Renewable and non-renewable electricity consumption, carbon emissions and GDP: Evidence from Mediterranean countries

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Abstract

This article investigates the causal relationship between renewable and non-renewable electricity consumption, GDP and CO_2 emissions for North and South shore of Mediterranean over the period 1980-2012. Panel unit root tests, cointegration technique allowing cross-section dependence among the panel and causality tests are used to investigate this relationship. The results provide panel empirical evidences that there is a short-run bidirectional causality between GDP, renewable electricity consumption and CO_2 emissions; and between nonrenewable electricity consumption, GDP and renewable electricity consumption. As for the long-run causal relationship, the result indicate that there is bidirectional causality between non-renewable electricity consumption and CO_2 emissions. However, there is evidence of unidirectional causal relationship running from GDP to CO_2 emissions and non-renewable electricity, consumption; from renewable electricity consumption to CO_2 emissions and non-renewable electricity consumption. The findings imply that non-renewable electricity consumption and economic growth stimulate CO_2 emissions in Southern and Northern Mediterranean countries while renewable electricity reduces it. Therefore, expansion of renewable energy sources is a strategic plan for addressing energy security and reducing carbon emissions to protect the environment for future generations.

Key words: Renewable energy consumption, non-renewable energy consumption, CO_2 emissions, Panel cointegration, Mediterranean countries.

1. Introduction

The exponential increase of energy consumption and the rapid growth of pollutant emissions is expected to have noticeable effect in global environment: rising of global temperatures, erratic climate and weather extremes, and altered ecosystems and habitats. All of these effects present increasing challenges for energy production and use and coming to play a growing role in the design of the future energy system and energy policies. In this context, several countries pay close attention to climate change impacts and consider ways to adapt to adverse impacts by developing strategies with the aim of finding concert solutions to the problem. Incentivizing investment in renewable energy and low-carbon technologies will be a key challenge to achieve pollutant reduction targets.

However, increasing use of renewable energy has many potential benefits, including a reduction of global warming emissions, the diversification of energy supplies and a reduced dependency on fossil fuel energy market. In addition, renewable energy projects allow the replacement of carbon-intensive energy sources. Renewable energy industry is more labor-intensive, thus increasing renewable energy supply has the potential to stimulate employment, through the creation of jobs in new 'green' technologies.

The Mediterranean region are endowed with a huge renewable energy (solar and wind) potential. Meanwhile, the electricity generation mix is still predominated by fossil fuels and the renewable energy is poorly exploited. But during the last decades, efforts are being and the Mediterranean countries tried to implement different actions and strategies to resolve the energy and environmental problems and develop renewable energy. We can cite the Mediterranean Strategy for Sustainable Development (MSSD), the Mediterranean Solar Plan (MSP) and recently the Renewable Energy Solution for the Mediterranean (RES4MED). In fact, the development of large-scale renewable energy projects, in this region, would have a many advantages, such as meeting the rising electricity demand at a lower cost, sustain the long run economic growth, reducing energy bills in importing countries, creating new job opportunities, enhancing the quality of the environment and enhancing energy exchange cooperation both between Mediterranean countries and the EU.

Many researches have attempted to understand and to define the causality relationship between energy consumption, economic growth and CO_2 emissions. The objective is to analyze the effect of economic growth and energy consumption on environment. We can categorize these studies into three strands. The first group of studies focuses on the relationship between economic growth and environmental pollutant nexus. It is try to verify the validity of the Environmental Kuznets Curve (EKC) hypothesis.

The EKC hypothesis postulates an inverted-U-shaped relationship between different pollutants and per capita income, i.e., environmental degradation increases up to a certain level as income goes up; after that, starts declining after a turning point. Therefore, EKC hypothesis express a well-defined relationship between growth and environmental quality (see Grossman and Krueger [1], Dinda [2]). A second set of studies has focused on the relationship between energy consumption and economic growth. Since the pioneering study by Kraft and Kraft [3], a voluminous causality literature has emerged (Liz and Montfort [4], Belloumi [5], Tsani [6], Omri [7]). The third strand has emerged from the two last set of studies. That seeks to analyze the Granger causality between economic growth, energy consumption and pollutant emissions. The results of these studies are different from one country to another. The mixed findings reflect several factors, including institutional differences between countries model specification and econometric approach. We discuss some of these studies in Section 2. The main objective of this article is to explore the dynamic relationship between renewable electricity consumption, non-renewable electricity consumption, CO_2 emissions and GDP for a panel of 9[1] Mediterranean countries over the period 1980-2012 using the recently developed panel data methods. Therefore, the empirical estimates of this study are important to guide policy-maker's decisions in terms of energy use, sustainable growth and CO2 emissions reduction the Mediterranean countries.

The choice of the Mediterranean countries is motivated by the fact that little attention has been paid to these countries. There is a common interest between the two shores of the Mediterranean to develop north-south energy exchange. In addition, like in many other countries, the literature on causality between renewable and non-renewable and other variables of Mediterranean countries is rather limited. However, to the best of our knowledge, none of the empirical studies have focused to investigating the dynamic link between renewable and non-renewable electricity consumption–carbon emissions–GDP in this region. This paper sheds light on the possible sources and directions of the relationship between pollutant emissions, economic growth, renewable, and non-electricity consumption. The study can also provide ideas on the design and the implementation of future economic and energy policies in the region.

However, this study aims to provide information that answer to the following questions:

- What are the role of the renewable electricity consumption in reducing carbon emissions in the Mediterranean countries?
- Is there a possibility of substitution of renewable electricity for non-renewable electricity in the region both in GDP growth process?
- How renewable energy can contribute to reduce the pollutant emissions and sustain the long run economic growth.
- What are the impact of the increasing of electricity demand on the environmental quality in the Mediterranean countries?

In addition to the introductory section, the rest of the paper is organized as follows: Section 2 presents the state of the art dealing with literature on the subject. Section 3 provides a brief overview of renewable energy in Mediterranean countries. Section 4 describes the data and the econometric model. We report our empirical findings in Section 5. Based on the results of the model, we draw conclusion and provide some policy implications in Section 6.

[1] Algeria, Egypt, France, Greece, Italy, Morocco, Spain, Tunisia and Turkey.

