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Energy security and renewable energy deployment in the EU: *Liaisons Dangereuses* or Virtuous Circle?

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ABSTRACT

A large body of literature estimates the effect of energy security drivers on renewable energy deployment using import dependence as a proxy for energy security, which is an approach that ignores the potential effect of other energy security strategies, such as the diversification of energy sources. Using panel data for the energy sector across 21 EU member States, we investigate the effect of different energy security concepts on the development of renewable energies. We compare the results of applying different energy security indicators, including the ones used in EU energy policymaking. Unlike previous studies, this study reports a long-term relationship between energy security and renewable deployment. Our findings suggest that the relationship between energy security policies and Renewable Energy Sources (RES) deployment is far from straightforward and depends on the chosen energy security strategy, which is usually linked to different energy security conceptualizations. Our primary findings confirm (i) that RES deployment is a consequence of a combination of energy security strategies including environmental concerns rather than being solely caused by a shift towards more sustainable energy policies; and (ii) that among the different energy security strategies, the diversification of energy sources through renewable energy deployment is a more coherent strategy than using RES to reduce dependency.

Contents

1. Introduction

Energy systems in the EU are largely managed at the national level. This fragmented context leads to policy conflicts, whereas a

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coordinated European energy security framework could increase policy coherence [1]. For this reason, the EU's energy policy is becoming increasingly directed at a supranational level, as shown by the setting of common energy targets for 2020, 2030 and 2050. This attempt to homogenise EU energy policy forces member States to adapt their energy sectors to a new context characterized by a continuous commitment to develop Renewable Energy Sources (RES) without neglecting their energy security preferences. These efforts have evolved from the support of research and development (R&D) to the support of RES deployment through regulatory incentives such as Feed-in Tariffs. Therefore, researchers agree that the EU's current state of RES development has largely been achieved only because of member States' commitment towards the three goals of the EU energy policy: competitiveness, security of supply and sustainability [2–5].

Nevertheless, the energy security factors behind the support of RES have been less investigated [6–9]. This article aims to fill that gap concerning the effect of energy security drivers on RES deployment, conceptualizing RES as a generic response to energy security threats. Its relevance lies in the fact that the main driver responsible for RES deployment is not set *ex ante* or *a priori* but rather explored using econometric regression techniques that unveils a non-expected, counter-intuitive finding. The article identifies energy security strategies, and not environmental concerns, as the main driver on current RES deployment in the EU. It also allows the identification of areas of strategic importance and possible synergies between policy choices, raising the important issue of consistency between individual EU member States energy policies and a common European energy security policy.

The idea behind this article is the following: one of the main reasons for the lack of significant results in existing studies on the effect of energy security on RES is the use of inappropriate proxies. Energy security is a multidimensional concept that cannot be reduced to one indicator – in particular, to import dependence ratios. Thus, this article aims not only to compare alternative energy security indicators (ESI) but also to capture the various dimensions that generate policy support for RES. In this context, it is closely related to previous studies on RES drivers and barriers [6–9] insofar as it estimates the effects of various ESI, which are closely related to socio-economic and country-specific variables, on the deployment of RES in the EU. Furthermore, the article extends this research agenda to address the issue of RES deployment from an energy security perspective compared to the traditional sustainability prism. In this regard, the article explores strategies that would simultaneously promote energy security and sustainability, overcoming the trade-off that allegedly limits the achievement of both.

The key role played by variables related to energy security in the development of renewable energy in the EU partially contradicts almost all earlier empirical findings [6,7,9] and have clear policy implications for a common European energy policy. In order to find a European energy security approach coherent with RES deployment it will be necessary (i) to explore strategies that promote a sustainable and secure energy supply, such as the diversification of primary energy sources; and (ii) avoid other strategies focused on decreasing import dependence like supporting domestic coal or developing European shale gas resources.

More precisely, the article hypothesizes that the relationship between energy security policies and RES deployment is far from straightforward and depends on the selection and weight given to each energy security target. To test this hypothesis, the article follows an innovative approach: instead of setting energy dependency as proxy for energy security policies, it recurs to different ESI used in EU energy policymaking or in the energy security literature. The reason for introducing a variety of indicators is that past studies [10–12] report significant differences depending on the ESI chosen. Combining ESI with country-specific energy sector data, we examine national investment in RES for 21 EU countries. We expect that the use of a wide range of ESI will allow to make a distinction between different energy security concepts and dimensions, and determine whether the use of import dependence as the only proxy variable to represent the energy security dimension represents a source of potential bias. Finally, we want to know what strategies related to energy security present a higher consistency with RES deployment.

The article starts by introducing existing theoretical models and empirical evidence on the relationship between energy security and RES in Section 2. Section 3 discusses some drivers and barriers that influence the demand for RES within a country. Section 4 follows with the data description, including different ESI, and presents the methodological approach. Regression results are presented and discussed in Section 5. Section 6 presents the final remarks regarding the coherence between energy security and RES deployment in the EU, while Section 7 concludes with its policy implications. Our primary findings confirm (i) that RES deployment is a consequence of a mix of energy security strategies and not only of environmental policies; and (ii) that within energy security strategies, the diversification of energy sources through renewable energy deployment is a more coherent strategy than the search for an energy independence based on RES.

2. The renewable energy and energy security nexus: background

2.1. Theoretical literature

The main body of literature on energy security focuses on the geopolitics of fossil fuels, and the relationship between RES and energy security has been poorly analysed [13]. However it is not difficult to introduce RES in conventional energy risk frameworks. Escribano et al. [14] break down energy risks into primary (socioeconomic or technical causes), secondary (interruption of energy supply or environmental, property and human health damages due to primary energy risks), price volatility and vulnerabilities (exposure) finding RES could mitigate energy risks in every layer of their "causal taxonomy of energy risk (Fig. 1)".

First, decentralised renewable energy facilities are less insecure than highly centralised conventional ones concerning physical failure or sabotage (primary energy risk). Second, with the only exception of hydropower, renewables are considerably safer than conventional energy sources in case of an accident (secondary energy risks). Third, renewables are 'zero marginal cost' technologies that do not need 'fuels' to produce power and are thus not affected by price volatility in international energy markets, unlike oil, natural gas or coal. Furthermore, they could be used to balance the price volatility inherent to fossil fuels, with which they are uncorrelated. Finally, renewables could reduce energy vulnerability through the diversification of the energy mix regarding both technologies and energy sources. Thus, even if sustainability is not included (as it should) in a comprehensive energy security definition, renewable-associated risks are lower than those of conventional energy sources.

A new framework to analyse energy security has been developed by Cherp and Jewell [15]. They point out that currently three main points of view on energy security coexist: Sovereignty, Robustness and Resilience (Fig. 2). Each perspective identifies different key risk for energy systems. Problems related to oil security have historically shaped the "Sovereignty" perspective on energy security rooted in international relations theories and political science. The "Robustness" perspective threats are seen as 'objective', predictable and measurable, allowing for the quantification of energy risks. The third

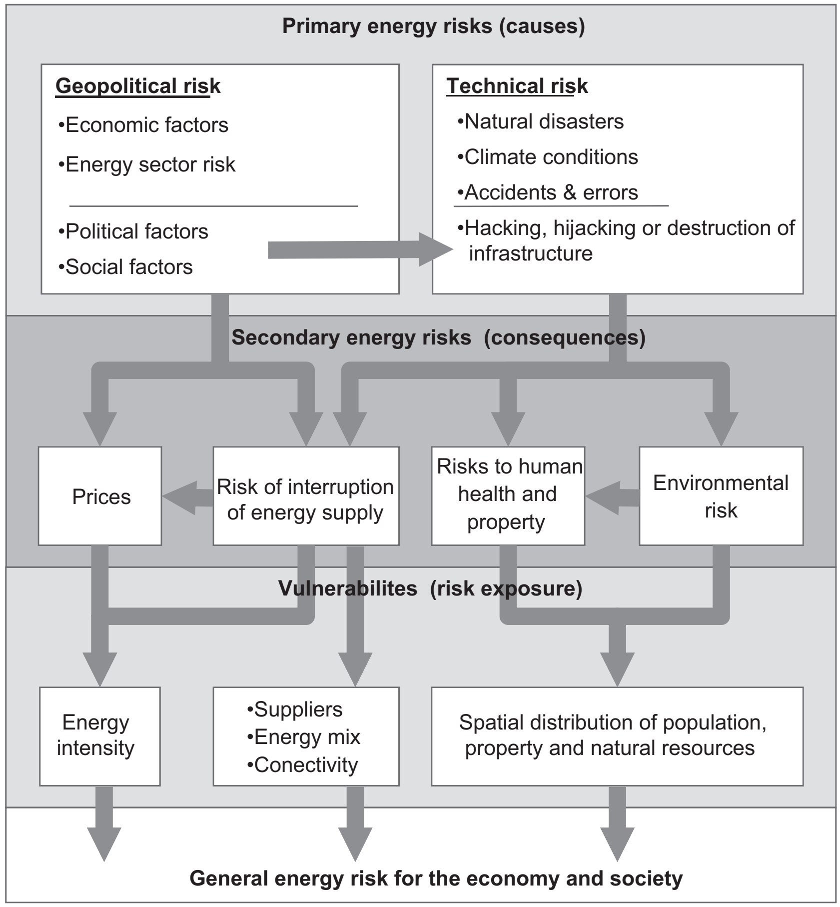

Fig. 1. A causal taxonomy of energy risk.

perspective, titled "Resilience", is based on the uncertainty and non-linearity of energy systems, markets, technologies and societies. It searches for generic features of energy systems such as flexibility, adaptability, diversity that ensure protection against uncertainty.

