018 to 2023 (Sigler, 2019).

The suspension of long-term auctions had a strong impact on the trend of the use of Renewable Energy in Mexico which is decreasing despite the Law for the Development of Renewable Energy and Energy Transition Financing (LAERFTE), enacted in 2008. By following this Law, Mexico should be able to define and regulate the use of Renewable Energy to produce power and enact some instruments such as a Special Programme, an Energy Transition Strategy and an Energy Transition Fund, among others. In the 2011 reform we also find information regarding the maximum targets of fossil generation in the total power mix by the year 2024, 2035 and 2050. The Energy targets are the following: 65% of fossil generation by 2024; 60% by 2035 and 50% by 2050. Finally, this law says that the Energy Secretariat must develop a National Renewable Energy Inventory to provide reliable information on renewable energy resources in Mexico (IEA, 2008).

Which solutions have been already implemented to boost the use of renewable energy in the long term? The current situation is characterized by the presence of “Fondo de Garantía CSolar”. This is a fund whose objective is to ensure that the objectives of “Programa Especial para Transición Energética (PETE)” are pursued. One of the objectives is: to increase the installed capacity and the electricity generation with clean energy. With this scheme, one of the most important lines of PETE is served: facilitating access to distributed solar generation through financing guarantee schemes. In fact, the Fund provides a temporary financial support mechanism with the aim to overcome the principal financing barriers facing the photovoltaic distributed solar generation sector. This support mainly consists of a partial Credit Guarantee, located in Nacional Financiera and linked to the credit portfolio of interconnected photovoltaic solar systems, of local financial institutions.

The “Certi‡cados de Energía Limpia (CEL)“ is an instrument to promote new investment projects in the generation of electricity which encourage the development of the National Electricity System and the diversification of the Energy mix by boosting pollutant-emission reduction. Starting from 2018, the intensive users of electricity have to show that 5% of its consumption of eletricity comes from clean sources. Thus, we can understand the CEL as financial instruments through which the use of clean energy is promoted, the energy matrix is diversified and the competition of clean energy and conventional energy is. This validation is controlled by the Energy Regulatory Commission (CRE) which, in case of non-compliance, can impose fines that go from 6 to 50 minimum wages for each CEL not acquired. Therefore, the supply and demand of CELs is not only an agreement, but an indispensable requirement for the operation of the MEM (Mercado Eléctrico Mayorista). The CEL payment obligation is for everyone (domestic use, industries, shops, governments, etc.) and is indistinct to the origin of the supply, that is, those who consume renewable and/or conventional energy are equally obligated. The obligation for this year was established at 5% of the total energy consumed during the year. This obligation is increased every year: by 2019 the percentage will increase to 5.8% and will continue to rise year by year. By 2021, at 10.9%; and in 2022 the minimum required will be 13.9% (ENEL, 2019).

Another policy already implemented is based on the use of the FOTEASE (Fund for Energy Transition and Sustainable Energy Use). FOTEASE is a public policy instrument of the Ministry of Energy whose objective is to execute actions that give a contribution to the fulfillment of the National Strategy for Energy Transition and Sustainable Use of Energy, promoting the use and investment of renewable energy and energy efficiency. Thanks to FOTEASE, it is possible to promote, encourage and disseminate the use and application of clean technologies in all productive activities and domestic, commercial, industrial and agricultural use; promote the diversification of primary energy sources, increasing the supply of renewable energy sources.

The Funds that the Federal Public Administration allocates for the Energy Transition and Sustainable Use of Energy will have the purpose of capturing and channeling public and private financial resources, national or international, to implement actions that contribute to the fulfillment of the Strategy and Support programs and projects that diversify and enrich the options for compliance with the Clean Energy and Energy Efficiency Goals (SEMARNAT, 2015).

From our point of view, one of the things that could be done is to raise awareness on the importance of the use of Renewable Energy and on the fact that some important tools and policies can be used from citizens to invest in renewable energy technologies such as solar panels for domestic use (Islas & Ubaldo, 2001). For example, the instruments stated above such as CEL and FOTEASE are a good example to how it is possible to promote the use of clean energy and how to invest in it. In the same way, also private firms should be encouraged to invest on this kind technologies. Moreover, research grants may have a good impact on technology breakthroughs and tax incentives could be a fundamental tool on a local basis for example by boosting the development of project development, construction or installation skills.

