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Investigating the Environmental Kuznets Curve Hypothesis in Egypt: The Role of Renewable Energy and Trade in Mitigating GHGs

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ABSTRACT

This paper aims to investigate the existence of the environmental Kuznets curve (EKC) for Egypt during the period 1971−2012. Also, it attempts to examine the potential role of renewable energy and trade in mitigating greenhouse gas emissions in Egypt. Accordingly, the study examines the dynamic relationship between the GHG emissions, economic growth (real gross domestic product [GDP] per capita), renewable energy consumption (% of total), and trade openness. Using Autoregressive Distributed Lag bounds testing approach, the empirical evidence of the EKC hypothesis is analyzed. The main findings of the analysis, concerning the validity of EKC, reveal that the EKC hypothesis does not exist for GHG emissions in Egypt for both short - and long-term. In addition, the empirical results indicate the potential significant role of renewable energy to reduce GHG emissions. However, it has been found that trade openness has insignificant impact on GHG emissions.

Keywords: Greenhouse Gas Emissions, Environmental Kuznets Curve, Renewable Energy, Egypt
JEL Classifications: C32, O55, Q43, Q56

1. INTRODUCTION

Climate change is widely recognized as one of the main challenges affecting our world in the 21st century. It raises concerns that are linked to its potential wide-ranging effects on the environment, and socio-economic sectors.

Furthermore, it is mostly due to the human influence on the climate system through the man-made emissions of greenhouse gases[1] (IPCC, 2007). Over the last century, worldwide rapid economic growth and industrialization has been consistent with a considerable increase in atmospheric concentrations of greenhouse gases compared to its pre-industrial levels (IPCC, 2014).

This motivates researchers to investigate the relationship between economic growth and environmental quality. In this context, the environmental Kuznets Curve (EKC) hypothesis has risen.

The EKC hypothesis is an analogy of Kuznets curve hypothesis. Kuznets (1955) found that the relationship between economic development and income inequality is represented by the inverted U-shaped curve. This suggests that, in the early stages of economic development, up to a certain point, income inequality increases as economic growth increases and where, further economic growth will result in less income inequality.

According to the EKC hypothesis, environmental degradation increases at the beginning of economic development determined by per capita income, but after per capita income exceeds a certain level, the environmental degradation starts to decline (Stern, 2004). Panayotou (1993) called this relationship as EKC.

Egypt faces many challenges, such as attempting to stimulate economic growth without deteriorating the environment. Moreover, economic growth in Egypt has two main features. First, there is heavy dependence on fossil fuels, which had represented 96% of energy consumption in 2014 (World Bank, 2017). Second, the industrial base in Egypt constitutes several polluting industries, such as iron, steel, aluminum, cement, and ceramic industries

1 These greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (hydrofluorocarbons HFCs, perfluorocarbons PFCs, sulfur hexafluoride SF_6).

(Ibrahiem, 2015). As a result, GHG emissions increased from 122 in 1990 to 272 $MtCO_2e$ in 2013. The energy sector is the major contributor to those emissions with about 70%, followed by the agricultural sector, industrial sector, and finally, the waste sector (CAIT, 2017).

Egypt's vision for 2030 was launched with the aim of tackling these challenges and was called the Sustainable Development Strategy. With respect to the energy sector, it aims to reduce GHG emissions from this sector by 10% and generate 35% of the country's electricity production from renewable resources (hydropower, solar and wind energy) by 2030 (Ministry of Planning, Monitoring and Administrative Reform, 2016).

The objective of the present study is to test the validity of EKC hypothesis in Egypt, besides pointing out the role of renewable energy and trade in reducing GHG emissions for the period between 1971 and 2012 using Autoregressive Distributed Lag (ARDL) approach.

This paper is structured as follows: Section 2 provides a survey on literature, highlighting relevant previous studies on the subject. Section 3 details the methodology and data that has been used for analysis. Section 4 discusses the results and Section 5 concludes and proposes some policy implications.

2. LITERATURE REVIEW

The growth-versus-environment debate began in the early 1970s and can be primarily categorized into two opposing views. The first perspective assumes a positive relationship between economic growth and environmental quality, while the second perspective argues that economic growth causes deterioration of the environment (de Bruyn, 2000).