RES could contribute to improve energy security in each of the aforementioned three dimensions addressing most threats to energy security. Regarding Sovereignty, as a domestic and decentralised energy supply, RES are less vulnerable to the use of energy as political weapon or to physical attacks. Even in the case of transnational RES flows, its own nature (electricity in most cases) limits their capacity to serve as a driver for power politics, contributing instead to diversify geographical origins, corridors and energy sources. Besides, the atomization of the RES industry compared to the oligopolistic nature of conventional energy firms could help to prevent market power abuse.

Robustness threats could also be mitigated introducing RES in the energy system, although it must be kept in mind that, from a technical point of view, RES need some back up capacity due to its fluctuating nature. From left to right regarding Robustness threats in Fig. 2 the decentralised nature of RES, as it has already mentioned, with more sites of smaller size, could reduce the risk of technical failures. However, against extreme natural events the result is not that clear: on one side, the geographical scattered pattern of RES deployment could avoid most facilities being caught in the same event; on the other side, some RES, like windmills, could trip (disconnect) automatically with high speed gust of wind that could be supported with ease by conventional energy infrastructures. The smaller size and decentralization of RES could also play a role if demand outgrows supply, as RES facilities could be built faster and nearer demand centres minimizing power line needs. As a negative point, RES are not completely dispatchable due to its fluctuating nature, limiting its viability in case of non-interruptible energy consumption requirements. Finally, the threat of resource depletion is perfectly matched with RES as main modern renewable energies (wind and solar) are inexhaustible resources.

In the Resilience dimension RES could help to address unpredictable changes such as technology changes, variations of climate or market volatility. RES are cutting edge technology being at the forefront of research and development (R&D) programs. Thus it is possible that a technological change in energy, even a game changer, could appear from this field. Renewable sources allow technological diversification too, with different technologies competing and exploring alternative development pathways. RES neither use 'fuels' to produce power, nor release CO_2, as there is no combustion to generate power, strongly contributing to reduce energy risk related to climate change or to energy price volatility, as it was mentioned above. The only Resilience threat that could not be dealt better with RES than with conventional energy sources are regulatory risks. However, the problem here is more the fact that the regulatory framework has been working for conventional energy sources since its beginning, than the own features of RES. An energy source, conventional or unconventional, suffering from abrupt, frequent, quick or unexpected changes in its regulatory framework will bear an increase in its risk levels.

As it has been shown, from a general point of view RES have a huge potential to increase energy security with positive externalities outweighing most of the time their (not so) higher cost compared to conventional energy. Let's focus now in the concrete case of climate change, one of the most pressing concerns related to energy nowadays.

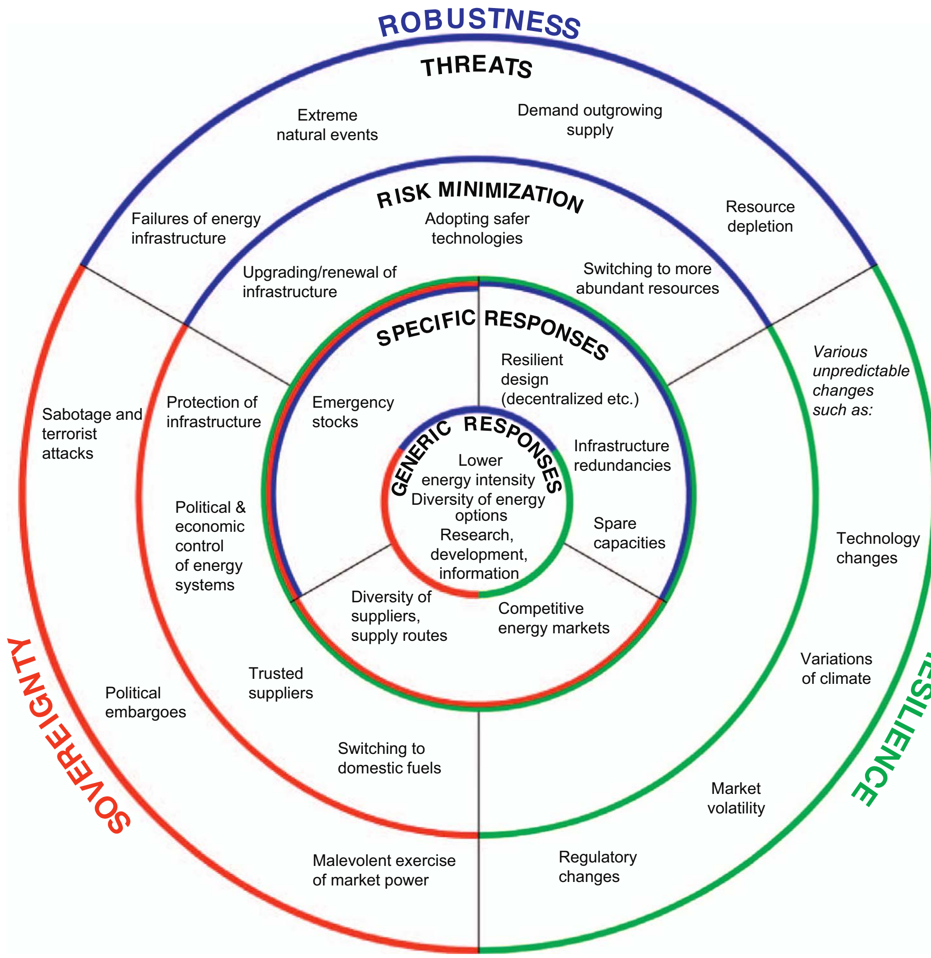

Fig. 2. Three perspectives on energy security.

The role of RES within the relationship between energy security and climate change policies has recently been the subject of heated discussion [1,15–21]. Currently, there is no agreement on whether a complementarity or a trade-off exists between these two dimensions [22–26]. In order to conceptualize this relationship some theoretical frameworks have been constructed. For instance, Brown and Huntington [27] examine the complementarity between climate change and energy security policies. Their theoretical model conceptualises the existence of complementarity among energy security targets and individual RES technologies within a context of trade-off between the two policy dimensions: reduction of CO_2 vs. reduction of energy prices. According to the authors, RES contribution to either objective (or both) is a consequence of their different costs and technical characteristics. The trade-off that must be managed is diversifying energy sources to minimize the risk of a supply disruption or price shock. To that end, Brown and Huntington present an energy mix in which the optimal share of each technology is reached when the marginal cost in the energy mix is equal to the value of the additional energy security and the reduction in greenhouse gas emission that it provides. Although it is a theoretical model, the difficulties in measuring energy security levels must be highlighted.

In line with the precedent model, Röpke [28] presents a cost benefit analysis of policy objectives in electricity markets. Developing the framework of analysis by Tishler et al. [29] and De Nooij et al. [30], her research focusses on supply security problems that arise from decentralized renewable energy grid integration. Measuring energy security by the (social) damages of outages, energy security is associated with supply interruptions. One important assumption behind Röpke's model is that the costs associated with the development and maintenance of the electricity grid should be considered part of RES deployment costs. Applying the model to the German electricity system, the costs associated with the expansion of the electricity grid due to the deployment of RES exceed the induced welfare gains from the maintenance of a constant supply security level.

Conversely, Bauen [31] suggests that complementarity exists between climate policies and energy security policies. In his words "*the stronger the Green House Gas policy, the more positive the effect on security of supply is likely to be*". Nevertheless, the reverse of this relationship does not work. Therefore, the technological solutions to the dilemma between energy security and sustainability may consist of a range of options that will evolve over time, depending on technological trends and security risks. This argument is partially in contradiction with Correljé and Van der Linde [32], who stated that RES development in Europe is stimulated by security of supply reasons. More precisely, they argue, *"[r]esearch and development efforts are basically geared towards reducing the import dependency and increasing energy system flexibility."* In this article, environmental policies are considered part of energy security policies: *"[n]evertheless, in addition to energy policy specifically, trade and foreign relations and security policy are also part of the energy security tool-set, as is environmental policy."*

Constantini et al. [33] follow a Portfolio-Based Approach for assessing energy security levels under different scenarios. For this purpose, they define energy security in the classical terms of availability of a regular supply of energy at an affordable price, and distinguish two main categories: dependency and vulnerability of gas and oil supplies. This specification allows them to differentiate between different sources of risk. They conclude that reducing energy imports due to energy efficiency policies would affect European future energy security, as would technological investments on the supply side. This view highlights the role of oil and gas as main sources of risk and ignores the potential associated with other energy sources as renewables.

This article assumes that all of the above energy security frameworks may be right, representing different concepts on the subjective trade-off between energy security and the economic and environmental dimensions of energy policy. In this context, the definition of energy security and its associated strategies could be one of the most important, if not the main, driver/barrier in RES deployment. Therefore, energy security policies can spur the deployment of RES to achieve certain desired results, for instance, increasing the technological or geographical diversification of the energy system, decreasing the effect of oil volatility on growth and inflation, or reducing the carbon intensity of the economy.

