A Study of the Correlation of Renewable Energy Consumption in Egypt with Specific Economic and Environmental Indicators

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Abstract

The research problem is to measure the extent to which renewable energy (hydroelectric, solar, wind) consumption in Egypt is correlated with a set of economic indicators that include: GDP, average annual per capita income, unemployment rate, and inflation rate. In addition to these indicators, the correlation between consumption of renewable energy and carbon (CO2) emissions will be studied because of its impact on all economic activities.

The study period is between 2000 to 2019. The two years 2020 and 2021 are excluded because of the effect of COVID19 on the economy. Pearson's correlation coefficient is used to quantize the relation between two sets of data. The first set is the consumption values of renewable energy in Egypt. The second set is the values of the economic indicators mentioned before as well as CO2 emission. Given the different nature of the two sets of data in terms of the units used in the measurement, the standard values of the data will be used so that the correlation between them can be studied.

The study shows a moderate direct correlation between the consumption of renewable energy on the one hand and the GDP and the average annual per capita income on the other. There is a weak inverse correlation between the consumption of renewable energy and the unemployment rate, and there is a weak direct correlation between the consumption of renewable energy and the inflation rate for the period. Finally, there is a weak inverse correlation between the consumption of renewable energy and the amount of CO2emissions.

***Keywords**: Pearson's Correlation Coefficient, Renewable Energy, Co2emissions, Economic Indicators.*

Introduction

Renewable energy is the cornerstone for achieving sustainable development in Egypt (Morsi, 2018), and the Integrated and Sustainable Energy Strategy in Egypt has indicated that renewable energy should contribute 42% of the country's total energy capacity by 2035 (The Paris Agreement, 2015). This calls for studying the correlation between renewable energy and the key economic indicators, as well as carbon CO2 emissions, in a quantitative way, not just descriptive (Gareeb, 2018).

Previous Studies

The first study, presented by Ghareeb (2022) (Ghareeb, 2022), is entitled "Forecasting the consumption of solar photovoltaic energy in China with the combined application of specific and random models". The study presented an entire chapter on the study of the correlation of the consumption of solar photovoltaic energy with a number of indicators of the Chinese economy through the use of Pearson's correlation coefficient.

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The second study was presented by Abergeo and Peñolteo (Abergeo and Peñolteo, 2014), and entitled "Renewable Energy and Economic Growth", concluded that the consumption of renewable energy mitigates the rise in energy prices and reduces environmental pollution. The study also found that there is a direct correlation between the consumption of renewable energy and GDP.

The third study is presented by the Egyptian Central Agency for Public Mobilization and Statistics in 2015 and entitled "Studying the future of solar energy in Egypt" (Egyptian Central Agency for Public Mobilization and Statistics, 2015). The study concluded that Egypt has strong radiation throughout the year, and therefore the state has developed a number of projects that seek to exploit solar energy and replace traditional energy with it.

In the report issued by the International Renewable Energy Agency entitled "Prospects for Renewable Energy in Egypt", it indicated that renewable energy should contribute 42% of the total energy produced by 2035 (IAEA, 2018).

Previous studies indicated in a descriptive and limited manner that there is a correlation between the quantities produced from renewable energy and macroeconomic indicators, with the exception of the first study that dealt quantitatively with this problem, but on the State of China, and with the goal that renewable energy in Egypt contribute 42% of the energy produced, which is how much Huge, it is necessary to make a quantitative determination of the relationship between the amount of renewable energy produced and a number of key indicators of the overall economy in Egypt, as well as their relationship to carbon dioxide emissions and then levels of environmental pollution. Which is what we will do in this study.

Research Problem

Measuring the correlation of renewable energy consumption in Egypt with a set of important economic indicators as well as carbon emissions.

Research Objectives

1- Knowing Egypt's consumption of renewable energy from 2000 to 2019.

2- Knowing the data of a number of important economic indicators in Egypt, as well as the amounts of carbon emissions.

3- Measuring the correlation of renewable energy consumption in Egypt with a set of economic indicators and carbon emissions.