In the early 1990s, the EKC concept emerged with two pioneering works, Grossman and Krueger's study (1991) of measuring the environmental impacts of the North American Free Trade Agreement, or NAFTA in Mexico using three comparable measures of air pollutants. They indicated the channels through which the changes in trade and foreign investment affect the level of pollution; namely, scale effect, composition effect, and technique effect.

Their results show that air pollutants (sulfur dioxide and dark matter) increase with GDP per capita at low levels of national income but decrease with GDP growth at higher levels of income.

The second study is Shafik and Bandyopadhyay's background paper for the 1992 world development report (1992). They expanded the analysis to include additional environmental indicators and a large number of countries. The empirical results revealed that unsafe water and poor urban sanitation decrease as the per capita national income rises, whereas, income is positively related with municipal waste and carbon emissions per capita.

Since then, many studies have examined the validity of the EKC hypothesis that have differed in many aspects, such as specifications, environmental indicators, countries, periods of time, and econometric methods. They also found different outcomes. So we have divided the EKC literature into three strands.

The first strand of studies is related to examining the relationship between environmental pollutants and economic growth in order to test the validity of the EKC hypothesis. Some empirical studies provide evidence on the existence of the EKC hypothesis (Selden and Song, 1994; Fodha and Zaghdoud, 2010; Esteve and Tamarit, 2012; Saboori et al., 2012; Chow and Li, 2014; Al Mamun et al., 2014; Tang et al., 2016), while others provide no support to the presence of the EKC hypothesis (Poudel et al., 2009; Wang, 2012).

The second strand of empirical studies focuses on investigating the energy consumption-economic growth-environment nexus, as energy consumption is the main source of GHG emissions. Hence, it can be drawn from the findings of these studies that energy consumption has a negative effect on environmental quality (Acaravci and Ozturk, 2010; Lean and Smyth, 2010; Apergis and Payne, 2010; Pao and Tsai, 2010; Hamit-Haggar, 2012; Pao et al., 2011; Arouri et al., 2012; Saboori and Sulaiman, 2013a; 2013b; Cho et al., 2014; Al-mulali et al., 2016; Jebli et al., 2015; Shahbaz et al., 2015; Alam et al., 2016).

Some economists differentiated between nonrenewable or fossil fuel, and renewable energy. Zambrano-Monserrate et al. (2018) examined the impact on emissions of both electricity consumption from renewable sources and fossil fuel consumption (petroleum and natural gas). They found that gas and petroleum consumption have positive effects on CO_2 emissions while electricity consumption from renewable sources has a negative impact. Furthermore, Gill et al. (2017) pointed out that renewable energy negatively affects CO_2 emissions.

The third strand in the literature includes many other important variables while investigating the EKC hypothesis. Trade openness is one of these variables that several authors have included in their models. The initial view was that more trade boosts the size of the economy and hence, deteriorates the environment (Dinda, 2004). However, many empirical studies investigated the relationship between free trade and environmental degradation and attained contradictory results.

Some economists found that free trade is positively correlated with environmental degradation (Ozturk and Acaravci, 2013; Ertugrul et al., 2016; Benavides et al., 2017). This may be explained by the displacement hypothesis which suggests that pollution-intensive industries are displaced from countries with strict regulations to those with weak regulations, mainly, less developed countries (Ekins, 2000).

Other researchers argued that there is a negative relationship between trade openness and environmental degradation (Shahbaz et al., 2012; Kanjilal and Ghosh, 2013; Kang et al., 2016) and have provided a few reasons in support of this argument. First, more trade raises real income per capita. Consequently, this will motivate individuals to increase their demands for a clean environment through setting effective regulatory system, and the expansion of using clean technology and production of environmental goods (Liddle, 2001). Second, free trade may reduce pollution through technique effect, which refers to the transfer of cleaner and upgraded technology through international trade (Harris, 2004). In addition, some studies found that trade openness had no significant impact on CO_2 emissions (Jalil and Mahmud, 2009; Jayanthakumaran et al., 2012; Farhani et al., 2014).

The other variables, which have been examined by many studies, include population density (Onafowora and Owoye, 2014; Ibrahiem, 2016), population growth (Ahmed and Long, 2012; Lin et al., 2016), financial development (Ozturk and Acaravci, 2013; Abid, 2017), labor and capital (Al-Mulali et al., 2015), urbanization (Shahbaz et al., 2016; Lin et al., 2016), industry share in GDP (Abdou and Atya, 2013; Apergis and Ozturk, 2015), energy prices (Al-Mulali and Ozturk, 2016), culture (Disli et al., 2016), corruption (Sahli and Rejeb, 2015; Abid, 2017), employment (Ozturk and Acaravci, 2010), foreign direct investment (Haisheng et al., 2005, Linh and Lin, 2014), and technology progress (Du et al., 2012).

