The investments in renewable energy sources: do low carbon economies better invest in green technologies?

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2011

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ABSTRACT: The aim of this study is to analyse the driving of investment in renewable energy sources in low carbon and high carbon economies. To address these issues, a dynamic panel analysis of the renewable investment in a sample of 29 countries was proposed.

Results demonstrate that the dynamic of investments in renewable sources is similar in the two panels, and depends by nuclear power generation, GDP and technological efficiency. Results show that countries try to reduce their environmental footprint, decreasing the CO_2 intensity . Based on the estimation results, we think that energy sustainability passes through the use of renewable resources that can complement the nuclear technology on condition that both exceed their limits.

Keywords: CO_2 intensity; Dynamic model; Nuclear Energy.
JEL Classification: C23;O13; Q42;

1. Introduction and Background

It has reached consensus worldwide that greenhouse gas (GHG) emissions due to anthropogenic causes are contributing to the ongoing global warming. In fact, the overall economic growth is based on traditional fossil fuels and, particularly, on a return to significant use of coal resulting in increased CO_2 emissions arising from the energy sector (Jaccard et al., 2003; Soytas and Sary, 2009), responsible, to a large extent, for climate change (Sadorsky, 2009).
The Kyoto Protocol, whose measures were deemed insufficient by many, has tried to limit the total emission of carbon dioxide and other greenhouse gases, addressing especially to the industrialized countries, some of which are making every effort to get out of the previous conditions of underdevelopment.
More recently, international agreements in Cancun (Mexico, December 2010) have established the necessity for technology transfer to developing countries, reiterated the urgent need to limit CO_2 emissions to keep global temperature increase in the limit of 2°C, and finally, set out certain measures for the protection of forests.
Regarding, in particular, the electricity production, all the technologies employed have some impact on the environment and therefore, beyond the normal economic considerations of reliability and safety, a special ethical responsibility towards future generations is required for focusing on the "footprint" analysis of the plant environment.
Therefore, the negative environmental impact of the energy sector may be remarkably reduced by a larger share of renewable energy sources on total electricity generation, but the implementation of renewable energy strategies, as remembered by Lund (2010) typically involve three major technological changes: energy savings on the demand side (Blok, 2005; Lund, 1999); efficiency improvements in the energy production (Lior, 1997; 2002), and replacement of fossil fuels by various sources of renewable energy (Afgan and Carvalho, 2002; 2004). If a country wants to choose a large-scale renewable energy implementation plans it has to integrate renewable sources in a new energy

systems influenced by energy savings and efficiency measures (see, *e.g.* Li, 2005; Ghanadan and Koomey, 2005), but they, in the state of the art, alone would not suffice to achieve sustainability and keep climate change manageable (Silva et al., 2011).

Recently, the International Energy Agency (IEA) has identified a possible solution in increasing energy efficiency and in reducing CO_2 emissions. Given the long lead times for developing new technologies and given the characteristics of renewable sources, the IEA recommends the use of large nuclear facilities and technologies for carbon capture and storage (Philibert, 2011).

An important issue is related to the CO_2 emissions per GDP, or CO_2 intensity of GDP, resulting from fossil fuel combustion that is highly dependent on the weather and the overall demand for power. Although it is also influenced by energy efficiency, carbon intensity is mainly subjected to energy structure, so it is a problem about energy quality (the proportion of clean energy in energy structure). Some developed countries have reduced their CO_2 impact thanks to nuclear power plant deployment. Other countries try to reduce their footprint improving energy efficiency or try the approach of changing energy structure, such as investing in renewable energy sources.

Both technologies do not produce polluting gases. A growing number of scientific works are dedicated to renewable energy sources and the impact of economic growth on its own sustainability in the medium-long perspective. Many Authors (see, e.g. Sary and Soytas, 2004; Bradley et al., 2007, Apergis and Payne, 2010) investigate the causal relationship between renewable energy consumption and economic growth in heterogeneous countries but with inconclusive results.