2.2. Empirical evidence

The current academic debate on the use of RES and energy security issues is dominated by studies on economic modelling of RES deployment [23,25,34], their role in possible future energy systems [35–37], their optimal contribution in energy supply portfolio [38–42] and, more recently, their geopolitical implications [43]. Regarding the empirical evidence, the literature stresses the importance of policy interventions [5,44,45] and market liberalization [5,46,47]. Yet these studies focus more on promoting RES through policy instruments as feed-in-tariff or quotas, or the challenges associated with their market and system integration, largely ignoring the energy security aspect.

But there are also some studies analysing the different ways in which energy security and RES deployment interact. Nevertheless, they only perform an analysis of the energy security drivers as a secondary objective. In addition, the search for empirical evidence has been focussed on the relationship between RES and one of the many possible objectives of energy security policies, energy independence (or reducing energy dependence).

For instance, a great deal of research has been performed to test the hypothesis that energy security promotes RES deployment by including the indicator of import dependency as one of the independent political variables [5,7,9,48,49]. For instance, Marques et al. and Marques and Fuinhas [6,7] analyse 23 EU countries including the candidates to the EU adhesion with different results. The results of Marques et al. [6] confirm that energy dependency has a positive effect on RES development. However, in Marques and Fuinhas [7], the results are not statistically significant for energy price and energy import dependency variables.

Popp et al. [4] measured the investment on RES by using the annual variation in installed renewable energy capacity per capita. This study measures the effect of technological change on RES deployment. Among other variables, the study determines the effect of energy security using as explanatory variables the share of imported energy in total energy supply and the production per capita of coal, natural gas, and oil. Nevertheless, their findings show no significant results.

In their recent analysis of RES deployment drivers, Aguirre and Ibikunle [9] follow the previous studies of Marques et al. [6] and Marques and Fuinhas [7,8], including as explanatory variables a set of public policies, energy import dependence, energy prices and fossil fuel participation in the electricity mix. Their results show significant evidence for the effect of public policies aiming at climate change mitigation, but are not significant for the energy security variable, energy dependence. Concerning the participation of fossil fuels in the electricity mix, their findings corroborate the negative effect of fossil fuels on RES deployment, but they do not find significant results for the variables connected to energy import prices. Based on the evidence of their study, they conclude that environmental concerns are more relevant than is energy security for countries in their sample.

The fundamental reason for including a broad range of ESI instead of arbitrarily considering one indicator rather than others is that each energy security concept defines its own policy objectives and strategies. In that sense, energy independence, the proxy used in the reviewed literature, could not even be an energy security target for most of the EU members because they are historically energy importers. In this respect, Bigano et al. [10] follow a different strategy; they initially use a wide range of indicators to assess whether different policies that affect energy efficiency performance also have an effect on different ESI for 16 EU countries. Their work has two main implications for our purposes. First, they show the differences in the measurement of energy security by using different indicators, i.e., countries may have high levels of energy dependence but a highly diversified energy supply. Second, the study shows that policies for improving energy efficiency or carbon efficiency have non-significant effects on all energy security dimensions. This is a very interesting result considering that most of the literature uses the level of energy dependence as a proxy for energy security. In our view, the differences in their results are explained by the fact that an exact and unique definition of energy security, and therefore the use of a single specific indicator, is almost impossible because energy security is a complex, multidimensional and evolutionary concept which allows several subjective interpretations

To summarize, the several channels through which energy security affects innovation and deployment in RES call for the inclusion of a broad set of potential interactions in the empirical specification of the econometric model. Currently, there is no agreement in the literature, and therefore energy security targets could be viewed as a driver or a barrier. Depending on the level of analysis (national, regional or global), chosen dimension (availability, accessibility, affordability or acceptability) or indicator (economic, environmental or security of supply-based indicators) and, in particular, the specific circumstances of each energy system (e.g., composition of the energy “mix”, key energy partners and geopolitics, and resource endowments), results may change. Nonetheless, supply disruption concerns are not the only energy security factor that determines RES deployment. The next section presents some energy security drivers of and barriers to RES deployment and its effects.

3. Determinants of renewable energy deployment

3.1. Conceptualizing energy security

Currently, a variety of energy security definitions coexist, and the literature is rapidly growing[1] without having a common or unique security indicator able to embrace them all [19]. Moreover, measuring the levels of security associated with any concept of energy security from an economic perspective is a fundamental problem because the value of energy security is not reflected in any price [23,30] and the use of multiple indicators generates an aggregation problem [50]. However, many energy security indices have been constructed, being many of them country or region

[1] After reviewing 104 articles from 2001 to 2014, Ang and Choong [17] reported that energy security has been an actively studied area and its definition is characterized by being contextual and dynamic in nature.

specific [19]. Although some characteristics of energy security could be measured, the problem is that the contour defining energy security remains undefined, if only because the energy system is not isolated from environmental or political dimensions. There is no consensus on whether the interactions of energy security and the environmental and economic dimensions of energy policy may be part of energy security concerns.

Most likely, the best framework of analysis to address the energy security aspects of RES is the one adopted by Johansson [13,51], in which energy systems are not merely an object exposed to security threats but instead a subject generating or enhancing insecurity. Energy systems could act as a generator of insecurity due to the economic importance of energy, the physical and technical characteristics of the energy carriers and the environmental consequences of energy use. However, as we will see next**,** there is significant opposition to the subjective perspective, in which the concept is extended to other dimensions beyond the security of supply or demand. For that reason energy security has been conceptualized as everything about managing conflicts and commonalities between the different dimensions of energy security [52].

The narrowest visions conceptualizing energy security in terms of availability and accessibility and accessibility to energy resources remain dominant. This approach is held by many actors in the energy sector such as the Department of Energy & Climate Change (DECC) [53], which defines energy security in the following terms: "*Secure energy means that the risks of interruption to energy supply are low*". Other points of view extend the concept of energy security to new fields but contain secure energy supplies as the core of the concept. Examples of these concepts include the approach developed by the IEA: "*Energy security is defined in terms of the physical availability of supplies to satisfy demand at a given price*"[54]. An additional example is from Mabro [55]: "*Security is impaired when supplies are reduced or interrupted in some places to an extent that causes a sudden, significant and sustained increase in prevailing prices".* Milov [56] alludes to the International Atomic Energy Agency, presenting a more sophisticated definition after highlighting that there is no clear-cut definition of the concept: *"Experts from the International Atomic Energy Agency define it as a concept aimed to protect customers against any interruptions in their energy supplies due to emergencies, terrorism, underinvestment in infrastructure, or poor organization of markets"*. From this point of view, the concept is developed within new areas or dimensions, such as a timeframe of risk sources, differentiating from short and long-term energy security, or the classification between technical, regulatory and human threats. However, perhaps the most relevant area of these new developments is the social dimension represented by initiatives such as *Sustainable Energy for All*, which focussed on energy poverty and final consumers' protection [52,57,58]. For instance, the energy security social dimension in the EU ensures that the final product (energy services) meets end-consumer needs, particularly the socially disadvantaged [59].

For the EU, the definition of an energy security policy and its respective indicators should be able to evolve and adapt to increasing dependence on external suppliers. In this respect, as a consequence of the recent events involving Russia and the Ukraine, the European Commission has recently published an in-depth study of European energy security, which defines energy security as the "*uninterrupted access to energy sources at an affordable price*" [60]. This definition skips the environmental dimension and is far from the vision promoted in recent years in which "…*energy supply security must be geared to ensuring… the uninterrupted physical availability of energy products on the market, at a price which is affordable for all consumers (private and industrial), while respecting environmental concerns and looking towards sustainable development*" [60].

Concerning the studies about EU energy security, currently there is not a unique or official set of indicators; therefore, different indicators have been used depending on the context. Nevertheless, the EU is working on their development; the most complete group of indicators is the European Commission Occasional Paper, "Member States' Energy Dependence: An Indicator-Based Assessment" [61]. To assess the subjective energy concept of the EU and recreate the European energy security framework for our purposes, it is interesting to use ESI that are being used in decision making at the European level. Additionally, to capture different concepts, other indicators commonly used in the academic literature are also included because energy systems have been largely managed at the national level.

3.2. Energy security indicators (ESI)

The indicators used in this study come from three main sources. Table 1 summarizes the indicators, classifying them by their relationship to each energy policy dimension: environmental sustainability, energy security and competitiveness. These three different sources have been included to cover European subjectivity and different national and academic visions. The main source is the European Commission Occasional Paper, "Member States Energy Dependence: An Indicator-Based Assessment" [61], in which various indicators are discussed. These indicators are used to capture the subjective energy security concept of the EU. The European Commission report classifies the indicators in three dimensions: security of energy supply, energy and carbon intensity of the economy, and contribution of energy products to the trade balance. It is interesting to highlight that a large part of the variables included in past studies [3,6–9,46,62] are included in the European Commission report [61] and have not been interpreted from an energy security point of view. Instead, they have been interpreted from an environmental or purely economic perspective because they are not exclusively used as ESI. For that reason, these studies are used as the second source of variables to be analysed from an energy security perspective. The last source that feeds our study is the specialised literature on gas and oil. Chester [63] argues that the energy security literature is marked by a dominant focus on securing supplies of two primary energy sources, oil and gas [33,64–66]. Hence, we use the specific indicators used by Costantini et al. [33] to measure energy security levels related to these two energy sources.