2. Literature review

More studies confirm that energy consumption is a key determinant of CO_2 emissions. That's why, the nexus between energy consumption, pollutant emissions and economic growth has been the subject of considerable academic research over the past few decades (see table 1). In this section, we will outline some results of this field of research and we will first focus on the relationship between energy consumption, CO_2 emissions and growth. Secondly, we will present some empirical results on the relationship between electricity consumption, CO_2 emissions and growth and finally, we will cite some empirical finding of research between renewable energy consumption, CO_2 emissions and growth.

Ang [8] initiated the strand of research between energy consumption, pollutant emissions and economic growth for France and using cointegration and vector error-correction modeling techniques. The Granger causality test confirm that economic growth cause energy consumption and CO_2 emissions in the long run. Hamit-Haggar [9] investigates the long-run and the causal relationship between greenhouse gas emissions, energy consumption and economic growth for Canadian industrial sectors over the period 1990–2007 using a Panel Vector Error Correction Model. The empirical findings suggest that in the long-run equilibrium, energy consumption has a positive and statistically significant impact on greenhouse gas emissions whereas a non-linear relationship is found between greenhouse gas emissions and economic growth, consistent with the environmental Kuznets curve. The Granger causality test confirms that there is unidirectional causality running from energy consumption to greenhouse gas emissions; from economic growth to greenhouse gas emissions and a weak unidirectional causality running from greenhouse gas emissions to energy consumption; from economic growth to energy consumption. However, in the long-run there find a weak one way causality running from energy consumption and economic growth to greenhouse gas emissions.

Table 1
Summary of the existing empirical studies on the relationships between CO_2 emissions, energy consumption and GDP

Authors	Year	Country and period	Variables	Methodology	Results
Ang	(2007)	France 1960-2000	GDP, CO_2, EC	EKC, VECM, ARDL	GDP→EC GDP→ CO_2
Ang	(2008)	Malaysia 1971-1999	GDP, CO_2, EC	VAR	EC→ CO_2
Apergis and Payne	(2009)	6 central American countries 1971-2004	GDP, CO_2, EC	EKC, panel VECM	CO_2 ↔GDP EC→ CO_2
Haliacioglu	(2009)	Turkey 1960-2005	GDP, CO_2, EC	VECM, ARDL	CO_2 →GDP
Sadorsky	(2009)	G7 1980-2005	GDP, CO_2, REC		GDP, CO2 affect (+) REC
Soytas and Sari	(2009)	Turkey 1960-2000	GDP, CO_2, EC, K,L	VAR	CO_2 →EC
Zhang and Cheng	(2009)	China 1960-2007	GDP, CO_2, EC,K,URBAN POPULATION	Toda and Yamamoto procedure	GDP→EC EC→ CO_2
Lean and Smyth	(2010)	5 Asean countries 1980-2006	GDP, CO_2, ELEC	EKC, VECM	CO_2 →EC
Lotfalipour et al.	(2010)	Iran 1967-2007	GDP, CO_2, EC	Toda-Yamamoto	GDP→ CO_2
Ozturk and Acaravci)	(2010)	Turkey 1965-2006	GDP, CO_2, EC,L	VECM, ARDL	CO_2 →GDP

Menyah and Woldrufael	(2010)	Afrique du Sud 1965-2006	GDP, CO_2, REC, Nuclear Energy Consumption	ARDL	$CO_2 \leftrightarrow$ GDP NEC$\rightarrow CO_2$ GDP$\rightarrow$ REC
Arouri et al	(2012)	MENA 1981-2005	GDP, CO_2, EC	Panel unit root tests and cointegration	EC$\rightarrow CO_2$
Payne	(2012)	US 1949-2009	GDP, CO_2, REC	TY procedure	No causality on REC
Omri	(2013)	MENA 1990-2011	GDP, CO_2, EC, K,L	GMM	EC$\rightarrow CO_2$ $CO_2 \leftrightarrow$ GDP
Ozcan	(2013)	12 Middle East countries 1990-2008	GDP, CO_2, EC	Panel unit root test, panel cointegration method and panel causality tests	GDP$\rightarrow$EC ST GDP$\rightarrow$ CO2 LT EC$\rightarrow$CO2 LT
Sebri and Ben Salha	(2014)	BRICS countries 1971-2010	GDP, REC, NREC, CO_2, Trade	VECM, ARDL	$CO_2 \rightarrow$GDP GDP$\leftrightarrow$REC CO2$\leftrightarrow$REC LT
Cowan et al.	(2014)	BRICs 1990-2010	GDP, CO_2, ELEC	Panel causality analysis	GDP$\leftrightarrow$ELEC Russia No causality for Brazil GDP$\leftrightarrow$CO2 Russia GDP$\rightarrow CO_2$ South Africa $CO_2\rightarrow$GDP Brazil EC$\rightarrow CO_2$ India
Shafiei and Salim	(2014)	OCDE countries 1980-2011	GDP, CO_2, REC,NREC, urbanization, population size, industrialization, population density	STIRPAT	CO2$\rightarrow$REC GDP$\rightarrow$ CO2 CO2$\leftrightarrow$NREC
Kasman and Duman	(2015)	15 European countries 1992-2010	GDP, CO_2, EC, trade openness, urban population	Panel unit root test, panel cointegration method and panel causality tests	EC$\rightarrow CO_2$ ST GDP$\rightarrow$EC ST GDP$\leftrightarrow$ EC LT GDP$\leftrightarrow$CO2 LT EC$\leftrightarrow$CO2 LT
Alshehry and Belloumi	(2015)	Saudi Arabia 1971-2010	EC, CO_2,GDP, energy price	Johansen multivariate cointegration technique	EC$\rightarrow CO_2$ EC $\rightarrow$GDP GDP$\leftrightarrow$CO2

Note: EC, CO_2 and GDP indicate Energy Consumption, CO_2 emissions and Gross Domestic Product, $\rightarrow$, $\leftrightarrow$ indicate unidirectional causality and feedback hypothesis respectively.