The Importance of Research

The research helps clarify the impact of the expansion of the use of renewable energy on the economy and the environment in Egypt.

Temporal and Spatial Boundaries

The research includes archival data on Egypt's consumption of renewable energy from 2000 to 2019, as well as some economic indicators such as gross domestic product, average annual per capita income, unemployment rate, inflation rate, and others for the same period, and the correlation between consumption of Renewable energy and those important economic indicators in Egypt.

Research Methodology

The descriptive analytical approach was used (Badwy, 1977), where the consumption of renewable energy in Egypt was described in the period from 2000 to 2019, as well as the description of economic indicators data for the same period, and then the data was analyzed to measure their correlation.

Research Sample

The study sample consists of 20 observations of the actual consumption valuesof Egypt from renewable energy for the years 2000-2019.

Research Tools

Excel was used, the Pearson coefficient of correlation between two sets of data was used. The first group is the values of renewable energy consumption in Egypt, and the second group is the values of indicators of the Egyptian economy as well as carbon emissions.

Study Questions

a- What is the value of the Pearson coefficient of the relationship between renewable energy consumption and GDP?

b- What is the value of the Pearson coefficient of the relationship between renewable energy consumption and average annual per capita income?

c- What is the value of the Pearson coefficient of the correlation between the consumption of renewable energy and the unemployment rate?

d- What is the value of the Pearson coefficient of the correlation between renewable energy consumption and the rate of inflation?

e- What is the value of the Pearson coefficient of the correlation between the consumption of renewable energy and the amount of carbon emissions?

research Assumes

a- There is a direct correlation between the consumption of renewable energy and the GDP.

b- The relationship between renewable energy consumption and average annual per capita income is direct.

c- There is an inverse relationship between the consumption of renewable energy and the unemployment rate.

d- There is an inverse relationship between the consumption of renewable energy and the rate of inflation.

e- There is an inverse relationship between the consumption of renewable energy and the amount of carbon emissions.

Research Items:

Item 1: Introduction, item 2: previous studies, item 3: the theoretical framework for research, item 4: application to data, and item 5: research findings and recommendations.

Theoretical Framework for the Research

In this research, Pearson's coefficient was used to measure the correlation between two sets of data: the first set is the values of renewable energy consumption in Egypt, and the second set is the values of a set of indicators of the Egyptian economy in addition to the amount of carbon emissions in the period from 2000 to 2019. The selected Egyptian economy indicators are GDP, unemployment rate, average annual per capita income, and inflation rate. In view of the different nature of the two groups in terms of the units used in the measurement, the standard values of the data were used so that the correlation between them could be studied.

To calculate the standard values {zi, i = 1,2,..., n} for a set of data{xi, i = 1,2,..., n} with mean $\bar{x}$ and standard deviation s, we use the equation [4].

$$z_i = \frac{x_i - \bar{x}}{s}$$

where

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

n is the number of data.

The correlation coefficient r between two sets of data {xi}, {yi} is calculated from the following equation:

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{[n\sum x_i^2 - (\sum x_i)^2][n\sum y_i^2 - (\sum y_i)^2]}}$$

The correlation coefficient is a quantitative criterion whose value is between -1 and 1, where the calculated value of the correlation coefficient indicates the strength of the correlation between the two variables, and the sign indicates its direction and whether the correlation is direct (positive values) or inverse (negative values).

Application to Data:

Correlation of Renewable Energy Consumption with GDP:

Gross Domestic Product (GDP) is the total value of final goods and services produced by a country during a specified period, usually a year, or it is the total current internal economic output of final goods and services denominated at the market price during a specific period of time, usually a year (worldbank, 2019).

Table (2) shows renewable energy consumption and GDP in Egypt from 2000 to 2019, and this data has been calibrated so that the correlation between them can be measured.

Figure (1) shows the curves of standard numbers for renewable energy consumption and GDP for Egypt from 2000 to 2019.