Other studies investigated the normative perspective and the factor promoting energy from renewable source (Bird et al., 2005; Menz and Vachon, 2006). Recently, Marques et al. (2010) analyze the drivers promoting renewable energy in European countries and finds that lobbies of traditional energy source and CO_2 emission restrain renewable deployment. Evidently, the need for economic growth suggests an investment that supports, but does not replace, the installed capacity. Obviously, physical and economic considerations require that the design and construction of new plants take their place alongside, not replace, the traditional plant.

Other Authors analyzed the nuclear energy sustainability to oppose the renewable sources. Matsui et al. (2008) examine role and potentials of nuclear energy system in a sustainable development framework.

They argue that sustainable development is pursued through a policy of energy conservation and stress the importance that nuclear power plant plays in order to safeguard the environment. Fosberg (2009) suggests that the way forward must go through the integration of renewable energy sources, because nuclear power can meet the shortage of renewable energy and Löfstedt (2008), through a parallel between Austria and Slovakia, suggests that cannot be excluded *a priori* solution other than just to pursue policies aimed at overcoming the problem, but not to progress over time.

Marques and Fuinhas (2011) try to analyze the factors behind the deployment of renewable energy, focusing on the effect of energy efficiency policies and measures. In a forthcoming paper, Romano and Scandurra (2011) highlights divergences in renewable investment decision in nuclear and not nuclear countries find the renewable energy sources and nuclear energy can be considered complementary in the production portfolio.

The aim of this study is to investigate the driving of investments in renewable energy sources in a set of countries with low CO_2 intensity and in a complementary panel of countries that presents a high CO_2 per GDP. The former panel includes countries that have a low carbon dioxide emission per unit of GDP produced. These countries could be considered as "low carbon economies" because are efficient in production processes and use, in the electricity production portfolio, a high level of CO_2 free technologies, as nuclear or renewable energy sources. The latter panel, on the contrary, includes countries with a high environmental footprint. These countries produce more CO_2 per unit of GDP. In order to investigate the divergences among countries we focus on energy efficiency and amount of nuclear electricity consumption in the production portfolio. Results allow us to have an idea for planning new power plants and understand the energy policy adopted by countries in these years in which environmental sensibility is changing.

This paper addresses these issues by means of a dynamic panel analysis of the investments in renewable sources in a sample of 29 countries with distinct economic and social structures as well as different levels of economic development.

The organization of the paper is as follows: Section 2 describes data and analyzes the energy policy of countries in the sample; Section 3 discusses empirical results and policy implications and Section 4 concludes the paper.

2. Data

The data is from the annual time series from 1980 to 2008, from the *U.S. Energy Information Administration* (EIA), of Total Renewable Electricity Net Generation (REN), Gross Domestic Product in $2000 constant prices (GDP), Energy Intensity (EI), CO_2 emissions and the Nuclear Electricity Net Consumption (Nuc).

Different ways to evaluate the development of renewable energy source are proposed in literature. One is to measure the replacement of the traditional energy sources in the total energy supply while a second method is to measure the total amount of renewable energy produced (Bird et al., 2005). Marques et al. (2010) use the contribution of renewable to energy supply as a percentage of total primary energy supply while (Carley, 2009) use the yearly logarithm of the renewable energy percentage of electricity generation.

In our paper, we explain the investment in renewable energy sources (ShREN) as the ratio between renewable generation and the differences between Total Net Electricity Generation and the Net Electricity Imports. For nuclear energy, we use the ratio of Nuclear Electricity Net Consumption (ShNUC) and the differences between Total Net Electricity Generation and the Net Electricity Imports. In this way we take into account the full portfolio in electricity generation. In fact, the remaining part, not included in the model, is all ascribable to fossil fuel.

The share of Renewable Electricity Net Generation can be considered a proxy of investments in renewable energy source while the Energy Intensity, that is the total primary energy consumption per $ of GDP (Btu per Year 2005 *U.S. $*) is a proxy of technological efficiency. In order to reduce variability, GDP, EI and CO_2 are expressed through natural logarithm.