Mercan and Karakaya [10] investigate the relationships for selected eleven OECD countries between energy consumption, economic growth and carbon emissions over the period 1970-2011 using dynamic panel cointegration analysis. The empirical finding confirms that energy consumption affects CO_2 emissions positively. However, the effect of GDP on carbon dioxide emissions is very low and negative. Kasman and Duman [11] have analyzed the causal relationship between CO_2 emissions, energy consumption, trade and urbanization in new EU member and candidate countries over the period 1992-2010 by using a panel data analysis. The FMOLS estimations suggest the existence of an inverted U-shaped curve between real income and carbon emissions, which supports the validity of the EKC hypothesis. The Granger causality test confirm, in the short run, a unidirectional panel causality running from energy consumption, trade openness and urbanization to GDP; from GDP to energy consumption; finally from GDP, energy consumption and urbanization to trade openness. As for long run causal relationship, there is bidirectional causality between CO_2 emissions, energy consumption, GDP and trade openness. These results indicate that the carbon dioxide emissions in the sampled countries will not decrease if their economic outputs continue to increase. It is important to control the CO_2 emissions and follow the energy efficiency European program. Alshehry and Belloumi [12] analyze the relationship between carbon emissions, real GDP, energy consumption and energy price in Saudi Arabia over the period 1971-2010. They used Johansen multivariate cointegration approach. The results indicate that there exists at least a long-run relationship between energy consumption, energy price, carbon dioxide emissions and economic growth. The causality analysis showed a unidirectional causality running from energy consumption to both economic growth and CO_2 emissions; and bidirectional causality between growth and carbon emissions in the long run. Furthermore, in the short run, CO_2 emissions cause energy consumption and economic growth.

While, others studies focused on the desegregate energy consumption, particularly electricity consumption, and analyze the relationship between CO_2 emissions, GDP and electricity consumption. Acaravci and Ozturk [13] investigate this relationship for 19 European countries and they have explored the causality by using the Error Correction Model based on Granger causality. They found that in the long run, GDP and electricity consumption cause CO_2 emissions for 7 countries. In the short run, GDP causes CO_2 in Italy and Denmark, and causes electricity consumption in Greece and Italy. The both bidirectional causality found was between GDP and electricity consumption in Switzerland only. Pao and Tsai [14] studied the relationship between electricity consumption, GDP and CO_2 emissions in BRICS between 1971 and 2005 using panel data methods. They found bidirectional causality in the long run between GDP and electricity consumption and unidirectional causality running from CO_2 emissions to both GDP and electricity consumption. In the short run, the authors found bidirectional causality between CO_2 emissions and electricity consumption and unidirectional causality running from electricity consumption and CO_2 emissions to GDP. Akpan and Akpan [15] analyze the same relationship for Nigeria between 1970 and 2008 using a Vector Error Correction Model. They found a unidirectional causality running from GDP to CO_2 emissions. This result indicates that carbon emissions reduction can be conducted without affecting negatively the economic growth in Nigeria. The Granger causality test confirms no causality between GDP and electricity consumption and between carbon emissions and electricity consumption. Cowan et al. [16] reexamine the causal links between electricity consumption, economic growth and CO_2 emissions in the BRICS countries for the period 1990-2010 using panel causality analysis. There empirical results support different results between countries. There is no causality between electricity consumption and economic growth in Brazil, India and China. There is unidirectional causality running from economic growth to electricity consumption in South Africa and bidirectional causality in Russia. No causality found between CO_2 emissions and electricity consumption in Russia, China and South Africa. In India, there is a unidirectional causality running from electricity consumption to CO_2 emissions. Economic growth causes CO_2 emissions in South Africa, inversely in Russia and non-causality was found in India and China.

Most recently, a new line of standard research has focused on the relationship between renewable energy consumption, CO_2 emissions and economic growth. Sadorsky [17] finds that real GDP and CO_2 emissions had positive effects on renewable energy consumption in G7countries from 1980-2005. Menyah and Wolde-Rufael [18] explored the relationship between CO_2 emissions, nuclear energy, renewable energy and growth in USA over the period 1960-2007 using a Toda Yamamoto [19] causality test. The investigation confirms a unidirectional causality running from nuclear to carbon emissions and from CO_2 emissions to renewable energy consumption. Salim and Rafiq [20] analyze the relationship between CO_2 emissions and renewable energy consumption and income for 6 emerging countries using the dynamic OLS and fully modified OLS. They conclude that renewable energy consumption is significantly determined by income and CO_2 emissions in Brazil, China, India and Indonesia. For the same countries, the Granger causality test confirms a bidirectional causality between renewable energy consumption and CO_2 emissions in the short run and bidirectional causality between income and CO_2 emissions in Brazil, China and Turkey. Payne [21] demonstrate that real GDP and CO_2 emissions do not have effects on renewable energy in US, using Toda-Yamamoto procedure over the period from 1949-2009. Sebri and Ben Salha [22] investigate the relationship between renewable energy consumption, CO_2 emissions and economic growth for the BRICS countries over the period 1971 and 2010 within multivariate frameworks. The ARDL bounds testing approach to cointegration and Vector Error Correction Model are used to examine the longrun and causal relationships. The ARDL approach confirms the positive impact of renewable energy consumption on economic growth and vice versa. The causality test concludes a bidirectional causality between economic growth and renewable energy consumption in short and long run excepting India. And there is a bidirectional causality running among all the variables in the long run.

Shafiei and Salim [23] investigate the relationship between non-renewable and renewable energy consumption and CO_2 emissions in OECD countries using STIRPAT model over the period 1980 and 2011. Their results support the existence of an Environmental Kuznets Curve between CO_2 emissions and urbanization. They find that renewable energy consumption has a negative impact on CO_2 emissions, whereas non-renewable energy consumption has a positive and significant impact on carbon emissions. They conclude that policy makers should design and develop effective support policies to promote investment in new renewable energy technologies. Unfortunately there is no consensus yet on the results of these studies and the findings are diverse. The results regarding the direction of causality in these studies are still inconclusive. The variation must be attributed to different factors, including institutional differences between countries model specification, period, variable selection and econometric approach. To our knowledge, there have been no studies on the causal relationship between renewable and non-renewable electricity consumption, CO_2 emissions and GDP in Mediterranean countries.

3. Brief overview of renewable energy in Mediterranean countries

In the South and East Mediterranean countries, the energy demand and supply has progressively increased over the last decades and the growth rates-in comparative terms-well surpassed the ones in OECD European countries. The electricity plays a crucial role in Mediterranean regions especially in south shore and the consumption grew by an annual growth rate of about 6% between 1990 and 2010, so 3 times more than north Mediterranean countries whose grew by an annual growth rate of 1,8% (FEEM[24], p15). In the future, the higher level of economic growth and population will push up demand for electricity and will put additional pressure on the existence electricity infrastructure, requiring major invest on the construction of new electricity generation facilities, transmissions lines and distribution networks.