3.2.1. The environmental dimension

It is widely accepted that RES are promoted due to the commitment by European countries to reduce GHG emissions. Nevertheless, there is no clear evidence that increasing use of renewable energy sources is effective in this context [67]. However, although this commitment has influenced RES deployment in some countries, the main instrument to reduce GHG emissions is the EU CO_2 trading scheme. However, the EU commitment to climate change objectives became stronger after the signature of the Kyoto Protocol, initially binding emissions commitment to limit GHG. Since its signature, the Kyoto Protocol has boosted RES development, displacing more polluting sources from the energy mix. For that reason, as in past studies [4,5,9], a dummy variable has been used for the year, indicating whether a country has ratified the Kyoto Protocol.[2]

Energy intensity is used by the EU as an indicator of energy consumption and energy efficiency. Low energy intensity means low energy use per unit of GDP/per capita, implying that the

[2] Ratification dates are taken from the website of the U.N. Framework Convention on Climate Change. unfccc.int/files/kyoto_protocol/status_of_ratification/application/pdf/kp_ratification20090601.pdf, accessed in June 2015.

Table 1
Energy security indicators (ESI).
Source: Own elaboration

Dimension	Indicator	Resume
Environmental	Kyoto protocol	Dummy variable
	Energy intensity	Energy consumption per GDP
	Carbon intensity	Green House Gas Emissions (as CO_2 equivalent) per GDP
		Green House Gas Emissions (as CO_2 equivalent) per capita
Security of supply	Energy dependence	Energy net import (% TPES)
	Gas energy intensity	Gas Cons. per $ of GDP
		Gas used per capita
	Oil energy intensity	Oil Cons. per $ of GDP
		Oil used per capita
	HHI primary energy diversity index	Index that represents the level of diversity of the energy mix of an economy. The values range from 0.2 to 1, 0.2 being the most diversified and 1 the more concentrated; only five energy sources (gas, oil, coal, nuclear and renewable) have been considered.
	Contribution of coal oil gas and nuclear to electricity generation	Share of electricity from Coal/Oil/Gas/Nuclear sources as part of total electricity generation in Mtoe
Competitiveness	Oil price	Annual average of daily Brent price per Mtoe
	Gas price	Annual average of daily German import price per Mtoe
	Coal price	Annual average of daily Northwest Europe market price per Mtoe
	GDP per capita	GDP per capita in one year

economy is less influenced by changes in energy prices and energy disruptions. The effects of both variables (energy use per unit of GDP and energy use per capita) in RES deployment are uncertain because large energy use and/or growing energy needs due to population/GDP increases could be supplied either by traditional energy sources or by renewable energy [6,9,46]. To make our results comparable to past findings, energy consumption by sector was not considered.

The European Commission report included carbon intensity of the economy as an indicator that measures the average amount of GHG emissions necessary to generate one unit of GDP. *Ceteris paribus*, higher carbon intensity of its energy sector implies increased vulnerability of a member State to more stringent climate-change mitigation policies and a higher likelihood of facing negative consequences in terms of inflationary pressures and competitiveness losses [61].

3.2.2. Competitiveness

Distinguishing between competitiveness and energy security dimensions is difficult because energy prices are core components of both. We assume that energy prices are good indicators of latent factors affecting international energy markets that are not represented by other ESI already included such as the level of energy offer and demand, political stability or marginal extraction cost. For that reason, it is interesting for our purposes to test whether high oil and natural gas prices foster RES deployment. As in previous studies [6,7,9], we consider coal, gas and oil prices. We expect the increase in commodity prices to boost the adoption of RES technologies because an increase in oil prices makes the substitution of exhaustible energy sources with sustainable energy more profitable. To assess the effect of overall economic well-being, we include GDP per capita.

3.2.3. Security of supply

The 2013 Occasional Paper section devoted to security of supply focusses on three indicators of energy security: energy import dependency, the degree of diversification of energy sources, and the degree of diversification in the electricity mix. Import dependency shows the extent to which a country relies upon imports to meet its energy needs. The theory suggests that higher reliance of a country on energy imports requires a higher level of RES deployment to improve that country's energy independence, but as we have highlighted previously, the results are contradictory. We will analyse later the pros and cons of using this variable alone.

The second variable introduced, to measure the degree of diversification, is the Herfindahl–Hirschman Index, or HHI indicator. As reported by Kruyt et al. [50], the HHI is widely used [68–73]. We utilize the index to assess the diversification of primary energy sources. We expect less-diversified economies to increase the deployment of RES as a means of managing their dependence on other energy sources. The Index is calculated as follows:

$$\mathrm{HHI} = \sum_{i=1}^{N} x_i^2 \quad (1)$$

Finally, we introduce as independent variables the share of fossil fuels and nuclear energy sources in electricity generation to assess the degree of diversification in the electricity mix. As past studies [6,9,38,46] have, we use the contribution of coal, oil, natural gas and nuclear energy sources to the electricity generation in a country because this enables capturing the individual effect of each energy source on RES deployment. It is expected that the lobby power of fossil fuel technologies acts as a barrier to RES deployment [5,18,72] and to nuclear energy, which can also be considered a “green” technology [9].

Some of the selected indicators could overlap with other dimensions. The variable energy intensity in addition to sustainability, may reflect the affordability and the security of supply of the energy system. As Fig. 2 shows, this is because some instruments of energy security are generic and may affect different areas. For instance, more energy intensive systems may be seen as less efficient and may be more vulnerable to resource depletion or price volatility. Therefore, it is possible to classify the indicators with respect to the dimensions they focus on, signalling in some cases their multidimensionality[3].

4. Data and methodology

We use data collected from several sources: Eurostat Database, United Nations Statistics Division and BP Statistical Review of World Energy 2012. Although the focus is on the EU, the list of countries

[3] This multidimensionality can be seen clearly in Kruyt et al. [50], Fig. 2.

included is restricted by data availability: Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Greece, Germany, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and the United Kingdom.[4] We use RES contribution to Total Primary Energy Supply (TPES) per year as the dependent variable. Data for specific RES contribution to TEPS are not used because the article considers the overall energy security effects. Other candidates for dependent variable are the level of renewable energy produced [73] or the per capita investment in RES-installed capacity [4]. As stated by Aguirre and Ibikunle [9], the use of RES Contribution to TPES instead of other measures is preferred for two reasons. First, policy targets are focussed on achieving a certain share of RES in the TPES. Second, it is expected that RES progressively displace more-polluting energy sources in the energy mix. Table 2 presents the variables included in each dimension, summarizing their descriptive statistics.

The analysis begins with the detection of non-linearities and outliers. Because we detect signs of Skewness and Kurtosis in our dependent variable, a logarithm transformation is applied to address asymmetry. To determine the model specification, the analysis continues examining the existence of multicollinearity through the correlation Matrix (see Annex A). At first glance, the correlations between the GDPpc, Commodity prices (OilP, CoalP and GasP) and the vulnerability Index for Oil and gas (OilEco, GasEco, OilPh, GasPh) are the mean sources of potential bias.

To avoid problems of collinearity in the final model, a simple Ordinary Least Squares (OLS) regression is performed and checked for collinearity, calculating the centred variance inflation factors (VIFs) for the independent variables specified in a linear regression model. Following Chajerte and Hadi [74], a variable is considered problematic if its VIF is 10.0 or greater. The results of our first set of independent variables are reported in Table 3. The model specification (A) shows very high values for some variables. It is therefore necessary to drop some of the variables; the remaining ones are reported in Model (B). The new model's VIF is significantly smaller than Model (A), which means that multicollinearity is not an issue. Moreover, the GDPpc and the GasPh in the model have a VIF value slightly greater than 10, breaking the rule of Chajerte and Hadi. Because we are interested in using the GDP variable as a control variable and we have already dropped the Oil vulnerability variables, we decided to keep these two variables. We will consider that issue in our final regressions.

Once collinearity problems are avoided, a test for heteroskedasticity is performed using the Modified Wald test for heteroskedasticity because it works when the normality of the errors assumption is violated. The results confirm the existence of heteroskedasticity in our data panel. The following step is to test for the existence of serial correlation in u_{it}, using the Wooldridge first difference test for serial correlation in panel data [75]. The test indicates the presence of country-specific autocorrelation that needs to be removed (i) by taking first differences if the correlation is of order one or (ii) using a dynamic approach to address it. We decide to use a simple panel-data model with a first-order autoregressive component that controls for the dependence of t with respect to $t-1$. Finally, Pesaran's [76] cross-sectional dependence test, Friedman's statistic [77], and the test statistic proposed by Frees [78] are used to test for cross-sectional independence in the panel finding that the error terms are contemporaneously correlated. Potentially allowing for the country's fixed effects, our model is the following:

$$LogCRES_{it} = \propto + \gamma_1 ECO_{it} + \theta_2 \mathrm{ENV}_{it} + \varphi_3 SEC_{it} + \mu_i + \epsilon_{it} \quad (2)$$

where $i=1\ldots N$ indexes countries and $t=1\ldots T$ indexes time. $\mathrm{LogCRES}_{it}$ is the dependent variable: the logarithm of the RES contribution on TPES for each country i and year t. Our explanatory variables are divided into $\mathrm{ECO}_{i,\ t}$, a vector of Economic variables; ENVi, t corresponds to sustainability variables; $\mathrm{SEC}_{i,\ t}$ corresponds to Security variables; μ_i is the country-specific effects; and ε_{it} corresponds to the error terms.