Table (1) The Significance of the Value of Pearson's Correlation Coefficient:

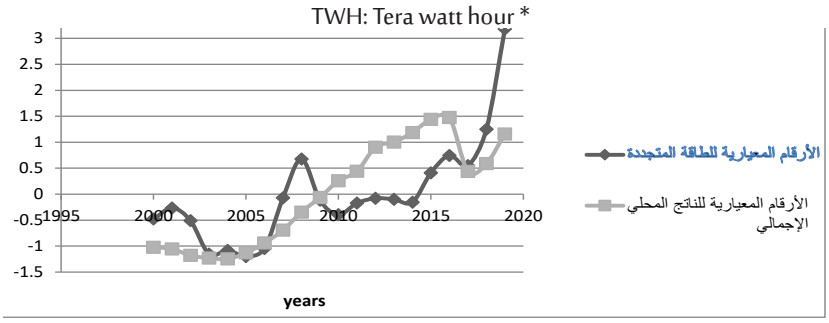
Direct Correlation		Inverse Correlation	
Value of Correlation Coefficient	Significance	Value of Correlation Coefficient	Significance
1	complete	−1	Complete
0.8 to 1	Strong	−0.8 to −1	Strong
0.5 to 0.8	medium	−0.5 to −0.8	Medium
0 to 0.5	Weak	0 to −0.5	Weak

Data source [Gareeb2022],[http//ar.tradingeconomics.com],{Attwan 2017}.

Table (2): Calculation of the Standard Numbers for Renewable Energy Consumption and GDP

Year	Renewable energy consumption (TWH)*	GDP ($ Billion)	Standard numbers for renewable energy consumption	Standard numbers for GDP
2000	14.259	99.839	-0.478017641	-1.020292346
2001	14.584	96.685	-0.265696016	-1.054133155
2002	14.209	85.146	-0.510682507	-1.177940731
2003	13.226	80.288	-1.152873762	-1.23006459
2004	13.337	78.782	-1.08035776	-1.2462232
2005	13.155	89.601	-1.19925787	-1.130140856
2006	13.391	107.426	-1.045079705	-0.938887711
2007	14.882	130.438	-0.071013418	-0.691980704
2008	16.027	162.818	0.677012002	-0.344559843
2009	14.812	189.147	-0.116744229	-0.062063121
2010	14.389	218.984	-0.393088991	0.258072649
2011	14.729	235.99	-0.170967906	0.440538343
2012	14.868	279.117	-0.08015958	0.903269025
2013	14.839	288.434	-0.099105202	1.003235677
2014	14.755	305.595	-0.153982176	1.187364441
2015	15.621	329.367	0.411773294	1.442425859
2016	16.133	332.442	0.746261516	1.475419039
2017	15.833	235.734	0.550272324	0.437791594
2018	16.905	249.713	1.250607039	0.587779124
2019	19.86	303.081	3.181100588	1.160390505
Mean	14.9907	194.93135	**Correlation Coefficient**	
Standard Deviation	1.530696646	93.20108145	0.638124253	

Raw data source [http://data.worldbank.org/country/CN], [BP, 2020].
The table was prepared by the researcher



The Figure was prepared by the researcher

Figure 1: Curves of Standard Numbers for Renewable Energy Consumption and Egypt's GDP

The correlation coefficient between renewable energy consumption and GDP in Egypt from 2000 to 2019 was 0.638, which means an average direct correlation between them. This means that the higher the consumption of renewable energy, the higher the average GDP.

Correlation of Renewable Energy Consumption with the Average Annual Per Capita income (in Dollars):

Average per capita income is the GDP for the year divided by the mid-year population (worldbank, 2019). In the following, the correlation between it and the consumption of renewable energy will be studied.

Table (3) shows the consumption of renewable energy and the average per capita income in the Arab Republic of Egypt from 2000 to 2019, and this data has been calibrated so that the correlation between them can be measured.