In the context of Egypt, Abdou and Atya (2013), Onafowora and Owoye (2014), and Ibrahiem (2016) investigated the existence of the EKC hypothesis. Their results revealed that the EKC hypothesis is not verified for CO_2 emissions in Egypt.

In contrast, Al-Ayouty et al. (2017) found that the EKC hypothesis is valid for two environmental quality indicators; namely, CO_2 emissions and lack of access to improved water sources.

The present study differs from the existing literature as it investigates the EKC hypothesis in Egypt in two aspects. It uses GHG emissions as an environmental quality indicator, and it aims at figuring out the effect of renewable energy and trade openness on those emissions.

3. METHODOLOGY AND DATA

The objective of the present study is to test the validity of the EKC hypothesis for GHG emissions in Egypt. We examined the long-run relationship between GHG emissions, GDP, renewable energy, and trade openness using annual time series data over the period 1971−2012. Based on the EKC formula proposed by Dinda (2004) and in light of the objective of the study, the following equation was specified:

$$GHG_t=f(GDP_t,GDP_t^2,RE_t,TR_t) \quad (1)$$

Where, GHG is greenhouse gas emissions per capita (measured in kt of CO_2 equivalent divided by total population), GDP is real GDP per capita (constant 2010 US$), GDP^2 is square of GDP per capita, RE is the percentage of renewable energy of total energy consumption (including hydro, solar, and wind energy), and TR is trade openness ratio (sum of exports and imports of goods and services measured as a share of GDP). All the variables were not transformed into a logarithmic form to avoid zero or negative indicator values.

The annual data from 1971−2012 for GHG emissions per capita, real GDP per capita, renewable energy consumption, and trade openness ratio were obtained from the World Development Indicators Database (World Bank, 2017).

All the time series variables should be tested for stationary property to ensure that the econometric model being estimated is not subject to spurious regression (Granger and Newbold, 1974). In this regard, several unit root tests have been developed (Dickey and Fuller, 1979; Phillips and Perron, 1988; Kwiatkowski et al., 1992).

However, there is a special case, where, even if variables are non-stationary, they can be combined through a linear combination into a series, which is stationary. Series that have such a property are called co-integrated series (Charemza and Deadman, 1997).

There are two proposed methods that are used to test for a co-integration relationship between variables. The first is the residual-based approach that was developed by Engle and Granger (1987). The second method is Johansen maximum likelihood, which is named after one of its developers (Johansen and Juselius, 1990).

However, the aforementioned co-integration techniques assume that the time series, which is under investigation, must have the same order of integration. Therefore, a recent co-integration test developed by Pesaran et al. (2001) overcame the condition of equal integration order between variables. This test is known as the ARDL bounds testing approach and has the advantage of allowing the time series variables to have a different order of integration.

This study employed the ARDL bounds test to estimate long run equilibrium relationship among GHG emissions per capita, GDP per capita, renewable energy and trade openness as follows:

$$GHG_t=\beta_0+\beta_1 GDP_t+\beta_2 GDP_t^2+\beta_3 RE_t+\beta_4 TR_t+u_t \quad (2)$$

According to the EKC hypothesis, the sign of β_1 was expected to be positive; whereas, the sign of β_2 was expected to be negative and the sign of β_3 was expected to be mixed. Jebli et al. (2016) argue that renewable energy affects CO_2 emissions negatively if the level and contribution of renewable energy to energy consumption is high enough and the technology used in industries is clean.

The sign of β_4 was also expected to be mixed according to the level of economic development of the country.