The regional electricity generation mix still predominated by fossil fuel. Indeed, the trend scenario of the Energy World Organization shows that the energy consumption in Mediterranean region will be based on oil in 2030. These countries will import 39% of their need on oil and 28% on natural gaz. This consumption will increase CO_2 emissions and this situation is incompatible with environmental preoccupations and the international commitments in terms of sustainable development. However, in this region there is a huge potential of renewable energy resources, such as wind and solar and biomass energies. The South and East Mediterranean countries has a high rate of sunshine between 2,700 and 3,400 hour per year, and the average annual radiation is between 1,900 Kwh per m^2 in the coastal areas and 3,200 Kwh per m^2 in the desert areas. In the framework of the "Solar Atlas for the Mediterranean" the economic potential of CSP in the overall South and East Mediterranean countries could be estimated at 431,382 TWh/year in 2030 and in the North Mediterranean region 1,450 TWh/year. The potential of photovoltaic is calculated to 122 TWh/year in the South shore, and only 22 TWh/year in the North shore. The wind potential is also high; the wind speed is between 6 and 11 meter per second. The technical potential is estimated to 21,967 TWh/year in Southern and East and 648 TWh/year in Northern (FEEM 2015). Nevertheless of these high potential, the share of renewable energy production still below needs. So, the cooperation between both of them can have many advantages. The North shore has the human skills, the technology and the experience while the south shore has abundant natural resources. Over the world, the renewable energy represent in 2012[2], 20% of global final energy consumption and a share of electricity production by renewable energy in 2012 represent 21.7%, is lower comparatively to fossil fuel 68.1% and nuclear 10.9%. In Mediterranean countries, the share is fluctuating from one to other countries (fig.1). In 2012, Spain consume 35.34% of its electricity by renewable energy, in Turkey 33.3%, in Italy 28.89% and France and Greece around 18%.The share is more high in developed countries comparatively to developing countries. Only Morocco is making efforts to increase a renewable electricity consumption, which rose from 5.94% in 2000 to 9.47% in 2012 in North Africa. The share still low for Tunisia (2.38%) and Algeria (1.61%).

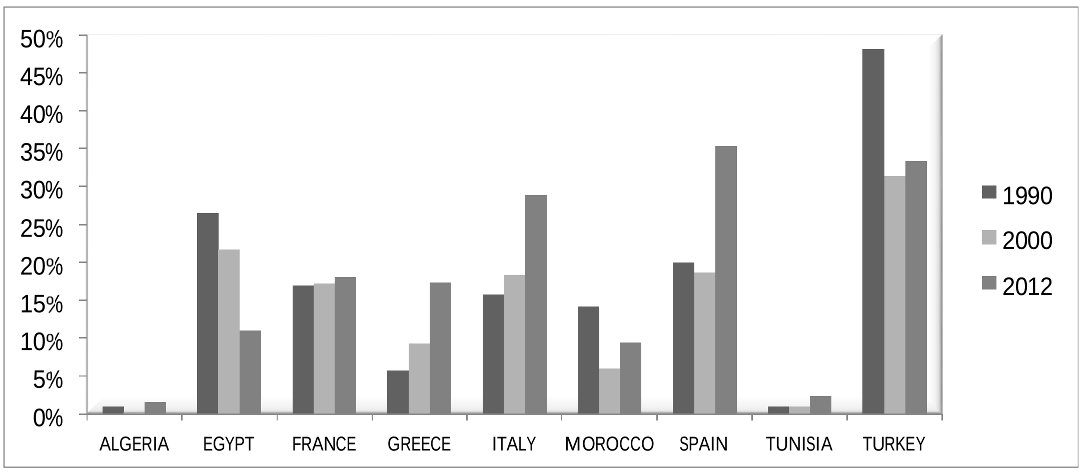

Fig 1. Share of renewable electricity consumption in total electricity consumption between1990-2012. Source: IEA2015

The fig.2 illustrates the change in renewable electricity consumption in Mediterranean countries between 1980 and 2012. There is only 3 countries who increase its renewable electricity consumption through this period: Italy 46.85%, Spain 65.99% and Turkey 82.54%.

[2] Key World Energy Statistics, 2014, IEA.

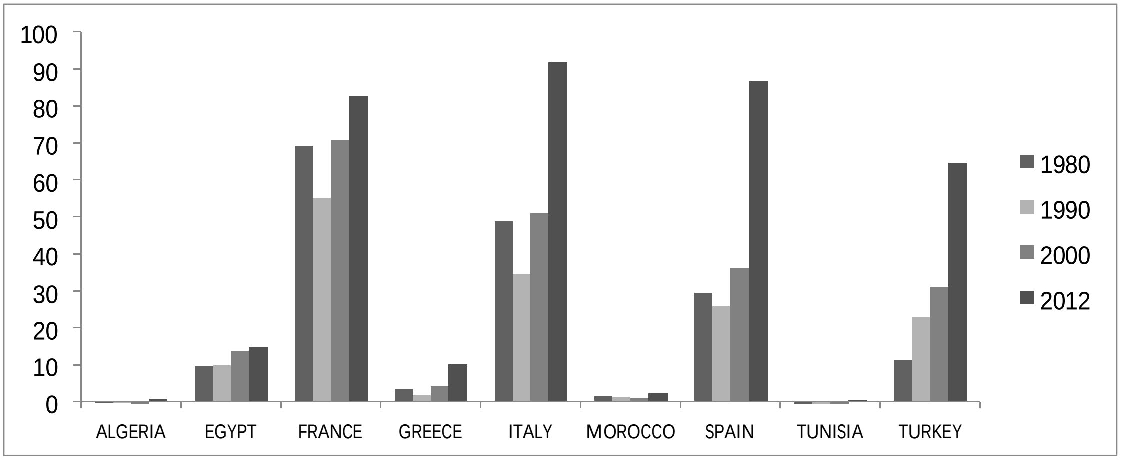

Fig 2. Renewable electricity consumption. Source: IEA2015

The last decades, many renewable energy projects was developed, the aim is to develop cooperation between the two shore of Mediterranean countries might to export to Europe the electricity potentially produced by South and East Mediterranean countries via solar and wind energy resources through HVDC (high voltage direct current) electricity interconnection. We can named TREC (Trans Mediterranean Renewable Energy Cooperation) developed in 2003, DESERTEC in 2009, MSP (Mediterranean Solar Plan) in 2008, MEDGRID created in 2010 and RES4MED (Renewable Energy for Mediterranean) in 2012. Almost, all government adopted their own national renewable energy plans with the aim to enhance their domestic exploitation of renewable energy resources. And many countries in the south of Mediterranean put in place dedicated agencies to support their renewable energy plans and implement the policy of the government on the ground.