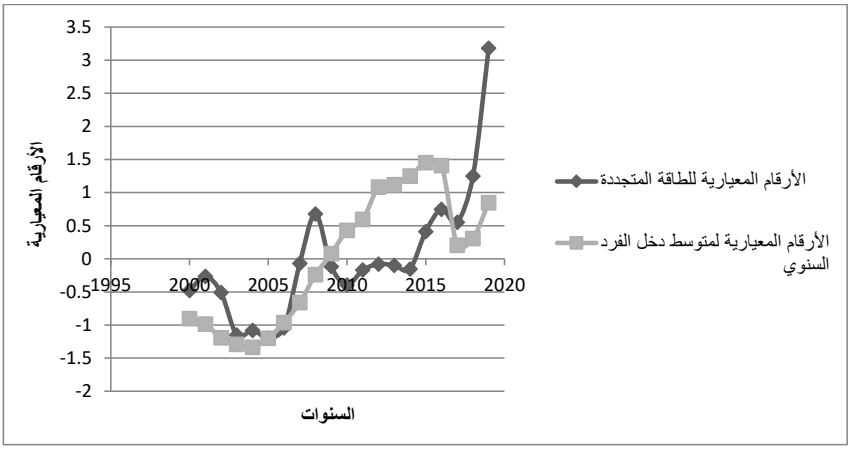
Figure (2) shows the curves of the standard numbers of renewable energy consumption and the average annual per capita income in Egypt from 2000 to 2019:

The correlation coefficient between renewable energy consumption and the average annual per capita income in the Arab Republic of Egypt from 2000 to 2019 was 0.565, which means an average direct correlation between them. That is, the higher the consumption of renewable energy, the higher the average per capita income.

Table No. (3): Calculation of the Standard Numbers for Renewable Energy Consumption and the Average Per Capita Income in Egypt

Year	Renewable energy consumption (TWH)	Average GDP per Capita (US $)	Standard numbers for renewable energy consumption	Standard numbers for average GDP per capita
2000	14.259	1451	-0.478017641	-0.903119297
2001	14.584	1378	-0.265696016	-0.984586963
2002	14.209	1191	-0.510682507	-1.193278107
2003	13.226	1103	-1.152873762	-1.291485704
2004	13.337	1062	-1.08035776	-1.337241516
2005	13.155	1186	-1.19925787	-1.198858084
2006	13.391	1397	-1.045079705	-0.963383049
2007	14.882	1667	-0.071013418	-0.662064285
2008	16.027	2045	0.677012002	-0.240218015
2009	14.812	2331	-0.116744229	0.078956676
2010	14.389	2646	-0.393088991	0.430495235
2011	14.729	2792	-0.170967906	0.593430567
2012	14.868	3230	-0.08015958	1.082236562
2013	14.839	3263	-0.099105202	1.119064411
2014	14.755	3380	-0.153982176	1.249635876
2015	15.621	3563	0.411773294	1.453863038
2016	16.133	3520	0.746261516	1.405875235
2017	15.833	2444	0.550272324	0.205064159
2018	16.905	2537	1.250607039	0.308851734
2019	19.86	3019	3.181100588	0.846761528
Mean	14.9907	2260.25	**Correlation Coefficient**	
Standard Deviation	1.530696646	896.0610221	0.565042795	

Raw data source [http://data.worldbank.org/country/CN]], [BP,2020].
The table was prepared by the researcher



The figure was prepared by the researcher

Figure (2): Curve of standard numbers of renewable energy consumption and average per capita income in Egypt.

Correlation of Renewable Energy Consumption with the Unemployment Rate:

The unemployment rate is one of the important economic indicators in formulating economic policies and evaluating their activities. Countries calculate unemployment rates periodically and regularly using the sampling

method; in the sense that a representative sample is taken from the active category of the population, through which the number of the unemployed is estimated, and then the unemployment rate is determined.

The unemployment rate is measured as the ratio of the number of the unemployed to the labor force in the community or the active group at a certain point in time (Worldbank, 2019), meaning that the unemployment rate = (the number of the unemployed ÷ the total members of the labor force) x 100.