The ARDL methodology was applied in two stages. First, bounds test was used for investigating the existence of long run equilibrium relationship among time series variables. The ARDL unrestricted model is represented in the following equation:

$$\Delta GHG_t=\beta_0+\sum_{i=1}^{p}\beta_{1i}\Delta GHG_{t-i}+\sum_{j=0}^{q}\beta_{2j}\Delta GDP_{t-j}+ \quad (3)$$

$$\sum_{k=0}^{m}\beta_{3k}\Delta GDP_{t-k}^2+\sum_{l=0}^{n}\beta_{4l}\Delta RE_{t-l}+\sum_{r=0}^{o}\beta_{5r}\Delta TR_{t-r}+$$

$$\beta_6 GHG_{t-1}+\beta_7 GDP_{t-1}+\beta_8 GDP_{t-1}^2+$$

$$\beta_9 RE_{t-1}+\beta_{10} TR_{t-1}+u_t$$

According to the bounds test, the null hypothesis stated that $\beta_6=\beta_7=\beta_8=\beta_9=\beta_{10}=0$ (no co-integration) against the alternative hypothesis, at least one β_k was not zero (there is co-integration relationship).

The bounds test also states that if the computed F-statistic is higher than the upper bound, then the null hypothesis is rejected, and so, there exists a long-run co-integrating relationship among the variables. Conversely, if the computed F-statistic is smaller than the lower bound, we cannot reject Ho.

In the second stage, we estimated the short- and long-run relationship between variables. First, estimation of long-run ARDL model is as follows:

$$GHG_t=\beta_0+\sum_{i=1}^{p}\beta_{1i}\Delta GHG_{t-i}+\sum_{j=0}^{q}\beta_{2j}\Delta GDP_{t-j}+\sum_{k=0}^{m}\beta_{3k}\Delta GDP^2_{t-k}+\sum_{l=0}^{n}\beta_{4l}\Delta RE_{t-l}+\sum_{r=0}^{o}\beta_{5r}\Delta TR_{t-r}+\mu_t \quad (4)$$

Second, we estimated short-run ARDL model (or error correction model) as follows:

$$GHG_t=\beta_0+\sum_{i=1}^{p}\delta_{1i}\Delta GHG_{t-i}+\sum_{j=0}^{q}\delta_{2j}\Delta GDP_{t-j}+\sum_{k=0}^{m}\delta_{3k}\Delta GDP^2_{t-k}+\sum_{l=0}^{n}\delta_{4l}\Delta RE_{t-l}+\sum_{r=0}^{o}\delta_{5r}\Delta TR_{t-r}+\lambda ECT_{t-1}+\mu_t \quad (5)$$

Here, ECT stands for error correction term, which represents the speed adjustment of model from disequilibrium state in short-run to long-run equilibrium.

4. EMPIRICAL RESULTS

Both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are employed to test stationary properties of time series variables used in the analysis. According to the ADF and PP tests, the null hypothesis stated that the series had a unit root and hence, was non-stationary.

Table 1 displays the unit root tests for the variables at their levels and at their first and second differences. The optimal lag was determined automatically depending on Schwarz information criterion.

The results of both the ADF and PP tests indicated that GHG, RE, and TR were non-stationary at levels and that they were integrated of order one I (1) at the 1% significance level. Also, GDP and GDP^2 were non-stationary at levels but were integrated of order two I (2) at the 1% significance level.

Based on the Akaike Information criterion, the best ARDL model with the minimum AIC value was ARDL (4, 3, 3, 0, 4) as shown in Figure 1. The results of Bounds test are reported in Table 2. They indicate that the null hypothesis was rejected as computed F-statistic was higher than the upper bound critical values. Consequently, there existed a long-run relationship among the variables.

Table 3 reports long run estimates. It can be seen that all variables were significant except for trade openness variable. The coefficient of GDP was negative and the coefficient of GDP^2 was positive, suggesting that there was no evidence for the presence of inverted U-shaped EKC hypothesis in the long-run.

This empirical finding was consistent with that found by Abdou and Atya (2013); Onafowora and Owoye (2014); and Ibrahiem (2016). Also, the results indicate the significant negative relationship between GHG emissions and renewable energy.