Panel dataset of OECD countries and developing countries (Brazil, China and India) is used in order to limit the effect of the small time span of the aggregated data. There are three main issues that can be solved using a panel dataset. In fact, a panel dataset allows to:

- solve some problems of non-standard distributions of test statistics used for the identification of unit roots in the regression equations;
- have more informative data;
- reduce co-linearity between the variables.

In order to identify investment decision in countries with low CO_2 per GDP or with high CO_2 per GDP ratio we consider the median of distribution of the countries' mean of CO_2 intensity. Countries that have mean of CO_2 intensity under the median level are considered low carbon economies while countries that are in the upper tail of distribution (over the median) can be considered high carbon economies.

The sample has been split into two subsamples. The former which includes low carbon countries, and the latter including the remaining countries.

Of course, low carbon economies is a complex concept because involve a series of long-term policy plans in areas such as transport, energy and climate change. Recently, European Commission is looking at cost-efficient ways to make the European economy more climate-friendly and less energy-consuming and has proposed a roadmap (European Commission, 2011) with a detailed analysis of cost-effective ways of reducing greenhouse gas emissions by 2050. In our paper we analyze the production of goods and services, and consider as low carbon economies the countries that produce more with a lower environmental impact. Furthermore, the split of the sample using the median doesn't allow analysis that follow the principle of granularity, but the need to assure a relevant sample dimension suggests the use of median rather than the quartiles of distribution.

The first subsample, including Austria, Brazil, Denmark, Finland, France, Ireland, Israel, Italy, Japan, Norway, Portugal, Sweden, Switzerland and United Kingdom is made up of the low carbon economies.

The second subsample comprising the countries with high CO_2 per GDP: Australia, Belgium, Canada, Chile, China, Greece, India, South Korea, Luxemburg, Mexico, Netherlands, New Zealand, Spain, Turkey and USA.

Given the lack of data, countries excluded by the OECD panel are: Czech Republic, Poland, Slovak Republic, Slovenia and Germany (which is not included because of difficulty in time series reconstruction until 1989). Accession candidate countries and enhanced engagement ones are also not considered.

All the countries included in dataset are categorized as high income by World Bank. Only Brazil, Mexico, Chile and Turkey are categorized as upper middle income while China and India are in the lower middle income group.