Table (4) shows the consumption of renewable energy and the unemployment rate in Egypt from 2000 to 2019, and this data has been calibrated so that the correlation between them can be measured.

Figure (3) shows a curve of standard numbers of renewable energy consumption and the unemployment rate in Egypt from 2000 to 2019.

The correlation coefficient was calculated as its value was -0.227, which is a weak inverse correlation between them. In other words, an increase in the consumption of renewable energy leads to a small reduction in unemployment.

Table (4): Calculation of the Standard Numbers for Renewable energy Consumption and the Unemployment Rate in Egypt 2000-2019

Year	Renewable energy consumption (TWH)	Unemployment Rate %	Standard numbers for renewable energy consumption	Standard numbers for the unemployment rate
2000	14.259	9	-0.478017641	-0.940335595
2001	14.584	9.3	-0.265696016	-0.765117782
2002	14.209	10	-0.510682507	-0.356276219
2003	13.226	11	-1.152873762	0.227783157
2004	13.337	10.3	-1.08035776	-0.181058406
2005	13.155	11.2	-1.19925787	0.344595032
2006	13.391	10.5	-1.045079705	-0.064246531
2007	14.882	8.8	-0.071013418	-1.05714747
2008	16.027	8.5	0.677012002	-1.232365283
2009	14.812	9.1	-0.116744229	-0.881929657
2010	14.389	8.8	-0.393088991	-1.05714747
2011	14.729	11.9	-0.170967906	0.753436595
2012	14.868	12.6	-0.08015958	1.162278158
2013	14.839	13.2	-0.099105202	1.512713783
2014	14.755	13.1	-0.153982176	1.454307846
2015	15.621	13.1	0.411773294	1.454307846
2016	16.133	12.4	0.746261516	1.045466283
2017	15.833	11.7	0.550272324	0.63662472
2018	16.905	9.8	1.250607039	-0.473088094
2019	19.86	7.9	3.181100588	-1.582800908
Mean	14.9907	10.61	**Correlation Coefficient**	
Standard Deviation	1.530696646	1.712154691	-0.226963353	

Raw data source [http://data.worldbank.org/country/CN]], [BP,2020].
The table was prepared by the researcher

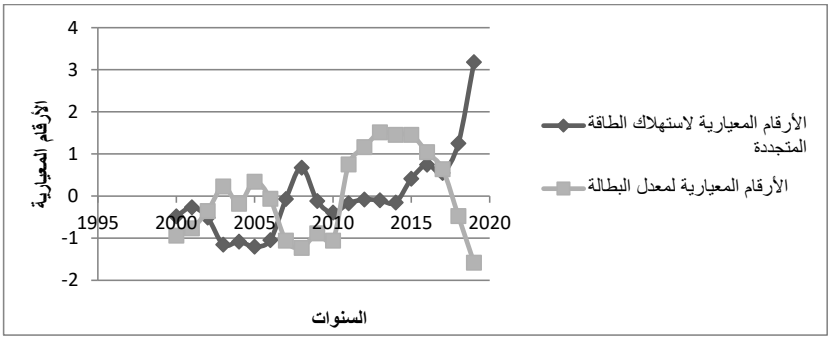


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Figure 3: Curves of the Standard Numbers of Renewable Energy Consumption and the Unemployment Rate in Egypt.

Correlation of Renewable Wnergy Consumption with the Inflation Rate:

The inflation rate is defined as a sustained increase in the general level of prices for goods and services. (Worldbank, 2019), and it is an important economic indicator that will be examined in relation to the consumption of renewable energy in Egypt.

Table (5) shows the consumption of renewable energy and the rate of inflation in Egypt during the study period, as well as their standard values.

Figure (4) shows the curves of standard numbers of renewable energy consumption and inflation rate in Egypt from 2000 to 2019.

The correlation coefficient between the consumption of renewable energy and the inflation rate was calculated for the period from 2000 - 2019 and its value was 0.380. It is a **weak direct correlation**, and this means that increased consumption of renewable energy leads to a small increase in inflation.