Despite all its efforts, the share of renewable energies in the region remains low and the projects fail to start, this is explained essentially by the different barriers (commercial, infrastructural regulatory and financial) prevailing in the region and particularly on the Southern and Eastern Mediterranean countries. The most Blocking barrier is the energy subsidies. The justification of this political economy of energy, among other raisons, is: to limit energy poverty and also to boost domestic supply. But there is a negative consequence of these subsidies: discourage efficient energy use, limit financial resources available to invest in the energy sector, limit the competitiveness of renewable energy source. [24]

4. Methodology

4.1. Data and model

Our empirical analysis is based on annual time series data over the period 1980-2012 for 9 Mediterranean countries. Data on electricity consumption, renewable and non-renewable (Billion kilowatt hours) are obtained from the International Energy Agency (IEA, 2012). The data on real GDP per capita (constant 2005 US$), CO_2 emissions (metric tons) are taken from World Development Indicator for the World Bank (WDI 2015).

In this paper, we investigate the causality between renewable and non-renewable electricity consumption, CO_2 emissions and GDP. Consequently, the logarithmic form of the estimated equation is as follow:

$$Ln\mathrm{CO2}_{it} = \alpha_0 + lnGDP_{it} + lnNREC_{it} + \ln REC_{it} + e_{it} \quad (1)$$

Where CO_2, GDP, NREC, REC denote CO_2 emissions, Gross Domestic Product, Non Renewable Electricity Consumption, Renewable Electricity Consumption, respectively. e is the error term. The subscript *i* refers to countries and *t* denotes the year.

4.2. Estimation strategy

To explore the dynamics of the relationships between both CO_2 emissions, electricity consumption and GDP the following steps are performed.

4.2.1. Testing cross section dependence

One important issue in a panel causality analysis is to take into account possible cross-section dependence across regions. First, the cross-section dependence is tested to decide which unit root test would be appropriate. We use the Lagrange Multiplier test (LM) developed by Breusch and Pagan [25]. This test is favorable if T is larger than N. Pesaran's [26] cross-sectional dependence (CD) test is valid when *T<N* and can be used with balanced and unbalanced panels. A growing body of the panel-data literature concludes that panel-data models are likely to exhibit substantial cross-sectional dependence in the errors (De Hoyos and Sarafidis [27]).Cross correlations of errors could be due to omitted common effects, spatial effects, or could arise because of the presence of common shocks and unobserved components that ultimately become part of the error term (Robertson and Symons [28]; Pesaran [26], Anselin [29]; Baltagi [30]).

The presence of some form of cross-sectional correlation of errors in panel data applications in economics is likely to be the rule rather than the exception. According to De Hoyos and Sarafidis [27], one reason for this result may be that during the last few decades we have experienced an ever-increasing economic and financial integration of countries and financial entities, which implies strong interdependencies between cross-sectional units. This is because high degree of economic and financial integrations makes a region to be sensitive to the economic shocks on the region.

However, ignoring cross-sectional dependence of errors (as it is commonly done by practitioners) can have serious consequences. It is well known that ignoring cross-sectional dependence may affect the first-order properties (unbiasedness, consistency) of standard panel estimators and leads to incorrect statistical inference. The decrease in estimation efficiency can become so large that, in fact, the pooled (panel) least-squares estimator may provide little gain over the single-equation ordinary least squares (Phillips and Sul [31]).

4.2.2. Panel unit root tests

As a first step, it is necessary to check whether each variable of interest is stationary. Since the seminal works of Levin and Lin [32, 33] and Quah [34], the investigation of integrated series in panel data has known a great development and panel unit root tests have been applied to various fields of research. For this purpose, it is common practice in the literature to perform several panel unit root tests, given the shortcomings of any single test with regard to sample size and power properties.

A number of panel unit root tests have been developed in the literature (Levin and Lin [32], Im, Pesaran and Shin [35], Harris and Tzavalis [36], Madala and Wu [37], Choi [38], Hadri [39], Levin, Lin and Chu [40], Pesaran [41]). Two generations of tests can be distinguished. The first generation of panel unit root tests is based on the crosssectional independency hypothesis and includes the contributions of Maddala and Wu [37], Choi [42], Hadri [39], Im et al.[43].

Various tests have been proposed in response to the need for panel unit root tests that relax the cross-sectional independence assumption and allows for cross-sectional dependence. The second generation unit root tests includes the contributions of Bai and Ng [44], Moon and Perron [45], Smith et al. [46], Pesaran [41] or Pesaran et al. [47]. This last category of tests is still under development, given the diversity of the potential cross-sectional correlations. In the presence of cross-section dependence, "first generation" panel unit root tests tend to reject the null hypothesis of a unit root excessively.

Hence we propose two different panel unit root tests: the Breitung [48] test, which assume homogeneity among each cross section, and a more recent CADF test suggested by Pesaran [41].

4.2.3. Panel cointegration tests

The next step in our analysis is to apply the cointegration test. When both series are integrated of the same order, we can proceed to test for the presence of cointegration i.e whether there is a long-run relationship between the variables. Consequently, panel cointegration test can be used to study the long-run equilibrium process. For this purpose we used the recently Durbin Hausman group mean cointegration test developed by Westerlund and Edgerton [49]. This test allows for cross-sectional dependence and they do not rely heavily on a priori knowledge regarding the integration orders of the variables which allows the stability ranks of the independent variables to be different. Thus, it can be applied under very general conditions.

4.2.4. Estimation of long-run relationship

As stated by Philips and Sul [50], when models suffer from the problem of cross-section dependence, heteroskedasticity and serial correlation panel estimators can results in misleading inference and even inconsistent estimators. Pesaran have suggested an estimation method to alleviate some of these difficulties, called Common Correlated Effects (CCE), which has been further developed by Kapetanios et al. [51], Chudik et al. [52]. The Pesaran [41] CCE estimator allows exhibits more advantages. It does not involve estimation of unobserved common factors and factor loadings. It allows for unobserved factors to be correlated with exogenous regressors and idiosyncratic components to be independent across countries. Furthermore, the proposed estimator is still consistent under different situations such as serial correlation in errors, unit roots in the variables and possible contemporaneous dependence of the observed regressors with the unobserved factors (Chudik et al. [52]).