For short-run estimates as shown in Table 4, most of the explanatory variables were significant and it can be seen that

Table 1: Results of the unit root tests

Variables	Augmented Dickey-fuller test	Phillips-perron test
	Test statistic	
GHG	−1.7445	−1.9688
GDP	−2.7272	−1.7336
GDP^2	−2.219	−0.7989
RE	−1.2182	−1.2389
TR	−0.3634	−0.3931
1st difference		
ΔGHG	−5.408592***	−5.404242***
ΔGDP	−3.534456**	−3.512297*
ΔGDP^2	−3.894225**	−2.983
ΔRE	−6.912994***	−6.885131***
ΔTR	−5.615843***	−5.615843***
2nd difference		
ΔΔGHG	−6.544554***	−14.88865***
ΔΔGDP	−8.081140***	−8.072751***
$\Delta\Delta GDP^2$	−7.819964***	−7.819964***
ΔΔRE	−14.97335***	−19.00507***
ΔΔTR	−7.926582***	−29.54820***

*.** and *** indicate 10%, 5%, and 1% level of significance, respectively. The unit root tests were conducted for GHG, GDP, GDP2 and RE with constant and trend, while for TR were conducted with no constant and no trend. GDP: Gross domestic product

Table 2: Results of bounds test

	Critical value bounds	
Significance %	I (0) Bound	I (1) Bound
10	2.2	3.09
5	2.56	3.49
2.5	2.88	3.87
1	3.29	4.37
F-statistic	11.36933	

Null Hypothesis: No levels relationship

Table 3: Estimates of Long-run coefficients

	Dependent variable: GHG	
Independent variables	Coefficient	P
GDP	0	0.0006
GDP^2	0	0
RE	−0.0001	0
TR	0	0.823
Constant	0.0033	0

the EKC hypothesis does not exist in the short-run. So, it can be concluded that the EKC hypothesis is not valid for Egypt either in the short-run or in the long-run.

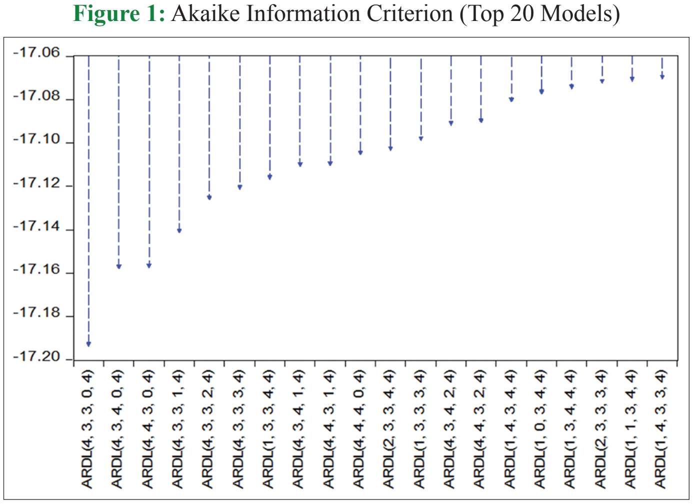
The coefficient of ECT was negative and significant, which provided evidence on the presence of long-run integrated relationship among the variables. The value -1.3 means that deviations of GHG emissions per capita from its long-run equilibrium level were corrected by 130% within 1 year.

This study conducted several diagnostic tests to ensure robustness of results. These tests include Lagrange Multiplier test for serial correlation, ARCH test for heteroscedasticity, Jarque-Bera test of normality of the residual, and Ramsey RESET test of the model specification. As displayed in Table 4, the null hypothesis could not be rejected. So, there was no presence of serial correlation and heteroscedasticity. Also, the model was specified correctly and the residuals were normally distributed.

Table 4: Estimates of Short-run coefficients and diagnostic tests results

Dependent variable: D (GHG)		
Independent variables	**Coefficient**	**P**
D(GHG(−1))	0.355	0.0011
D(GHG(−2))	0.39951	0.0011
D(GHG(−3))	0.39126	0.0017
D(GDP)	0	0.002
D(GDP(−1))	0	0.4837
D(GDP(−2))	0	0.0006
D(GDP^2)	0	0.0001
D(GDP^2(−1))	0	0.0849
D(GDP^2(−2))	0	0
D(TR)	0	0.6948
D(TR(−1))	0	0.0141
D(TR(−2))	0	0.0079
D(TR(−3))	0	0.0123
ECT(−1)	−1.3562	0
Diagnostic tests		
Adjusted R-squared	0.7325	
Test-statistics		
Serial correlation LM	3.3048	0.1916
ARCH	3.1439	0.0762
Normality test JB	0.3759	0.8286
Ramsey RESET	2.0024	0.0605

Figure 1: Akaike Information Criterion (Top 20 Models)



Furthermore, it employed the stability tests, such as cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ), to assert stability of coefficients throughout the period under analysis. It can be seen in Figures 2 and 3 that test statistics were within the critical bounds, meaning that the estimated coefficients were stable throughout the time period of the study.