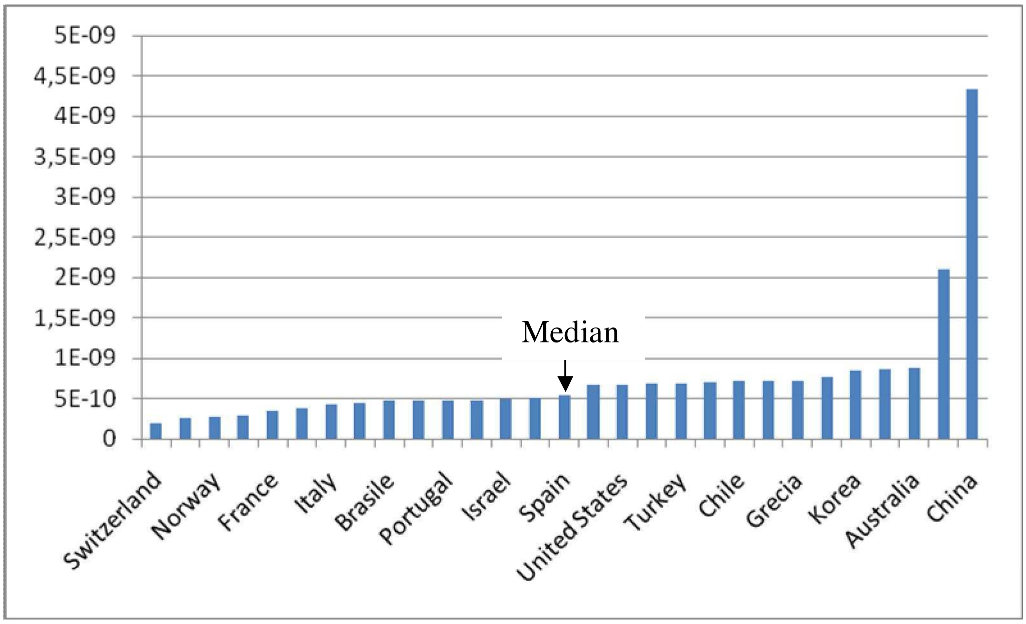

Figure 1. Carbon Dioxide Intensity (CO_2/GDP) for countries in the sample

In Figure1 we report the bar graph of the mean distribution of CO_2 intensity in the sample analyzed (Spain is on the Median). We observe that there is a relevant divergences beetween Switzerland and China, that are in the opposite of graphical representation. Furthermore, the countries that are in the low and upper middle income classess (emerging economies) are in the second part of the graph (except Brazil), near to other countries like USA, that haven't ratified the international protocols to reduce the GHG emissions. In the graphical representation of CO_2 intensity per time we observe that the indicator presents a decreasing trend (except for Brazil). This suggest that the production and environmental policies adopted by countries is based on future needs of environment and production efficiency.

2.1 The Energy Policy adopted by Countries: A Brief Exploratory Analysis

Before analyzing the dynamics of the panel of countries, an exploratory analysis to highlight the evolution of the choices of their energy policy is conducted. For this purpose, we use factor analysis, employing the same variables identified for the general model of the moments of Arellano and Bond (1991), which will be used below. To have a framework for the performance of countries considered in the 29 years between 1980 and 2008 is the main motivation of this decision. The values of the factor loadings are fairly stable over time, resulting in a distribution of the variables on the main floor that can identify a sufficiently plausible physical meaning of the two principal axes considered that explain about 70% of total variability. This is sufficient to highlight some features of the evolution of the energy choices made by various countries.

The first principal axis, opposing the variables on the scale of production (LnGDP), pollution (LnCO_2) and high energy intensity (LnEI) to the share of renewable sources (ShREN) compared to total energy production. As for the second principal axis, contrasts with the variables related to CO_2 emissions and energy intensity, compared to the shares of renewable energy production with low emission of pollutants, that is renewable and nuclear energy (ShNUC). Consequently, countries with a high production obtained with conventional pollutants, and energy inefficient should be placed in the first quadrant (Fig. 2).