[4] We do not include in our dataset Cyprus, Bulgaria, Latvia, Lithuania, Malta or Rumania, countries for which data are available only after the 1990s.

5. Estimation and results

The data described above were used to estimate Eq. (1) using Stata. We use the Feasible Generalized Least Squares (FGLS) and Partial Correlated Standard Errors (PCSE) methods to estimate our fixed effects models. The PCSE is an alternative FGLS and involves using Prais–Winsten estimates instead of OLS when autocorrelation is specified to determine parameter estimates, but replacing the Prais–Winsten standard errors with PCSE. Both methods allow for contemporaneous correlation and heteroskedasticity across the instruments and time series autocorrelation within the regressors. Following Reed and Ye [63], we decide to use PCSE because we are interested in estimating the confidence intervals and FGLS for coefficient estimates. We also run a Random Effects Model (RE) with an AR(1) disturbance using the GLS estimator of Baltagi and Wu [79].

In the PCSE model, the autocorrelation parameter may be constant across panels or different for each panel. Following the recommendation of Beck and Katz [80], we decide to estimate one AR parameter for all panels instead of panel-specific autoregressive parameters. Even after having employed the series of Unit Root tests, there remains a presence of heterogeneous p in the logCRES variable. Table 4 presents results for the logCRES variable. Columns (1) and (2) include country and time fixed effects, and columns (3) and (4) only time effects for the PCSE and FGLS models. Column 5 presents the results for the Random Effects Model.

The results are robust across regressions; the coefficient estimations have the same sign and similar standard deviations in all models except for the GDPpc variable, which shows different results, not clearly indicating a possible causality link. The first two columns present the results for the within country variation. Both PCSE and FGLS estimations present similar levels of significance except for the GasEco and GasPh variables, which lose explanatory power when the FGLS model is run. When the between variation is observed by omitting the country-specific effects, the power of explanation of some variables increases because the differences between countries are greater than within them. That is true of the Energypc variable that becomes significant and of CO_2pc and the contribution to electricity generation by source. All of these variables increase their explanatory power except for the case of OilElec, which remains at the same levels. The Random Effect model is a short estimation of the combination of within and between variations. The main differences from the other regressions are the increase in the significance level of the Kyoto variable, GasEco and GasPh, but with a change in the sign of the Kyoto variable. Moreover, the contribution of coal, oil, natural gas and nuclear energy sources to the electricity generation decreases their explanatory power; finally, the OilP and GDPpc variables become not significant.

Table 5 presents different selected specification models for the PCSE regression including country and time effects. We decide to introduce the variables by dimensions. Column (1) introduces variables linked to the environmental dimension: the Kyoto protocol, CO_2 per capita and energy per capita. As independent variables, they show a decrease in the coefficient of approximately one-third with respect to the model with all the variables (Column 5). As before (column 1 Table 4), the Kyoto and Energypc variables have no

Table 2
Summary statistics.

Dimension	Variable	Name	Obs.	Mean	Std. Dev.	Min.	Max.
Dependent variable							
	RES contribution to TEPS	LogCRES	483	−1.298673	0.4481592	−2.355201	−0.441138
Sustainability							
	Energy intensity per capita	CO_2pc	482	11.98916	4.41712	6.074542	34.98179
	Carbon intensity per capita	Energypc	482	4.063009	1.58617	1.791175	10.39742
	Kyoto protocol dummy variable	Kyoto	483	0.6501035	0.4774315	0	1
	Energy intensity per GDP	EnergyGDP	480	193.0256	127.1524	66.56004	850.806
	Carbon intensity per GDP	CO_2GDP	480	611.456	496.918	138.0597	3214.169
Competitiveness							
	GDP per capita	GDPpc	479	27.53174	15.55247	4.386804	88.41782
	Oil price	OilP	483	50.67555	29.39692	17.91067	113.558
	Coal price	CoalP	483	58.33768	30.78483	28.79	147.6737
	Gas price	GasP	483	4.987625	3.112044	1.878968	11.56177
Security of supply							
	Contribution of coal to electricity generation	CoalElec	483	0.3491968	0.26844852	0	0.9613757
	Contribution of oil to electricity generation	OilElec	483	0.06693580	0.0991045	0	0.5868281
	Contribution of gas to electricity generation	GasElec	483	2.698799	4.330625	0.0009829	17.69009
	Contribution of nuclear to electricity generation	NuclearElec	483	0.2099656	0.2292701	0	0.7894867
	Gas economic intensity	GasEco	480	97.2195	141.065	0.337845	644.1191
	Gas physical intensity	GasPh	482	2.698799	4.330625	0.0009829	17.69009
	Oil economic intensity	OilEco	480	170.512	243.1544	5.921919	1222.719
	Oil physical intensity	OilPh	482	0.0045873	0.0075851	0.0001625	0.0316645
	Energy import dependence	ImpDep	483	0.5393695	0.30036	−0.5180274	0.9959607
	HHI diversity index	HHI	483	0.3267868	0.076589	0.202486	0.6148757

significance power. The CO_2pc variable reveals that when an economy becomes more pollutant in terms of CO_2, it shows more resistance to the switch to RES. The interpretation is that carbon-intensive economies become more dependent on cheaper fossil fuels. This path dependence process, along with the brown lobby efforts, discourages RES support because it is more cost effective to continue using cheap fuels than using RES.[5] Conversely, higher carbon intensity increases the vulnerability of a member State to climate-change mitigation policies. Alternatively, to the extent transition to a cleaner energy system is more costly, the more prone it is to negative consequences in terms of inflationary pressures and competitiveness loss. However, our results suggest that this mechanism cannot offset the cost advantages of a carbon-based economy

Columns (2) and (3) introduce the variables linked with the security of supply dimension. The results for HHI are robust, being strongly significant in both Models (2) and (5). Conversely, GasEco, GasPh are not significant. ImpDep is significant but with a coefficient approximately two and three times smaller than the HHI variable. As it has been highlighted before, reducing import dependency is only one of the multiple potential targets of an energy security policy. Nevertheless, energy dependency is commonly used in the literature as the only proxy of energy security, reducing the multidimensionality of the concept. The results of our regressions show that to the extent that import independence is materially impossible, the diversification of the energy supply plays a major role for RES support in the EU's policy. This result holds even when the share of each of fossil fuel and nuclear energy in electricity generation is included (column 5). In fact, when comparing all of the coefficient estimates for all variables, the HHI appears to have the greater effect in RES development. These results are in line with theoretical models affirming that RES deployment increases the energy security of systems by the diversification of energy sources [14]. In the interpretation of the negative coefficient, it is important to

Table 3
Variance inflation factors. Model A (left) and Model B (right).

Model A Variable	VIF	1/VIF	Model B Variable	VIF	1/VIF
GasPh	81.3	0.012299	GasPh	1.4	0.08774
CO_2GDP	65.57	0.015251	GDPpc	9.56	0.10458
OilPh	63.87	0.015656	Energypc	7.96	0.125581
Energy GDP	62.58	0.015979	CoalElec	7.79	0.128378
GasEco	36.92	0.27085	CO_2pc	7.6	0.131642
OilEco	27.98	0.035743	GasEco	5.7	0.175404
GasPh	26.09	0.038331	GasElec	3.28	0.304601
OilPh	22.71	0.044041	NuclearElec	2.86	0.349731
Enegypc	19.37	0.051638	ImpDep	2	0.499004
GDPpc	18.16	0.055052	HHI	1.82	0.54963
CO_2pc	11.75	0.085085	Kyoto	1.63	0.613491
CoalElec	8.59	0.116452	OilP	1.57	0.635985
CoalP	7.72	0.129529	OilElec	1.5	0.668507
GasElec	3.56	0.281208	Mean VIF	4.97	
NuclearElec	2.98	0.335664			
ImpDep	2.19	0.456854			
HHI	2.18	0.458931			
Kyoto	1.85	0.539815			
OilElec	1.64	0.610581			
Mean VIF	24.58				

understand that a high HHI index means lower diversity and vice versa. Therefore, the diversification of energy supplies in EU countries fosters RES deployment. Similarly, a decrease in the diversification of the primary energy supply causes a reduction in RES deployment.

Column (3) includes the share of fossil fuels by source and nuclear energy in the electricity mix. The result agrees with other studies; the coefficients for coal and oil are negative, supporting the hypothesis of the brown lobby [38,52,72]. In most countries, coal power represents the core of the brown lobby. Coal's participation in electricity generation has decreased from an average of 43% in 1990 to 34% and 28% in 2002 and 2011, respectively. Moreover, it appears that this effect is going to persist as long as the value of Kw/h of coal internalizes its

[5] It must be kept in mind that there are also green lobbies. However, their relevance or financial muscle is much lower that their fossil fuel counterparts.