Correlation of Renewable Energy Consumption with Carbon Emissions (Environmental Pollution:

Carbon dioxide emissions are those resulting from burning fossil fuels. They include carbon dioxide produced during consumption of solid, liquid, and gaseous fuels (Worldbank, 2019), (Gareeb, 2019).

Table (6) shows the consumption of renewable energy and the total carbon emissions in the Arab Republic of Egypt from 2000 to 2019.

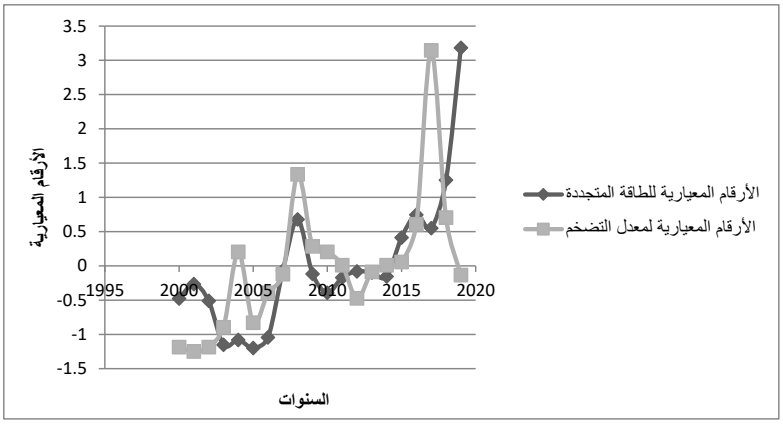
Figure (5) shows the curves of the standard numbers of renewable energy consumption and the amount of carbon emissions in Egypt from 2000 to 2019.

The correlation coefficient was calculated for the period 2000 - 2019 and its value was -0.191, which is a weak inverse correlation. This means that the higher the consumption of renewable energy, the lower the carbon emissions by a small amount.

Table (5): Calculation of the Standard Numbers for Renewable Energy Consumption and Inflation Rate in Egypt 2000-2019

Year	Renewable energy consumption (TWH)	Inflation rate %	Standard numbers for renewable energy consumption	Standard numbers for inflation rate
2000	14.259	2.7	-0.478017641	-1.186287063
2001	14.584	2.3	-0.265696016	-1.25093486
2002	14.209	2.7	-0.510682507	-1.186287063
2003	13.226	4.5	-1.152873762	-0.89537198
2004	13.337	11.3	-1.08035776	0.203640559
2005	13.155	4.9	-1.19925787	-0.830724183
2006	13.391	7.6	-1.045079705	-0.394351558
2007	14.882	9.3	-0.071013418	-0.119598423
2008	16.027	18.3	0.677012002	1.334976995
2009	14.812	11.8	-0.116744229	0.284450304
2010	14.389	11.3	-0.393088991	0.203640559
2011	14.729	10.1	-0.170967906	0.009697169
2012	14.868	7.1	-0.08015958	-0.475161303
2013	14.839	9.5	-0.099105202	-0.087274525
2014	14.755	10.1	-0.153982176	0.009697169
2015	15.621	10.4	0.411773294	0.058183017
2016	16.133	13.8	0.746261516	0.607689286
2017	15.833	29.5	0.550272324	3.145115293
2018	16.905	14.4	1.250607039	0.70466098
2019	19.86	9.2	3.181100588	-0.135760372
Mean	14.9907	10.04	**Correlation Coefficient**	
Standard deviation	1.530696646	6.18737254	0.380316142	

The source of the raw data [http://data.worldbank.org/country/CN]], [BP,2020], The table was prepared by the researcher



The figure was prepared by the researcher

Figure (4): Curves of Standard Numbers of Renewable Energy Consumption and Inflation Rate in Egypt, 2000-2019