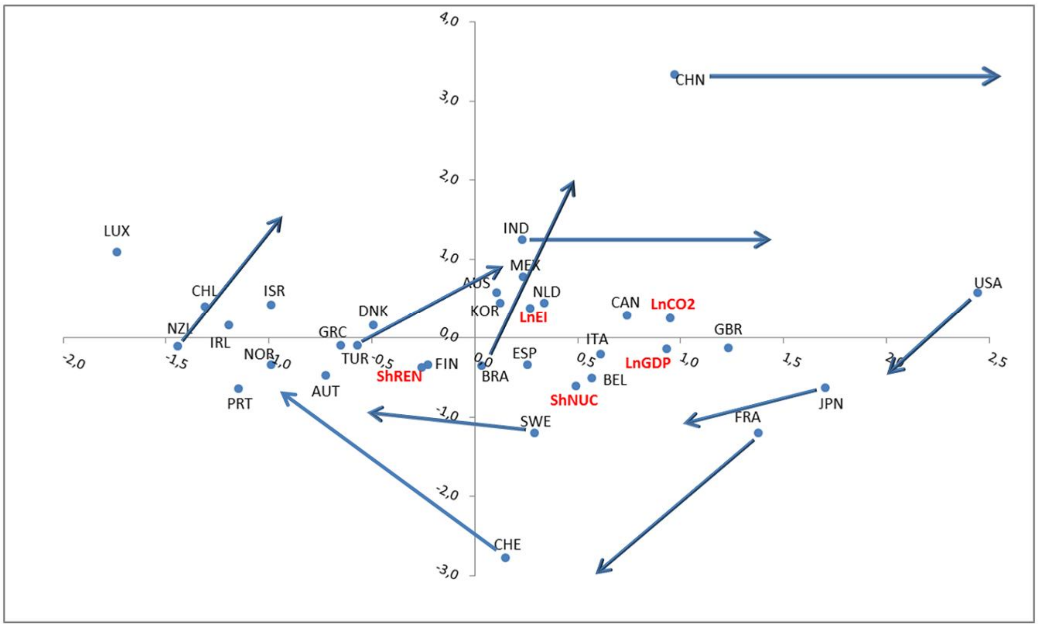

Figure 2. Factor analysis. Distribution of countries considered in the work on the first factorial plane relative to 1980. The arrows indicate the most significant shifts observed in factorial plan of 2008.

Countries with a less significant production, produced primarily with conventional production processes are in the second quadrant. Countries where a significant level of production is not achieved, however, even with an important application of renewable energy sources are placed in the third quadrant. Finally, the fourth quadrant is reserved for countries with a high production level obtained with a significant proportion of nuclear energy and, therefore, a low level of CO_2 emissions. The distribution of the countries considered in the plan shows a substantial stability over time with some notable exceptions which will be now mentioned.

Figure 2 shows the distribution of countries on the main factorial plane as it appeared in 1980. In the figure, the arrows indicate significant shifts in the positions of some countries. Such movements were observed within the 29-year period.

The first general consideration that emerges from the figure is the loss of share of world production from Western countries to the emerging reality of what can be considered as India, China, Brazil, Turkey and New Zealand. Equally we note that the number of countries gathered around the axis factor is relevant, which means that, at least with regard to the variables taken into account, they take sides energy choices not clearly defined. Some countries, however, show a clear dynamic:

- Brazil, China, India and Turkey: these countries show a marked increase in their share of world production (especially India and China) provided by a low production efficiency and high rate of pollution from carbon dioxide. In particular, Brazil and, even more, Turkey, faced with a significant increase in production, seem to have definitely opted for conventional production processes;
- Japan, France and the USA seem to have seen reduced their production levels compared to their competitors on the international market by shifting their energy choices even more, focused on the nuclear source. This is certainly evident with regard to France and Japan. For the USA, the situation in the years in between the two extremes shown in Figure 1, suggests an opportunity to consider the impact caused by the Three Mile Island accident, which, in all likelihood, hindered the development of nuclear sources;
- Sweden and Switzerland are two countries that leave the nuclear quadrant and definitely seem to have opted for renewable energy sources.

Essentially, factor analysis shows that the nuclear option does not privilege or particularly depress investment into renewable energy sources while it is quite worrying that in many countries the trend is to not renew their energy efficiency and to not invest in renewable energy with low pollution emissions.

3. Dynamic Specification of Renewable Investment

A dynamic specification of the equation that allows for slow adjustment is used. We estimate the following model:

$$y_{it} = \delta y_{i,t-1} + \mathbf{x}'_{it}\beta + u_{it} \tag{1}$$

where for country *i* (*i=1,…,N*) at time *t* (*t=1,…,T*), δ is a scalar, $y_{i,}$ is the investment in renewable energy sources, $\mathbf{x}'_{it}$ is a matrix of independent variables while the error term

$$u_{it} = \alpha_i + \tau_{it} \tag{2}$$

follows a one - way error component model where α_i denote a state – specific effect, τ_{it} denotes a year – specific effect and $\alpha_i \sim IID(0, \sigma^2_{\varepsilon})$ *e* $\tau_{it} \sim IID(0, \sigma^2_{\tau})$.

Several econometric problems may arise from estimating equation (1) (Baltagi, 2005):

- the variables in $\mathbf{x}_{it}$ are assumed to be endogenous. Because causality may run in both directions these regressors may be correlated with the error term;
- time-invariant country characteristics (fixed effects), such as geography and demographics, may be correlated with the explanatory variables. The fixed effects are contained in the error term in equation (1), which consists of the unobserved country-specific effects, αi, and the observation-specific errors, ε_{it};
- the presence of the lagged dependent variable y_{it-1} gives rise to autocorrelation.