In this step we employ Common Correlated Effects Mean Group (CCEMG) estimator, proposed by Pesaran [43], to estimate the long-run estimators that account for cross sectional dependence. Eberhardt [53] stated that CCEMG approach is robust to the presence of a limited number of “strong” factors and an infinite number of “weak” factors. In addition, the estimator is robust to non-stationary common factors (Kapetanios et al. [51]).

4.2.5. Granger causality test: Panel short-run and long-run causality test

Given the existence of a cointegration relationship, the next step is to determine the source and the direction of causality between the variables. Panel Granger causality is tested following the two-step Engle-Granger causality procedure (Engle and Granger (54]). To identify the sources of causality and distinguish between short-run and long-run relationships we apply the Pooled Mean Group (PMG) estimator proposed by Pesaran et al. [55]. The PMG estimator (see Pesaran et al. ([55], [56]) relies on a combination of pooling and averaging of coefficients.

This particular estimator allows us to deal with an important problem that confronts empirical panel studies: that of parameter heterogeneity. The major advantage of PMG is that it allows short-run coefficients, including the intercepts, the speed of adjustment to the long-run equilibrium values, and error variances to be heterogeneous country by country, while the long-run slope coefficients are restricted to be homogeneous across countries. In addition, the PMG estimation technique is robust to outliers and the choice of lag orders.

The basic PMG estimator involves estimating an ARDL model of order (pi, qi). In this case, the ARDL dynamic panel specified as follows:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij}\, y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij*} X_{i,t-j} + \mu_i + \quad_{it} \quad (2)$$

Where $X_{it}(k * 1)$ is the vector of explanatory variables; μ_i represent the fixed effects; λ_{ij} are scalars; and δ_{ij^*} are $(k * 1)$ coefficient vectors.

It is convenient to work with this following re-parameterization (see Pesaran et al. [55]) of Eq. (2):

$$\Delta y_{it} = \varphi_i(\, y_{i,t-1} + \theta_i' X_{it}) + \sum_{j=1}^{p-1} \lambda_{*ij}\, \Delta y_{i,t-1} + \sum_{j=0}^{p-1} \delta_{ij'*} \Delta X_{i,t-j} + \mu_i + \quad_{it} \quad (3)$$

Where:

$$\varphi_i = -\,(-\sum_{j=1}^{p} \lambda_{ij})$$

$$\theta_i = \sum\nolimits_{qj=0} \delta_{ij} / (1 - \sum\nolimits_k \lambda_{ik})$$

$$\lambda^*_{ij} = -\sum_{m=j+1}^{p} \lambda_{i,m}\,;\; j = 1, 2, \dots, p-1$$

$$\delta_{ij}{}'^{*} = \sum_{m=j+1}^{q} \delta_{i,m}\,;\; j = 1, 2, \dots, q-1$$

φ_i represents the error-correction speed adjustment term. The long run equilibrium relationship can be tested statistically using the significance of φ_i. If the null hypothesis $\varphi_i = 0$ then there would be evidence of long-run equilibrium, i.e. the variables are cointegrated and there is evidence of long run causality running from independent to dependent variable. The direction of short-run causality can be determined by testing the significance of the coefficients of each explanatory variable, that is, $\delta_{ij}{}'^{*} = 0$ in Eq.3.

In our case we can specify Eq.4 in terms of variables in Eq.1 as follows:

$$\Delta LnCO_{2itit} = \varphi_i (y_{i,t-1} + \theta_i' X_{it}) + \sum_{j=1}^{p-1} \lambda_{*ij} \Delta LnCO_{2i,t-1} + \sum_{j=0}^{p-1} \delta_{ij}'_{*} \Delta X_{i,t-j} + \mu_i + \quad_{it} \quad (4)$$

Where X is the vector of explanatory variables: LnGDP, LnNREC and LnREC. In the same way we can specify equation for other variables.

5. Empirical analysis and results discussion

5.1. Cross dependence tests

To test for cross-sectional dependency, the LM test of Breusch and Pagan [25] has been used in this study. The Breusch and Pagan test statistic is asymptotically distributed as chi-squared with $N(N-1)/2$ degree of freedom, under the null hypothesis of cross-sectional independence. From Table 2, it is clear that the null hypothesis of no cross-sectional dependency across the countries is decisively rejected at the 5% significance level. This finding implies that a shock occurred in one of these Mediterranean countries seems to be transmitted to other countries. To assess whether the cross-section independence assumption of the "first generation" tests is valid, we start with a test for error cross-sectional dependence (CD) as suggested by Pesaran [26].

Table 2

Correlation matrix of residual

	e1	e2	e3	e4	e5	e6	e7	e8	e9
__e1	1.0000								
__e2	-0.2937	1.0000							
__e3	0.6518	-0.6267	1.0000						
__e4	-0.6203	0.5313	-0.8018	1.0000					
__e5	0.3280	-0.1962	0.5606	-0.0357	1.0000				
__e6	-0.2217	-0.2420	-0.2955	0.2845	-0.2370	1.0000			
__e7	-0.4815	-0.1588	0.1532	0.1107	0.3007	-0.0907	1.0000		
__e8	-0.1518	0.1227	0.1052	0.3263	0.5816	0.0945	0.4762	1.0000	
__e9	-0.6080	0.4918	-0.8670	0.8326	-0.4081	0.2497	-0.0463	-0.1158	1.0000

Breusch-Pagan LM test of independence: chi2(36) = 205.742, Pr = 0.0000
Based on 32 complete observations over panel units

5.2. Unit-root test

In order to examine the stochastic properties of the four series (unit roots and stationarity), the Pesaran CADF [41] and Breitung [48]; Breitung and Das [57]) tests have been applied as we can see in Table 3.

Once we have found the presence of dependence in the variables, we have studied their order of integration using different tests that account for dependence. All are representative of the "second generation" panel unit root tests. These tests relax the restrictive assumption of cross sectional independence.

Table 3

Unit root test

Breitung Method	**PCO_2**	**GDP**	**REC**	**NREC**
Level	3.7212	4.9795	0.1513	4.1085
	(0.9999)	(1.0000)	(0.5601)	(1.0000)
First difference	-2.8656	-5.6083	-7.4590	-5.1068
	(0.0021)***	(0.0000)***	(0.0000)***	(0.0000)***
Pesaran Approch	**PCO_2**	**GDP**	**REC**	**NREC**
Level	-0.313	0.271	-1.292	2.248
	(0.3770)	(0.6070)	(0.0980)	(0.9880)
First difference	-7.085	-4.317	-7.518	-4.591
	(0.0000)***	(0.0000)***	(0.0000)***	(0.0000)***

Notes: The lambda-statistics and the standardized Zt-bars are reported for the Breitung (2000) and Pesaran (2007) unit root tests, respectively; p-values in parentheses; the null hypothesis for all tests is ''Panels contain unit roots''.