Conclusion

Mexico has the big advantage to be located in a geographical location which can benefit from the production of power using sunlight. However, the problem in Mexico is represented by the fact that the huge potential to generate power using sunlight is not exploited fully. Not using the renewable energies (such as solar energy) represents a problem for several serious problems linked with humans and planet health, which are rapidly increasing. For this reason, it is necessary starting to use the renewable energies in bigger scale.

This research analysed the consumption of renewable energy (including solar energy) for Mexico and on a world scale. Worldwide, the overall consumption of the renewable energy has increased and the future projections indicate an increasing trend. In fact, according to International Energy Agency (IEA, 2018), renewable capacity is expected to increase by over 1 TW (Terawatt), which results in 46% growth over the period from 2018 to 2023. And, the most relevant aspect for this research is that the weight of PV (Solar Photovoltaics) in this expansion represents more than 50%, thanks to the supportive government policies and market improvements across different regions.

On the contrary, even though Mexico implemented the National Energy Strategy 2013–2027 (Secretaría de Energía, 2015) which should lead to bigger use of renewable sources by 2024, our results show an increasing dependence on fossil fuels in the future. This dependence on fossil fuels comes at the expense of the solar energy source which show a decreasing trend in the next years. These findings are worrying if we consider 2 factors: the fact that Mexico could have a big advantage due to its geographical location and the fact that the worldwide trend is going in the opposite (and right) direction. Furthermore, the results obtained are a clear signal that something has to be done in order to promote the investments on solar energy.

So, what are the challenges and what has to be done to completely change the trend of the use of the two sources considered, in the next years? An important action to do is go on breaking down the barriers to solar deployment. For example, creating new consistent policies based on the ones already existing, reducing restrictive and time-consuming regulatory and permitting processes, continue to invest in policies to reduce the higher cost of solar technologies, especially in relation to fossil fuel subsidies, etc.

References

Alemán-Nava, G. S., Casiano-Flores, V.H., Cárdenas-Chávez, D. L., Díaz-Chavez, R., Scarlat, N., Mahlknecht, J., Dallemand, J. F. and Parra, R. (2014) Renewable energy research progress in Mexico: A review. Renewable and Sustainable Energy Reviews 32: 140 - 153. https://doi.org/10.1016/j.rser.2014.01.004

Allen, T.A. (2019), Information Technology Laboratory, NIST, [online], available at: https://www.itl.nist.gov/div898/handbook/pmc/section4/pmc443.html [3 Oct 2019].

APPA. (n.d.). "Energía primaria y producción eléctrica", APPA, [online], available at: https://www.appa.es/la-energia-en-espana/energia-primaria-y-produccion-electrica/ [3 Oct 2019].

Charters, W.W.S. (2001) Developing markets for renewable energy technologies. Renewable Energy; 22 (1-3): 217–222. https://doi.org/10.1016/S0960-1481(00)00018-5

Dincer I. (1999) Environmental impacts of energy. Energy Policy; 27(14): (845–854). https://doi.org/10.1016/S0301-4215(99)00068-3

ENEL, (2019) "Todo lo que tienes que saber sobre Certificados de Energía Limpia (CEL)", [online], available at: https://www.enel.mx/es/media-center/news/Todo_lo_que_tienes_que_saber_sobre_Certificados_de_Energia_Limpia_CEL [25 November].

Fridleifsson IB. (2011) Geothermal energy for the benefit of the people. Renewable and Sustainable Energy Reviews 5: 299–312. https://pangea.stanford.edu/ERE/pdf/IGAstandard/ISS/2001Romania/fridleifsson_benefit.pdf

Hanck, C., Arnold, M., Gerber, A. and Schmelzer, M. (2019), "Introduction to Econometrics with R", 14.3 Autoregressions, [online], available at: https://www.econometrics-with-r.org/14-3-autoregressions.html [3 Oct 2019].

IEA (2008). "Law for the Development of Renewable Energy and Energy Transition Financing (LAFAERTE)", [online], available at: https://www.iea.org/policiesandmeasures/pams/mexico/name-24706-en.php [25 November 2019].

Islas, J.; Manzini, F. & Masera, O. (2007) A prospective study of bioenergy use un Mexico, Energy, 32(12): 2306-2320, https://doi.org/10.1016/j.energy.2007.07.012.

Islas, J. & Ubaldo, J. (2001) The financing of the Mexican electrical sector, Energy Policy, 29(12): 965-973, https://doi.org/10.1016/S0301-4215(01)00030-1.

Jiménez-Bandala, C. (2018) Development in Southern Mexico: Empirical Verification of the “Seven Erroneous Theses about Latin America”, Latin American Perspectives, 45(2): 129-141, https://doi.org/10.1177/0094582X17736036.