With these assumptions, the OLS estimator is biased and inconsistent (Baltagi, 2005) so in this work we have employed the Generalized Method of Moments (GMM) estimator proposed by Arellano and Bond (1991).

The estimates are made separately for the two subsamples and for the full sample. The estimation results are in Table 1.

Table 1. Regression Results in the samples

Low Carbon Countries		**High Carbon Countries**		**Full Sample**	
Variables	Estimates	Variables	Estimates	Variables	Estimates
Constant	*-16.94****	Constant	*-8.78****	Constant	*-14.77****
$ShREN_{-1}$	*0.37****	$ShREN_{-1}$	*0.59****	$ShREN_{-1}$	*0.42****
LnEI	*0.48****	LnEI	*0.31****	LnEI	*0.44****
$LnCO_2$	*-0.52****	$LnCO_2$	*-0.38****	$LnCO_2$	*-0,53****
LnGDP	*0.59****	LnGDP	*0.31****	LnGDP	*0.52****
ShNUC	*-0.35****	ShNUC	*-0.12****	ShNUC	*-0.12****
Sargan test	351.82***	*Sargan test*	368.00***	*Sargan test*	646.70***

***: significant at 1%; **: significant at 5%;

Low carbon Countries show the estimated autoregressive component significant at lag 1. We point out that the 1% increase in the level of renewable energy at time *t-1* increases the same investment at time *t* of 0.37%, while GDP growth equates to an increase in the level of 0.59%.

Also the energy intensity shows a direct relationship with investment in renewable energy sources. Emissions of carbon dioxide and nuclear consumption have an inverse relationship with the outcome variable, as expected. Countries invest in renewable energy sources on the basis of past investments and GDP. Also the technological efficiency affects the investment in renewable energy sources. The investments in renewable sources are decreased by the presence of the nuclear power plants.

The second part of the Table 1 shows the estimates for the countries with a high CO_2/GDP ratio. They base investment decisions in new renewable power plants on the past and, like previous countries, they are conditioned by the level of production and technological efficiency and help the countries to reduce the CO_2 emission. In fact, CO_2 emission presents, as expected, an inverse relationship. The share of nuclear energy generation shows also an inverse relationship.

Furthermore, the estimates in the full sample confirm the previous results. All variables, except carbon dioxide emissions and the share of nuclear consumption, have a direct relationship with the outcome variable. In the samples, Sargan test for overidentification reject the null, so the model instruments are correctly identified.

The estimates show that past investments in renewable energy sources have a significant influence on these current investments in the three samples; in other words, there is a continuity of behavior in those countries that have shown sensitivity towards renewable energy sources.

If it can have some statistical significance, the estimates in the low carbon economies are generally higher, in absolute value, than in the high carbon sample, except the autoregressive parameters. In fact, the influence of investments in renewable energy source is stronger in the high carbon countries than to the other countries (low carbon). The former try to invest mostly in renewable sources in order to reduce their footprint and respect the international agreement that they ratified.

Significant is the inverse relationship between renewable investments and share of nuclear consumption. Probably, the continuous base load electricity ensured by nuclear power plants and the absence of greenhouse gas emission allow these countries to invest in additional renewable energy in a complementary way, in order to reach an optimal energy mix and to ensure the subsidies for investment in renewable energy.

Regarding industrial production technologies, factor analysis showed that the fast-growing countries tend to produce without particular attention to the environmental impact of production processes. Other countries traditionally stable in the high income cluster tend, instead, to show more attention to technologies with lower environmental impact and improved energy efficiency. In fact, from the results of the estimates in Table 1 we can observe the inverse relationship between CO_2 emissions and investments in renewable energy along with a direct relationship with energy intensity. On the other hand, the direct relationship with the level of national income shows that, reasonably, the resources needed for investment in renewable energy becomes available only after reaching a high enough gross domestic product.

The differences in the investment choices and the need for sustainable energy development can be analyzed. The electricity generation stations based on renewable and nuclear sources can be considered complementary in terms of environmental impact and the investments in renewable energy sources can be conditioned by the presence of nuclear power plants.