First, we apply Pesaran's [41] CADF test (Cross Augmented Dickey Fuller). To eliminate the cross dependence the standard DF regressions are augmented with cross-sectional averages of lagged levels and first differences of the individual series. The proposed test has the advantage of being relatively robust with respect to cross-sectional dependence, even if the autoregressive parameter is high. In addition, the approach is intuitive and simple to implement. It is also valid for panels where N and T are of the same orders of magnitudes. Second, we also apply Breitung test ([48]; Breitung and Das [57]) a suitable approach when cross-correlation is pervasive, as in this case. The Breitung test assumes that the error term $_{it}$ is uncorrelated across both i and t. Breitung test ajustes the data before fitting a regression model so that bias adjustments are not needed. In addition, the Breitung procedure allows for a prewhitening of the series before computing the test. The null hypothesis of these unit root tests is that all series contain a unit root.

5.3. Cointegration tests

Given that each of the variables presents a panel unit root, we need then to check whether there is a long-run relationship between the variables using the error correction based cointegration test for (unbalanced) panels developed by Westerlund [58]. The existence of negative error correction term is taken as proof for cointegration. To accommodate cross-sectional dependence, critical values are obtained through bootstrapping. The test is meaningful for application in our case for the following reasons: First, it is general enough to allow for a large degree of heterogeneity, both in the long-run cointegration relation and in the short-run dynamics (Persyn and Westerlund [59]). Second, it is developed to cope with cross-sectionally dependent data. Third, the test comes along with an optional bootstrap procedure that allows for multiple repetitions of the cointegration tests which is meaningful since we have indications for cointegration in the panel. While, the group-mean tests (Gt and Ga) examine the alternative hypothesis that at least one unit is cointegrated, the panel tests (Pt and Pa) have the alternative hypothesis that the panel is cointegrated as a whole (Persyn and Westerlund [59]).

As we can see in Table 4, the results of Westerlund's test shows that Groupe-t and Panel-a test statistics are significant and reject the null hypothesis of no cointegration indicating some evidences of cointegration.

Table 4
Westerlund cointegration test

Statistic	Value	Z-value
Group-t	-2.157	-1.313
Group-a	-7.208	0.290
Panel-t	-5.109	-0.883
Panel-a	-11.662	-3.511

*Notes: *** and ** indicate the test statistics are significant at 1% and 5% levels, respectively. Following Westerlund [59] (2007), the maximum lag length is selected according to $4(T/100)^{2/9}$. See Persyn and Westerlund (2008) for the details.*

5.4. Long-run estimation

Empirical evidence suggests that CO_2, GDP, REC and NREC are cointegrated. To further explore the sustainability condition, we estimate the long-run parameters in the cointegration relation of each panel using the Cross Correlated Effects (CEE) and the Common Correlated Effects Mean Group (CCE-MG) estimation procedures developed by Pesaran [41] CCE-MG estimations. In Table 5, we report estimates of Pesaran's long-run CCEMG.

Table 5
CO2 coefficients for the CCE-MG estimator

		Wald chi2(3) = 8.93 Prob> chi2 = 0.0302				
PCO2	Coef	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
GDP	0.4332657	0.2045031	2.12	0.034	0.32447	.8340845
REC	-.0025497	0.0011601	0.54	0.092	-.0365528	.0314534

NREC	0.3525521	0.1728916	2.04	0.041	0.136907	.6914134

Root Mean Squared Error (sigma): 0.0187 (RMSE uses residuals from group-specific regressions: unaffected by 'robust').

The results chow that GDP per capita and non-renewable electricity have positive and significant effects on CO_2 emissions, implying that increase in both GDP per capita and non-renewable electricity consumption in Mediterranean countries lead to increases in CO_2 emissions. In addition, we can observe that the coefficient for GDP is greater than that for NREC. This result demonstrates that in the long run, GDP per capita contributes more to increased pollutant emission than NREC in Mediterranean countries. The coefficient of GDP suggests that a 1% increase in this factor leads to in an increase in CO_2 emissions by 0.35%. Similar results have been found by Shafiei and Salim [23] for the OECD countries. However, it is found that renewable electricity consumption has a negative effect on CO_2 emissions, thus 1% increase in electricity consumption reduces CO_2 emissions by 0.002% in the long run. This finding is consistent with the negative relationship found by Shafiei and Salim [23] for the OECD countries.

5.5. Short-run and long-run causality test

The result of short and long run Granger causality test are reported in table 6 bellow. The findings are interpreted essentially for the relationships between CO_2 and the others variables.

Table 6
Results of Granger causality test

Dependent variables	Sources of causation (independent variable)				
	Short-run				Long-run
	ΔCO_2	ΔGDP	$\Delta NREC$	ΔREC	ECT
ΔCO_2	–	.4135 (0.000) ***	-.00160 (0.000)***	.1205 (0.006)***	-.2329 (0.002)***
ΔGDP	.1197 (0.033)**	–	.0093 (0.074)*	.0794 (0.079)*	-.0272 (0.143)
$\Delta NREC$	.2188 (0.114)	0.0213 (0.886)	–	-.0069 (0.058)*	-.1692 (0.017)**
ΔREC	-1.0273 (0.022)**	8.0581 (0.005)**	-4.8901 (0.000)***	–	-.0035 (0.141)

*Note: p-value are given in parentheses. ***, ** and * indicate the test statistics are significant at 1%, 5% and 10 % levels, respectively*

Regarding to the long-run causality, ECT's coefficients are negative and statistically significant where CO_2 and non-renewable electricity are the dependent variables. This is implying that there is a bidirectional long-run causality between CO_2 emissions and non-renewable electricity consumption. This result is consistent with the findings of Shafiei and Salim [23]. In addition, we find also unidirectional long-run causality running from renewable electricity consumption to CO_2 emissions is in contrast with the results of Shafiei and Salim [23] for OECD countries and Menyah and Wolde-Rufael [18] for the US. The finding of unidirectional causal relationship running from GDP to CO_2 emissions is in line with the results of Acaravci and Ozturk [13] and Akpan and Akpan [15]. This result indicates that controlling and reducing CO_2 emissions don't affect economic growth for this panel. Similarly, there is unidirectional causality running from GDP to non-renewable electricity consumption. This result was finding by Apergis and Payne [60] and Tugcu et al. [61] for Japan and England. This is implies that energy conservation policies may be efficient to reduce pollutant and will have no adverse effect on the real output growth. When the dependent variable is GDP, the ECT coefficient is negative but no significant, so there isn't causality running from CO_2 emissions, renewable and non-renewable electricity consumption to GDP in the long run. The same conclusion can be made if the dependent variable is the renewable electricity consumption. There is no causality running from CO_2 emissions, non-renewable electricity consumption and GDP to renewable electricity consumption. The non-causality between renewable electricity consumption and GDP is finding by Payne [62] and Menegaki [63]. The Fig.3 recapitulates the long-run causal relationship between the four series for the panel.