Table 4
Regressions results using PCSE, FGLS and RE.

Estimator	PCSE	FGLS	PCSE	FGLS	RE
Dependent Variable					
LogCRES					
CO_2pc	−0.0242***	−0.0242***	−0.0624***	−0.0621***	−0.0441***
	(0.00753)	(0.00722)	(0.00826)	(0.00681)	(0.00739)
Energypc	0.0250	0.0250	0.168***	0.167***	0.113***
	(0.0292)	(0.0296)	(0.0198)	(0.0222)	(0.0278)
Kyoto	−0.00473	−0.00473	−0.00492	−0.00485	0.0240*
	(0.0522)	(0.0441)	(0.0465)	(0.0534)	(0.0125)
ImpDep	−0.235***	−0.235***	−0.222***	−0.224***	−0.432***
	(0.0560)	(0.0549)	(0.0460)	(0.0541)	(0.0610)
HHI	−0.702***	−0.702***	−0.557***	−0.559***	−0.837***
	(0.191)	(0.176)	(0.184)	(0.194)	(0.198)
GasEco	0.000536**	0.000536	0.000227	0.000230	0.000579*
	(0.000231)	(0.000349)	(0.000169)	(0.000214)	(0.000319)
GasPh	−0.0197**	−0.0197*	−0.00708	−0.00724	−0.0272**
	(0.00991)	(0.0113)	(0.00952)	(0.00894)	(0.0113)
CoalElec	−0.240**	−0.240**	−0.649***	−0.647***	−0.306***
	(0.0983)	(0.101)	(0.102)	(0.0993)	(0.103)
OilElec	−0.274***	−0.274***	−0.244***	−0.242**	−0.279***
	(0.0954)	(0.0968)	(0.0840)	(0.116)	(0.101)
GasElec	−0.279***	−0.279***	−1.014***	−1.008***	−0.409***
	(0.0753)	(0.0776)	(0.139)	(0.0983)	(0.0859)
NuclearElec	−0.563***	−0.563***	−1.122***	−1.117***	−0.821***
	(0.121)	(0.145)	(0.0952)	(0.0982)	(0.136)
OilP	0.00414***	0.00414***	0.00490***	0.00490***	0.000240
	(0.000868)	(0.000782)	(0.000783)	(0.00100)	(0.000200)
GDPpc	0.00567**	0.00567**	−0.00828***	−0.00826***	0.00401
	(0.00254)	(0.00271)	(0.00231)	(0.00226)	(0.00266)
Constant	−0.541***	−0.541***	−0.407***	−0.411***	−0.457***
	(0.101)	(0.109)	(0.109)	(0.120)	(0.123)
Observations	479	479	479	479	479
R-squared	0.944		0.818		
Wald chi2	416580.68	4684.77	9.65e+07	597.12	242.15
Country FE	YES	YES	NO	NO	
Time FE	YES	YES	YES	YES	

*** Represent significance at the 1% levels.
** Represent significance at the 5% levels.
* Represent significance at the 10% levels.

pollution cost.[6] Nevertheless, its reduction to levels below 25% would increase, rather than decrease, the degree of diversification. When all of the variables are included (column 5), the effect of the variables decreases and becomes equal among coal, oil and gas sources. However, for the NuclearElec variable, the effect is almost double. This result can be explained by the low Kw/h cost of nuclear power and the absence of CO_2 emissions in its generation, which makes it an important competitor for RES [81]. This result also means that for European policymakers, the risk associated with nuclear energy generation did not represent a threat to the energy-system security level because the technical and environmental risk and externalities are not reflected in the price or in choosing alternative, and safer, energy sources.

Finally, columns related to the competitiveness dimension are introduced in columns (4) and (5). The results were inconsistent for the GDP variable in Table 4. Here, the significance is non-existent or below the 1% level of significance in the model with all the variables, which means that an interaction can exist. This is an expected result because the VIF coefficient is greater than 10 (Table 3). In the case of the OilP, the results are robust, and the variable is significant at the 1% level in both columns (4) and (5).

To continue, we will discuss the results in accordance with the classification of the three dimensions. The variables linked to the environmental dimension of energy security present a low level of explanation compared with the other dimensions, particularly security of supply. Concerning the negative coefficient of CO_2pc in all models, one explanation may be that it is a consequence of how GHG emissions reduction can be exhausted or discarded. That is, the use of other energy sources such as nuclear and gas pollute less in terms of CO_2, than does coal, the traditional source for electricity generation and the main source of CO_2 emissions. The decarbonisation of the economy by the shift from fossil fuels to a less polluted energy sector thorough RES deployment is a costly strategy only strongly promoted when other options have been achieved. In this sense, it could be more efficient to adopt and encourage energy efficiency measures or even the adoption of other technologies to reduce emissions, for example, with combined cycles that generate gains in efficiency and reduce CO_2 emission levels. Once these efficiency gains are achieved, RES deployment may be the next step to decarbonising the economy. If this is true, then RES deployment should be considered a fourth strategy to follow after (i) reducing energy intensity, (ii) turning to the EU Emissions Trading System, and (iii) gaining efficiency in sectors not covered by the EU ETS such as housing, agriculture, waste or transport.

In the second case, the competitiveness dimension of energy security could be a driver for RES deployment, but there are contradictory results for the GDP variable. The GDPpc variable

[6] Clearly, this is not happening today in the CO_2 markets. In June 2008, the daily average price of one tonne of CO_2 was 22€. However, in 2014, it was 6€ and now (June 2015) is approximately 7€ (http://www.sendeco2.com/uk/precio_co2.asp?ssidi=3).

Table 5
Selected model specifications for the PCSE estimator.

	(1)	(2)	(3)	(4)	(5)
Dependent variable					
LogCRES					
CO_2pc	−0.0317***				−0.0242***
	(0.00737)				(0.00753)
Energypc	0.0282				0.0250
	(0.0299)				(0.0292)
Kyoto	0.00857				−0.00473
	(0.0553)				(0.0522)
ImpDep		−0.280***			−0.235***
		(0.0512)			(0.0560)
HHI		−0.836***			−0.702***
		(0.196)			(0.191)
GasEco		0.000131			0.000536**
		(0.000208)			(0.000231)
GasPh		−0.0124			−0.0197**
		(0.00886)			(0.00991)
CoalElec			−0.525***		−0.240**
			(0.0872)		(0.0983)
OilElec			−0.242**		−0.274***
			(0.103)		(0.0954)
GasElec			−0.399***		−0.279***
			(0.0873)		(0.0753)
NuclearElec			−0.564***		−0.563***
			(0.136)		(0.121)
OilP				0.00640***	0.00414***
				(0.000362)	(0.000868)
GDPpc				0.00203	0.00567**
				(0.00270)	(0.00254)
Constant	−0.585***	−0.398***	−0.717***	−1.175***	−0.541***
	(0.0647)	(0.0740)	(0.0422)	(0.0742)	(0.101)
Country FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
N	482	479	483	479	479
R-squared	0.935	0.932	0.914	0.911	0.944
Wald chi2	697,822.24	202,166.80	28,503.61	113,249.11	416,580.68

***Represent significance at the 1% levels.
**Represent significance at the 5% levels.
*Represent significance at the 10% levels.

becomes negative for the between estimation, positive for the within and not statistically significant for the Random Effects. We would expect that economies with less economic resources are reluctant towards RES deployment because of the great challenge in terms of financing; accordingly, the improvement in the economic situation increases their RES deployment. However, the GDP per capita is not statistically significant when the other dimensions are not represented in the model. On balance, compared with other dimensions, the GDP per capita variable may present a driver or a barrier to RES depending on the county [82]. This can be because the GDP-RES nexus depends heavily on the type of RES technologies. For instance, Ohler and Fetters [83] report that increases in GDP decrease hydroelectric generation, but the reverse is true for waste generation. Therefore, to study the nexus, it may be necessary to differentiate between energy sources instead of taking all RES technologies as a whole.

Nevertheless, the competitiveness dimension remains significant in its second variable. More importantly, oil prices present one of the most consistent results. As expected, high oil prices are considered a signal of scarcity and risk of supply disruption by investors due to, among other things, demand increase, oil depletion or political instability in transit or producing countries. Therefore, oil price increases are one of the main factors affecting RES investment.

Conversely, a situation of local low economic growth in a country or region combined with low global energy demand may be a major threat to RES deployment, and the effect may be amplified by low gas and coal prices. Although gas and coal prices are not included in our regression, natural gas prices are directly linked to oil prices; thus, a shift from natural gas to coal in electricity generation is expected to be a major consequence of a possible increase in oil prices, in the absence of a stringent climate policy [84].[7] However, if coal prices increase together with oil and gas prices, and/or if climate policy is applied, the share of natural gas and renewable options is expected to increase, as happened in the last 20 years. The Nuclear energy sector's future is uncertain and will depend on the effects of the recent Fukushima disaster on public opinion and on the academic debate [85].