Jiménez-Bandala, C. (2020) Desigualdad y pobreza: El agotamiento del desarrollismo y el derecho a la prosperidad sustentable, en Apaez, O. y Bernal, R. (coord.) Dimensiones de la Desigualdad en México, México: Contraste-UAT-La Salle.

Johnson, P.M. (n.d.). A Glossary of Political Economy Terms, Marginal Analysis: A Glossary of Political Economy Terms - Dr. Paul M. Johnson, [online], available at: http://webhome.auburn.edu/~johnspm/gloss/marginal_analysis.phtml [3 Oct 2019].

Kalogirou, S. (2004) Solar thermal collectors and applications. Progress Energy Combust Sci, 30:231–95. https://doi.org/10.1016/j.pecs.2004.02.001

Matsumoto, Y.; Urbano, A.; Martínez, A. & Asomoza, R. (1994) Renewable energy application progress in Mexico, Renewable Energy, 5(1-4): 330-332, https://doi.org/10.1016/0960-1481(94)90391-3

Minitab. (n.d.). Pronósticos con análisis de series de tiempo, Minitab, [online], available at: https://support.minitab.com/es-mx/minitab/18/help-and-how-to/modeling-statistics/time-series/supporting-topics/basics/forecasting/ [3 Oct 2019].

REN21 (2013) Renewables 2013 - Global Status Report 2013, [online], available: https://www.ren21.net/wp-content/uploads/2019/05/GSR2013_Full-Report_English.pdf [18 Sep 2019].

REN21 (2018) Renewables 2018 - Global Status Report 2018, [online], available: https://www.ren21.net/wp-content/uploads/2019/08/Full-Report-2018.pdf [18 Sep 2019]

Resch, G., Held, A., Faber, T., Panzer, C., Toro, F. and Haas, R. (2008) Potentials and prospects for renewable energies at global scale. Energy Policy 36 (11): 4048–4056. https://doi.org/10.1016/j.enpol.2008.06.029

Romero-Hernandez, S., Rodriguez-Granada, B., Romero-Hernandez, O. and Wood, D. (2012) Solar Energy Potential in Mexico’s Northern Border States July 2012, [online], available: https://www.wilsoncenter.org/sites/default/files/Border_Solar_Romero.pdf [19 Sep 2019].

Rosas-Flores, J.; Rosas-Flores, D. & Fernández Zayas, J. (2016) Potential energy saving in urban and rural households of Mexico by use of solar water heaters, using geographical information system, Renewable and Sustainable Energy Reviews, 53: 243-252. https://doi.org/10.1016/j.rser.2015.07.202

Ruiz-Mendoza, B. J. & Sheimbaum-Pardo, C. (2010) Electricity sector reforms in four Latin-American countries and their impact on carbon dioxide emissions and renewable energy, Energy Policy, 38(11): 6755-6766, https://doi.org/10.1016/j.enpol.2010.06.046

Santoyo-Castelazo, E.; Satmford, L. & Azapagic, A. (2014) Environmental implications of decarbonising lectricity supplu in large economies. The case of Mexico, Energy Conversion and Management, 85: 272-291. https://doi.org/10.1016/j.enconman.2014.05.051

Secretaría de Energía (2015), Estrategia Nacional de Energía, [online], available at: https://www.gob.mx/sener/documentos/estrategia-nacional-de-energia [25 November 2019]

Secretaría de Energía (2016). "Presentación del Fondo CSolar", [online], available at: https://www.gob.mx/sener/articulos/presentacion-del-fondo-csolar?idiom=es [25 November 2019]

Sígler, E. (2019), "La Agencia de Energía dice que las renovables se están frenando en México", [online], available at: https://expansion.mx/empresas/2019/10/23/eu-ve-incertidumbre-las-renovables-mexico-fin-licitaciones [25 November 2019].

SEMARNAT (2015), Guìa de Programas de Fomento a la generacion de energìa con Recursos Renvoables, [online], available at: https://www.gob.mx/cms/uploads/attachment/file/47854/Guia_de_programas_de_fomento.pdf[25 November 2019].

Statistic Solutions. (n.d.). Time Series Analysis, Statistics Solutions, [online], available at: https://www.statisticssolutions.com/time-series-analysis/ [3 Oct 2019].

Statsoft. (n.d.). How To Identify Patterns in Time Series Data: Time Series Analysis, Statsoft, [online], available at: http://www.statsoft.com/textbook/time-series-analysis [3 Oct 2019].