Results and Recommendations

The research problem is to measure the correlation of renewable energy consumption in Egypt with a set of important economic indicators, namely the GDP, average annual per capita income, unemployment rate, inflation rate, and carbon emissions in the period from 2000 to 2019. These indicators are of paramount importance as a basis in making economic decisions, and their impact on the balance of payments and trade balance, which shows the strength of a country's economy. Pearson's Coefficient was used to measure the correlation between two sets of data: the renewable energy consumption group, and the selected Egyptian economy indicators group as well as carbon emissions. Due to the different units of measurement

in the two groups, the data was calibrated so that we could study the correlation between them. The study concluded that:

- there is an average direct correlation between the consumption of renewable energy and the GDP in Egypt, and it amounted to 0.63.
- there is a medium direct correlation between the consumption of renewable energy and the average annual per capita income, which amounted to 0.565.
- there is a weak inverse correlation of (-0.227) between the consumption of renewable energy and the unemployment rate.
- there is a weak direct correlation of 0.380 between the consumption of renewable energy and the rate of inflation,
- and finally, there is a weak inverse correlation of (-0.191) between the consumption of renewable energy and the amount of carbon emissions.

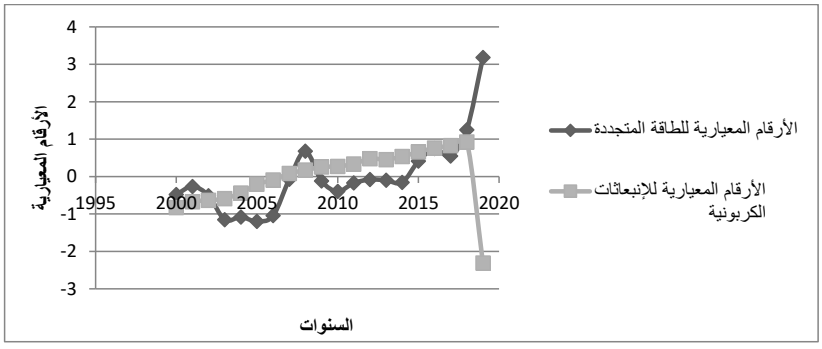
In Conclusion, increasing consumption of renewable energy has a positive impact on the economy and environment in Egypt.

The Study Recommends moving forward with the Egyptian plan, which aims to reach the share of renewable energy in the Egyptian energy mix to 42% by 2035.

Table (6): Calculation of the Standard Numbers of Renewable Energy Consumption and Total Carbon Emissions in Egypt 2000-2019

Year	Renewable energy consumption (Twh)	Carbon emissions KT	Standard numbers for renewable energy consumption	Standard numbers for carbon emissions
2000	14.259	112860	-0.478017641	-0.830751706
2001	14.584	125010	-0.265696016	-0.670770072
2002	14.209	127740	-0.510682507	-0.634823582
2003	13.226	131240	-1.152873762	-0.588738337
2004	13.337	142690	-1.08035776	-0.437973752
2005	13.155	160590	-1.19925787	-0.202280646
2006	13.391	169130	-1.045079705	-0.08983265
2007	14.882	182230	-0.071013418	0.082657836
2008	16.027	189120	0.677012002	0.173379931
2009	14.812	195490	-0.116744229	0.257255076
2010	14.389	196500	-0.393088991	0.27055396
2011	14.729	201610	-0.170967906	0.337838417
2012	14.868	212410	-0.08015958	0.480044314
2013	14.839	210430	-0.099105202	0.453973233
2014	14.755	216650	-0.153982176	0.535873295
2015	15.621	225950	0.411773294	0.658328373
2016	16.133	233960	0.746261516	0.763797746
2017	15.833	238960	0.550272324	0.829633809
2018	16.905	246260	1.250607039	0.925754462
2019	19.86	219	3.181100588	-2.313919706
Mean	14.9907	175952.45	**Correlation Coefficient**	
Standard Deviation	1.530696646	57946.21782	-0.190812313	

Raw data source [http://data.worldbank.org/country/CN], [BP,2020.
The table was prepared by the researcher



The figure was prepared by the researcher.

Figure (5): Curves of Standard Numbers of Renewable Energy Consumption and the Amount of Carbon Emissions in Egypt

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