Finally, for the security of supply dimension, the results are ambiguous. The share of fossil fuels in electricity generation shows that the electricity mix is the main factor decelerating RES deployment. A higher share of gas and nuclear energy may reduce the deployment of RES more than a coal-based energy system. This effect is a consequence of the low price of nuclear energy[8] and the absence of GHG emissions in nuclear electricity generation. A share increase of nuclear electricity allows generating high quantities of electricity at low prices, but it requires a huge amount of previous investment. This restriction in the use of the cheapest electricity source is covered by gas and hydro power plants, dispatchable technologies at request with low levels of CO_2 emissions. Therefore, the use of these technologies, and most important, their combination, is a barrier to the introduction of RES. Moreover, in the case of natural gas, it could also be argued that because gas imports in the EU were until 2008 largely fulfilled by long-term contracts [86], their replacement by RES is even more difficult.

Moreover, import dependence is not the variable with more explanatory power within and between countries. One interpretation of this result is that import dependence is not a large driver of RES deployment because to date the displacement of energy imports by RES sources has not been significant. In the case of HHI, the results show that the diversification of energy sources fosters RES deployment. If we consider this result together with the share of fossil fuels and nuclear energy in electricity generation, the explanatory power of our regression increases. For instance, a minimally diversified energy system highly reliant in gas and nuclear sources may present a higher barrier to RES deployment than would a more pollutant coal-based and diversified one.

Finally, it is interesting to observe how the GasEco and GasPh are not as significant as other variables are, and their coefficients are different – positive for GasEco and negative for GasPh. The negative coefficient of the ImpDep variable means that when countries become dependent on energy imports, the rate of RES deployment decreases. Additionally, more-dependent countries deploy fewer RES than do countries with lower levels of energy imports. By the same logic, an economy with higher natural gas levels of consumption per capita, represented by the GasPh variable, should present lower values of RES deployment than would economies with lower levels of gas consumption per capita because gas is considered a political weapon. The gas vulnerability is primarily associated with the political relationship of the EU with their suppliers, particularly Russia. Considering the stability of the energy relationship has existed for a long period in our sample, our variables may not fully reflect the effect of a possible political destabilization.

[7] Despite the recent drop in oil prices, most studies forecast a price recovery in coming years. There are no estimations that retain 2015 oil prices in the medium and longer term [87].

[8] It must be kept in mind that low prices in nuclear power are possible because most externalities are not considered.

6. Conclusions

It is commonly assumed that environmental sustainability is the primary driver behind RES deployment, although RES contribution to energy security through domestic electricity generation is widely recognized. However, the relationship between RES deployment and energy security merits proper assessment. The purpose of this article is, specifically, to analyse the relationship between RES deployment and the supply security dimension of the European energy policy. To do so, we employ a set of indicators to assess factors influencing RES' share of TEPS. Our study focussed on barriers and drivers concerning energy security and sustainability and competitiveness, the other two pillars of European energy policy. Using data from 21 EU Countries from 1990 to 2013, we implement several panel data models. Unlike previous studies, we report a long-term relationship between energy security and renewable deployment.

The results presented here imply that energy security issues have a significant role in RES deployment. Our findings suggest that the relationship between energy security policies and RES deployment is far from straightforward and depends on the chosen energy security strategy, usually linked to the different energy security conceptualizations presented in Section 3. Hence, this study contributes to the ongoing debate about the relationship between energy security and RES deployment with four main conclusions.

The most obvious one is that the introduction of a wide range of indicators of energy security appears to be not only relevant to assess the role of the energy security dimension in RES deployment but also necessary in the formulation of a coherent EU energy policy. The complex relationships between different energy security dimensions cannot be covered with only one indicator, as has traditionally been performed with energy dependence.

More importantly, our second and perhaps main conclusion is that variables related to energy security play a significant role in the development of renewable energy in the EU. This finding partially contradicts almost all earlier empirical findings [6,7,9] because the energy security dimension of the variables included in their models is omitted – except for the energy dependence variable. Moreover, the results of our analysis show that environmental policies such as the reduction of CO_2 emissions and energy intensity are not the main driver of RES deployment. In our view, although the pursuit of environmental targets may be theoretically one of the drivers of RES deployment, the EU environmental policy does not in fact really discourage the use of fossil fuels. In other words, despite the common opinion that renewable energy deployment is solely driven by the aim to reduce CO_2 emissions, our results suggest that this development is an intended consequence of the EU energy security strategy. Thus the main finding of this article contradicts a deeply rooted idea among policymakers, experts or the public opinion: the main driver behind RES deployment is energy security rather than environmental concerns and sustainability policies. This fact would imply the need to reassess the European energy policy approach to both energy security and renewable energies.

The third and fourth conclusions belong to the debate on the definition of energy security and its objectives. From a narrow perspective on energy security, accessibility to energy resources would be represented primarily by import dependence indicators, which our results show do not constitute the main security driver in RES deployment. Therefore, the non-inclusion of other factors may distort significantly the results and lead to biased conclusions. This result accords more with a modern approach to energy security without a prejudice against energy dependence [25,27]. Finally, our fourth conclusion is that an energy security definition primarily based on the disruption of energy supplies due to physical interruptions (accessibility dimension) constitutes a reductionism and implies a lack of coherence among the different EU's energy policy dimensions.

Although our indicators list was formed with the inclusion of variables from three different sources, the final assessment of the barriers does not cover all the indicators proposed in the energy security literature. Nevertheless, in a follow-up study of the coherence between energy policy dimensions, it would be informative to introduce a wider set of variables. Moreover, future research may need to consider the different characteristics of RES technologies. Considering their differences would allow to identify whether the effect of energy security issues depends on the level of maturity of each technology or on any other feature of different RES technologies.

7. Policy implications

The policy implications of our conclusions are straightforward: there is a need to find a European energy security approach coherent with RES deployment. To achieve this goal, our results show that it will be necessary to explore strategies that promote both energy security and sustainable energy avoiding policies focussed only on decreasing import dependence. Today, energy security and climate change mitigation commitments must not run in parallel, but rather converge. How EU energy policy will affect RES deployment depends on how energy security is framed. In that sense, a European energy security framework based on solidarity and coordination could increase policy coherence only if RES are included as an opportunity to improve European energy security through diversification.

That apparent lack of consistency among the different EU's energy policy dimensions suggests that it is critical to increase our knowledge about the coherence of energy policy targets, for instance by developing a more holistic view of energy security in which the environmental and the energy security dimensions are approached more effectively. To do that it is necessary to develop new indicators of energy security that embrace the sustainability dimension of the EU energy systems.

Moreover, the EU energy policy debate is dominated by the dependence on external energy resources due to its confrontation with Russia and the threat of a new gas crisis. But dependence, as our results show, does not constitute the main security driver in RES deployment. In this context, a diversification strategy of primary energy sources presents a higher consistency with RES deployment, and probably better results in terms of energy security, than pursuing import independence. Therefore, it is a more coherent strategy to achieve the EU 2020, 2030 and 2050 targets for RES deployment.

To gain more coherence within the economic, political and environmental objectives, the EU should focus on areas that need particular attention from a policy perspective such as the technological and geopolitical dimension of energy security. To do so, it would be necessary to explore strategies such as the diversification of energy corridors, the geographical diversification of energy sources or the socioeconomic and political risk influencing energy markets.

Finally, if RES deployment is not only about environment, but also about energy security, it should be easier to persuade the public opinion and member States to reach RES goals and fight climate change. Moreover, the willingness to pay for RES deployment should increase among European constituencies.

Annex A

See Annex Table A1.

Table A1
Correlation matrix.