4. Conclusion

In this paper we analyze the driving of investment in renewable energy sources in three samples. The first, in which are included low carbon countries (i.e. countries with a low CO_2 per GDP ratio) that base their electricity generation using fossil fuel but also renewable and nuclear sources while the second includes the countries that emit more carbon dioxide in atmosphere to produce a unit of GDP. Third sample analyzes all countries considered in this paper.

The presence of nuclear power plants depresses the trend of investment in renewable energy. This has been highlighted in the analysis in which a factor is the presence of economically advanced countries that strengthen their share of electricity from nuclear power. This result is consistent with the find of Marques and Fuinhas (2011). Furthermore, the need to reduce the environmental footprint encourages high carbon economies to increase the renewable investments. In fact, reducing carbon intensity could be achieved mainly through increasing clean energy and reducing coal consumption of per unit GDP. If a country wants to achieve a certain goal of carbon intensity, it can choose the way of improving energy efficiency or try the approach of changing energy structure, such as investing in wind power, solar power or other renewable sources. Returns can only be maximized when the marginal gains of improving energy efficiency and investing in clean energy become equal. Thus, the central government could have more alternatives to formulate an effective clean energy strategic planning.

With a concerted effort and strong policies in place, future energy efficiency improvements are likely to be very large. Heat is one of many forms of "energy wastage" that could be captured to significantly increase useful energy without burning more fossil fuels (Sawin and Moomaw, 2009).

The strategic importance of energy sectors requires similar attention by countries, in particular for the increasing demand of electrical power that is only partly offset by renewable energy sources. In fact, at this time, renewable energy sources do not guarantee continuity in the peak hours. Alternatives are the use of fossil fuel based power plants that have, as expected, a great environmental impact and contribute to increase the CO_2 emission or new nuclear power plants, that reduce the environmental footprint but requires a careful planning and enormous investments.

In spite of the different productive characteristics they have and without considering production costs (which are regarded as secondary, assuming the energy as a commodity whose demand is virtually inelastic) some authors (Verbruggen, 2008) argue that renewable sources and nuclear power technologies cannot have a common future in a perspective of sustainable energy. We think, however, that, at the state of the art, nuclear power is the only alternative to renewable energy sources because it permits to reduce the GHG emission and, primarily, to guarantee electricity also in the peak hours. Furthermore, nuclear power plants can substitute fossil fuel based plants.

Our results are consistent with the points of view of Lior (2011) and Philibert (2011). The road to energy sustainability passes through the use of renewable resources that can complement the nuclear technology on condition that both exceed their own limits. Inclusion of some socioeconomic variables and the impact of subsidies to investment in renewable sources will be aim of further researches.

References

Afgan, N.H., Carvalho, M.G. (2002), Multi-criteria assessment of new and renewable energy power plants. *Energy*, 27(8),739–755.

Afgan, N.H., Carvalho, M.G. (2002), Sustainability assessment of hydrogen energy systems. International *Journal of Hydrogen Energy*, 29(13), 1327–1342.

Apergis, N., Payne, J. E. (2010), A panel study of nuclear energy consumption and economic growth. *Energy Economics*, 32, 545 – 549.

Arellano, M., Bond, S. R. (1991), Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 58, 277 – 297.

Baltagi, B. H. (2005), "Econometric Analysis of Panel Data – 3rd Ed.". John Wiley & Sons Ltd, Chichester.

Bird, L., Bolinger, M., Gagliano, T., et al. (2005), Policies and market factors driving wind power development in the United States. *Energy Policy*, 33, 1397 – 1407.

Blok, K. (2005), Enhanced policies for the improvement of electricity efficiencies. *Energy Policy*, 33,1635–1641.

Bradley, T., Ewing, B. T., Sary, R. and Soytas, U. (2007), Disaggregate energy consumption and industrial output in the United States. *Energy Policy*, 35, 1274- 1281.

Carley, S. (2009), State renewable energy electricity policies: an empirical evaluation of effectiveness. *Energy Policy*, 37, 3071 – 3081.