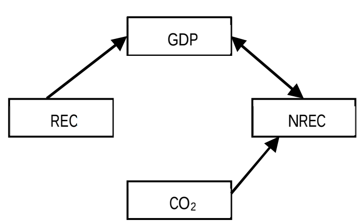

Fig. 3: Interaction between variables in long-run

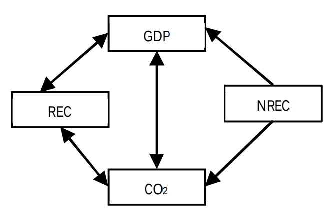

Fig.4: Interaction between variables in short-run

Turning to the short-run Granger causality relationship, the empirical results indicate the existence of bidirectional causality running between renewable electricity consumption and GDP. This result is similar to the finding by Sadorsky [7], Apergis and Payne [64], Beldiriçi [65] and Sebri and Ben Salha [22]. This is indicates that is economic growth granger cause renewable energy consumption and mutually influence each other in Mediterranean countries in the short run. Therefore, the development of renewable energy resource may lead to a significant positive impact on economic growth. However; any negative shock in the process may have a negative impact on economic growth in the region.

Renewable energy is one determinant of growth in Mediterranean's countries and the increase in income is a core factor driving the development of renewable energy sector. So governments of Mediterranean's countries considered in this study should be developed more renewable energy consumption and promote investment in new renewable energy technologies. Similarly, we find a bidirectional causality between CO_2 emissions and renewable electricity consumption. This result is in line with those finding by Salim and Rafiq [20]. Thus CO_2 emissions boost policy maker's to take different policy and measures of scaling down fossil energy consumption and developing more renewable energy. A bidirectional causal relationship is confirmed between CO_2 emissions and GDP and this result is consistent with the findings of Salim and Rafiq [20] for 6 emerging countries and Omri [7] for MENA countries. This implies that degradation environment have an impact on economic growth. The evidence seems to suggest that to reduce pollutant emissions it may sacrifice its economic growth. Finally, the empirical result suggests that there is bidirectional causal relationship between renewable electricity consumption and non-renewable electricity consumption.

As shown in Table 6, there is unidirectional causality running from non-renewable electricity consumption to GDP. This same result is finding by Hamit-Haggar [9]. The unidirectional causality from non-renewable electricity consumption to dioxide carbon emissions without feedback implies that energy conservations policies are determinant to limit pollutant and environment degradation. And the absence of causality running from GDP to non-renewable electricity consumption attest that energy conservations policies, such as controlling carbon emissions and rationing energy consumption, have no adverse effect on the real GDP of this panel. The Fig.4 recapitulates the short-run causal relationship between the four series for the panel.

6. Conclusion

In this study, we aimed to explore the dynamic relationship between renewable, non-renewable electricity consumption, CO_2 emissions and GDP for 9 Mediterranean countries over the period 1980-2012. To address the limitation of prior research we used the recent developed panel data methods that take into account cross section dependence across regions. In addition, statistical techniques used in this study allow to better distinguish between the short- and long- term causality; and takes into account possible endogeneity and heterogeneity. Our panel cointegration and causality test found several interesting findings and the results have clear implications for the implementation of future policies on promoting renewable energies in combination with macroeconomic policies in Mediterranean countries.

First, the results indicate the presence of a short-run bidirectional causality running from CO_2 emissions to GDP, renewable and non-renewable electricity consumption. We find also a feedback hypothesis between real GDP and renewable electricity consumption. So, the renewable energy is a determinant factor of growth and vice versa. The unidirectional causality running from non-renewable electricity consumption to GDP confirm that energy conservation policy will have no adverse effect on real output. And the unidirectional causality running from non-renewable electricity consumption and CO_2 emissions confirm the role of non-renewable electricity to affect environment; so it's important to limit this kind of energy more pollutant than renewable energy. Second, in the long-run, there seems in one hand bidirectional causal relationship between non-renewable electricity consumption and dioxide carbon emissions. In other hand, there is non-causal relationship finding running from CO_2emissions to real GDP; from non-renewable electricity consumption to real GDP. This results implies that energy conservation policy can be conducted without affecting real output.

The results of this research will be interesting in the sense that provide an important energy and economic policy implication for the Mediterranean countries.

Our results imply that the adoption of policies designed to encourage the development of renewable energy sources (e.g., wind, solar) and increased energy efficiency are the primary ways to future reduction of pollutant emissions and sustain the economic growth in Mediterranean countries. Results of this study could provide policymakers with a better understanding the energy demand trends and to measure progress towards energy efficiency and renewable to better target new developments, thus offering some guidance on energy performance policy. The projections for growth in demand for energy, and especially electricity, in the EU Mediterranean neighborhood until 2020 are very high. In this context, expanding renewable energy sources energy is a cornerstone of the MED-09 countries' efforts to address energy security of supply, CO_2 emissions, and climate change issues.

This findings, suggest that increasing the supply of renewable energy would allow the replacement of carbonintensive energy sources and significantly reduce global warming emissions in the North and South Mediterranean countries. Policy makers should encourage more effort to promote renewable energy and energy efficiency across countries between north and south shore of Mediterranean. It is more than urgent to promote deeper regional energy cooperation and developing concrete strategies to exploit the strong levels of complementarity and interdependence between the different Northern and Southern countries by taking into account the peculiarities of each country in the region. The huge potential of renewable energy sources in the

Mediterranean basin might provide mutual benefits to both sides of the Mediterranean in terms of energy security, replacing carbon-intensive energy sources, providing affordable electricity, stabilizing energy prices, economic growth and job creation.

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