6. CONCLUSION AND POLICY IMPLICATIONS

The main objective of this paper was to test the validity of the EKC hypothesis for GHG emissions in Egypt during the period 1971−2012. Moreover, it attempted to highlight the role of renewable energy and trade openness in curbing GHG emissions. To do so, ARDL method of estimation was applied and the empirical findings showed that the sign of GDP was negative and the sign of square of GDP was positive, which confirms that the EKC hypothesis was not valid for GHG emissions in Egypt. This means that higher economic growth yields an increase in GHG emissions and consequently, more environmental degradation.

Also, the results displayed the significant importance of renewable energy in mitigating GHG emissions, while there was insignificant positive impact of trade openness on GHG emissions in Egypt.

Some policy implications can be driven-based on the findings of this empirical study. Egypt has to pursue a low-carbon

Figure 2: Cumulative sum of recursive residuals

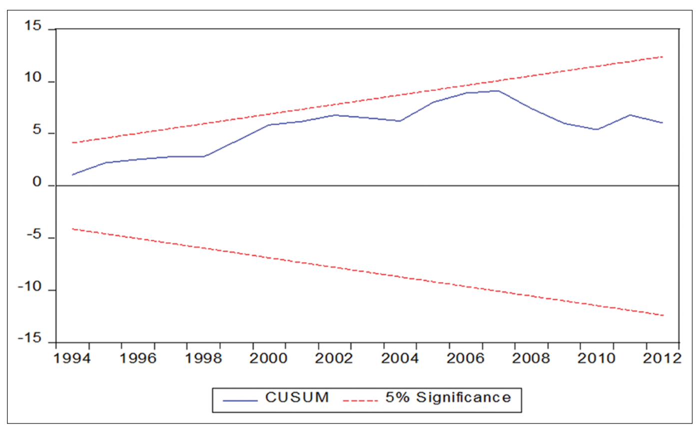
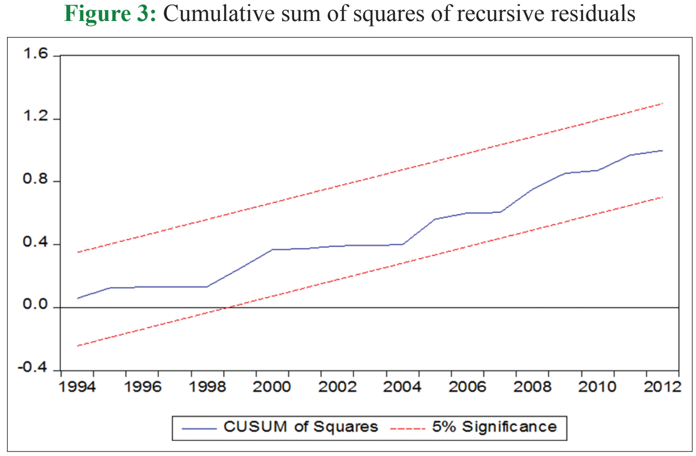


Figure 3: Cumulative sum of squares of recursive residuals



economic growth path to balance continued economic growth with environmental conservation. In this respect, we have suggested a number of key policies. First, Egypt should establish stricter environmental regulations and rules to reduce pollutants, particularly those emitted from the energy intensive and polluting industries. In addition, Egypt has to design a mixture of taxation and subsidy policies to curb polluting emissions (such as carbon tax and incentives for green investment).

Regarding the energy sector, focus should be oriented to change the structure of energy consumption toward increasing the contribution of renewable energy. Moreover, Egypt has great potential to achieve this policy as it is naturally endowed with diversified renewable energy sources like solar, wind, and hydropower energy. At the same time, this will increase energy security through reducing the imported fossil fuels.

Egypt's fossil fuels subsidies represent a challenge for the expansion of renewable energy. Consequently, in July 2014 the Egyptian government started to phase out energy subsidies, which decreased from 139.46 billion LE in the fiscal year 2013/2014 to 79.528 Billion LE in 2015/2016 (Ministry of Finance, 2017). It is also important to enhance energy efficiency and minimize the waste of energy.

Finally, Egypt can benefit from international collaboration and clean technology transfer from developed countries. Furthermore, the Clean Development Mechanism, which has been defined in the Kyoto Protocol, represents a great opportunity for Egypt to implement emission-reduction projects.

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