European Commission (2011), Roadmap for moving to a low-carbon economy in 2050. Available on line [http://ec.europa.eu/clima/documentation/roadmap/docs/com_2011_112_en.pdf] (June 23rd, 2011)

Fosberg, C. W. (2009), Sustainability by combining nuclear, fossil, and renewable energy sources. *Progress in Nuclear energy*, 51, 192 – 200.

Ghanadan , R, Koomey, J.G. (2005), Using energy scenarios to explore alternative energy pathways in California. *Energy Policy*, 33, 1117–1142.

Jaccard, M. K., Nyboer, J., Bataille, C., et al. (2003), Modeling the cost of climate policy: distinguishing between alternative cost definitions and long run cost dynamics. *The Energy Journal*, 24(1), 49 - 73.

Li, X. (2005), Diversification and localization of energy systems for sustainable development and energy security. *Energy Policy*, 33, 2237–2243.

Lior, N. (1997), Advanced energy conversion to power. *Energy Conversion and Management* , 38, 941–955.

Lior, N. (2002), Thoughts about future power generation systems and the role of exergy analysis in their development. *Energy Conversion and Management*, 43, 1187–1198.

Lior, N. (2011), Sustainable Energy development: The present (2009) situation and possible paths to the future. *Energy*, 35, 3976- 3994.

Lofstedt, R. (2008), Are renewables an alternative to nuclear power? An analysis of the Austria/Slovakia discussions. *Energy Policy*, 36, 2226 - 2233.

Lund, H. (1999), Implementation of energy-conservation policies: the case of electric heating conversion in Denmark. *Applied Energy*, 64, 117–127.

Lund, H. (2010), The implementation of renewable energy systems. Lessons learned from the Danish case. *Energy*, 35, 4003–4009.

Marques, A. C., Fuinhas J. A. (2011), Do energy efficiency measures promote the use of renewable sources?. *Environmental Science & Policy*, 14, 471 – 481.

Marques, A.C., Fuinhas, J.A., Pires Manso, J. R. (2010), Motivations driving renewable energy in European countries: a panel data approach. *Energy Policy*, 38, 6877 - 6885.

Matsui, K., Ujita, H., Tashino, M. (2008), Role of nuclear Energy in environment, Economy and Energy Issues of the 21st century Green House Gas emission Constraint Effects. *Progress in Nuclear energy*, 50, 97 - 102.

Menz, F. C., Vachon, S. (2006), The effectiveness of different policy regimes for promoting wind power: experiences from the States. *Energy Policy*, 45, 133 – 155.

Philibert, C. (2011), Interactions of Policies for Renewable Energy and Climate. *International Energy Agency Working Paper.*

Romano, A.A., Scandurra, G. (2011), New investments in electricity generation plants for sustainable energy: nuclear or renewable sources? *Proceeding of the 6th Dubrovnik Conference on Sustainable Development of Energy, Water and Environment Systems*.

Sadorsky, P. (2009), Renewable energy consumption, CO2 emissions and oil prices in the G-7 countries. *Energy Economics*, 31, 456 – 462.

Sary, R., Soytas, U. (2004), Disaggregate energy consumption, employment and income in Turkey. *Energy Economics*, 26, 335 – 344.

Sawin, J.L., Moomaw, W. R. (2009), Renewable Revolution: Low-Carbon Energy by 2030. Worldwatch Report. Available on line [http://www.worldwatch.org/files/pdf/Renewable%20Revolution.pdf} (June 05th, 2011)

Silva, S., Soares, I., Pinho, C. (2011), The impact of renewable energy sources on economic growth and CO2 emissions - a SVAR approach. *FEP Working Papers 407, Universidade do Porto, Faculdade de Economia do Porto.*

Soytas, U., Sary, R. (2009), Energy consumption, economic growth, and carbon emissions: challenges faced by an EU candidate member. *Ecological Economics*, 68, 1667 - 1675.

Verbruggen, A. (2008), Renewable and nuclear power: A common future?. *Energy Policy*, 26, 1036-1047 .