	LogCRES	CO2pc	Energypc	kyoto	GDPpc	OilP	CoalP	GasP	CoalElec	OilElec	GasElec	NucElec	GasEco	GasPh	OilEco	OilPh	ImpDep	HHI	EnergyGDP	CO_2GDP
LogCRES	1																			
CO2pc	−0.5111*	1																		
	0																			
Energypc	−0.1862*	0.7409*	1																	
	0.0001	0																		
kyoto	0.1098	0.0018	0.2120*	1																
	0.0182	0.9693	0																	
GDPpc	−0.1627*	0.5622*	0.7169*	0.5765*	1															
	0.0005	0	0	0																
OilP	0.2175*	−0.0926	0.0359	0.3215*	0.1807*	1														
	0	0.0469	0.4416	0	0.0001															
CoalP	0.1640*	−0.0594	0.0269	0.1525*	0.1288*	0.8776*	1													
	0.0004	0.2029	0.5642	0.001	0.0058	0														
GasP	0.2283*	−0.0998	0.0363	0.3428*	0.1849*	0.9637*	0.8770*	1												
	0	0.0321	0.4369	0	0.0001	0	0													
CoalElec	−0.1240*	0.1209*	−0.3400*	−0.4054*	−0.5156*	−0.1239*	−0.0863	−0.1311*	1											
	0.0076	0.0094	0	0	0	0.0077	0.0639	0.0048												
OilElec	−0.0157	−0.1971*	−0.2628*	−0.1141	−0.1661*	−0.2037*	−0.1634*	−0.2117*	−0.1661*	1										
	0.7361	0	0	0.0141	0.0004	0	0.0004	0	0.0003											
GasElec	−0.3550*	0.2625*	0.2262*	0.4804*	0.5458*	0.2527*	0.1732*	0.2589*	−0.3594*	−0.0314	1									
	0	0	0	0	0	0	0.0002	0	0	0.5006										
NucElec	−0.005	−0.3096*	0.1073	−0.0949	−0.1403*	−0.0152	−0.0122	−0.0157	−0.4196*	−0.0375	−0.3337*	1								
	0.9139	0	0.0213	0.0415	0.0026	0.7453	0.7934	0.736	0	0.4211	0									
GasEco	0.0223	0.0031	0.0232	−0.1528*	0.0155	−0.0383	−0.0333	−0.0373	−0.0742	0.1570*	0.0328	0.0446	1							
	0.6337	0.9466	0.6209	0.001	0.7402	0.4134	0.4771	0.4256	0.1126	0.0007	0.4838	0.3406								
GasPh	−0.0241	0.4535*	0.5038*	0.1374*	0.6104*	0.0235	0.012	0.0257	−0.1674*	0.0074	0.1784*	−0.1898*	0.6553*	1						
	0.6054	0	0	0.0031	0	0.6153	0.7971	0.582	0.0003	0.8749	0.0001	0	0							
OilEco	−0.0057	0.0534	−0.015	−0.1979*	−0.0256	−0.1104	−0.0804	−0.1142	0.0659	0.117	−0.0455	−0.0337	0.9272*	0.6064*	1					
	0.9031	0.2538	0.7486	0	0.585	0.018	0.0854	0.0143	0.1587	0.0121	0.3307	0.4709	0	0						
OilPh	−0.0779	0.5173*	0.4893*	0.0805	0.5777*	−0.026	−0.0215	−0.0274	−0.0708	−0.0305	0.1438*	−0.2424*	0.6137*	0.9641*	0.6498*	1				
	0.095	0	0	0.0843	0	0.5779	0.6457	0.557	0.1289	0.5129	0.002	0	0	0	0					
ImpDep	−0.0475	0.1215*	0.1453*	0.1766*	0.2023*	0.043	0.0361	0.0398	−0.4831*	0.2401*	0.1923*	0.0197	−0.0556	−0.0246	−0.0652	−0.0021	1			
	0.3079	0.009	0.0018	0.0001	0	0.3565	0.4389	0.3936	0	0	0	0.6727	0.2342	0.5978	0.1631	0.964				
HHI	−0.1996*	0.0742	0.0822	−0.1286*	−0.1309*	−0.1807*	−0.1298*	−0.1879*	0.2220*	−0.1626*	0.068	0.029	−0.1085	−0.2596*	−0.0829	−0.2427*	−0.2457*	1		
	0	0.1116	0.078	0.0057	0.005	0.0001	0.0052	0	0	0.0005	0.1444	0.5347	0.02	0	0.0762	0	0			
EneryGDP	−0.0242	0.0087	−0.1104	−0.5185*	−0.6416*	−0.1805*	−0.1302*	−0.1839*	0.5570*	0.0036	−0.3972*	0.0615	0.056	−0.2264*	0.0757	−0.2114*	−0.2903*	0.2894*	1	
	0.6057	0.8526	0.0181	0	0	0.0001	0.0052	0.0001	0	0.9394	0	0.1887	0.2312	0	0.1051	0	0	0		
CO_2GDP	−0.1159	0.0635	−0.2182*	−0.5109*	−0.6400*	−0.2002*	−0.1403*	−0.2057*	0.7054*	−0.0095	−0.3591*	−0.1300*	0.0034	−0.2321*	0.0632	−0.1936*	−0.3119*	0.3054*	0.9552*	1
	0.0129	0.1751	0	0	0	0	0.0026	0	0	0.8398	0	0.0053	0.9416	0	0.1767	0	0	0	0	

Notes: The table shows the correlation coefficients for all variables examined in this paper.
***, ** Represent significance at the 1% and 5% levels, respectively.
* Represent significance at the 10% levels.

References

[1] Strambo C, Nilsson M, Månsson A. Coherent or inconsistent? Assessing energy security and climate policy interaction within the European Union Energy Res Soc Sci 2015;8:1–12. http://dx.doi.org/10.1016/j.erss.2015.04.004.
[2] Popp D. Induced innovation and energy prices. Am Econ Rev 2002;92:160–80. http://dx.doi.org/10.1257/000282802760015658.
[3] Johnstone N, Haščič I, Popp D. Renewable energy policies and technological innovation: Evidence based on patent counts. Environ Resour Econ 2010;45:133–55. http://dx.doi.org/10.1007/s10640-009-9309-1.
[4] Popp D, Hascic I, Medhi N. Technology and the diffusion of renewable energy. Energy Econ 2011;33:648–62. http://dx.doi.org/10.1016/j.eneco.2010.08.007.
[5] Nesta L, Vona F, Nicolli F. Environmental policies, competition and innovation in renewable energy. J Environ Econ Manage 2014;67:396–411. http://dx.doi.org/10.1016/j.jeem.2014.01.001.
[6] Marques AC, Fuinhas JA, Pires Manso JR. Motivations driving renewable energy in European countries: a panel data approach. Energy Policy 2010;38:6877–85. http://dx.doi.org/10.1016/j.enpol.2010.07.003.
[7] Marques AC, Fuinhas JA. Drivers promoting renewable energy: a dynamic panel approach. Renew Sustain Energy Rev 2011;15:1601–8. http://dx.doi.org/10.1016/j.rser.2010.11.048.
[8] Marques AC, Fuinhas JA. Are public policies towards renewables successful? Evidence from European countries Renew Energy 2012;44:109–18. http://dx.doi.org/10.1016/j.renene.2012.01.007.
[9] Aguirre M, Ibikunle G. Determinants of renewable energy growth: a global sample analysis. Energy Policy 2014;69:374–84. http://dx.doi.org/10.1016/j.enpol.2014.02.036.
[10] Bigano A, Ortiz RA, Markandya A, Menichetti E, Pierfederici R. The linkages between energy efficiency and security of energy supply in Europe. Milan: Fondazione Eni Enrico Mattei; 2010.
[11] Winzer C. Conceptualizing energy security. Energy Policy 2012;46:36–48. http://dx.doi.org/10.1016/j.enpol.2012.02.067.
[12] Narula K, Reddy BS. Three blind men and an elephant: the case of energy indices to measure energy security and energy sustainability. Energy 2015;80:148–58. http://dx.doi.org/10.1016/j.energy.2014.11.055.
[13] Johansson B. A broadened typology on energy and security. Energy 2013;53:199–205. http://dx.doi.org/10.1016/j.energy.2013.03.012.
[14] Escribano Francés G, Marín-Quemada JM, San Martín González E. RES and risk: renewable energy's contribution to energy security. A portfolio-based approach. Renew Sustain Energy Rev 2013;26:549–59. http://dx.doi.org/10.1016/j.rser.2013.06.015.
[15] Cherp A, Jewell J. The three perspectives on energy security: Intellectual history, disciplinary roots and the potential for integration. Curr Opin Environ Sustain 2011;3:202–12. http://dx.doi.org/10.1016/j.cosust.2011.07.001.
[16] Darmani A, Arvidsson N, Hidalgo A, Albors J. What drives the development of renewable energy technologies? Toward a typology for the systemic drivers Renew Sustain Energy Rev 2014;38:834–47. http://dx.doi.org/10.1016/j.rser.2014.07.023.
[17] Månsson A, Johansson B, Nilsson LJ. Assessing energy security: an overview of commonly used methodologies. Energy 2014;73:1–14. http://dx.doi.org/10.1016/j.energy.2014.06.073.
[18] Ren J, Sovacool BK. Quantifying, measuring, and strategizing energy security : determining the most meaningful dimensions and metrics. Energy 2014;76:838–49. http://dx.doi.org/10.1016/j.energy.2014.08.083.
[19] Ang BW, Choong WL, Ng TS. Energy security: definitions, dimensions and indexes. Renew Sustain Energy Rev 2015;42:1077–93. http://dx.doi.org/10.1016/j.rser.2014.10.064.
[20] Eleftheriadis IM, Anagnostopoulou EG. Identifying barriers in the diffusion of renewable energy sources. Energy Policy 2015;80:153–64. http://dx.doi.org/10.1016/j.enpol.2015.01.039.
[21] Sovacool BK, Dworkin MH. Energy justice: conceptual insights and practical applications. Appl Energy 2015;142:435–44. http://dx.doi.org/10.1016/j.apenergy.2015.01.002.
[22] Böhringer C, Keller A. Energy security : An impact assessment of the EU climate and energy package climate and energy package. Germany: Inst. für Volkswirtschaftslehre, University of Oldenburg; 2011.
[23] Böhringer C, Bortolamedi M. Sense and no (n)-sense of energy security indicators. Ecol Econ 2015;119:359–71. http://dx.doi.org/10.1016/j.ecolecon.2015.09.020.
[24] Gracceva F, Zeniewski P. A systemic approach to assessing energy security in a low-carbon EU energy system. Appl Energy 2014;123:335–48. http://dx.doi.org/10.1016/j.apenergy.2013.12.018.
[25] Guivarch C, Monjon S. Would climate policy improve the European energy security? Clim Chang Eco 2015;06:1550008. http://dx.doi.org/10.1142/S2010007815500086.
[26] Lima F, Portugal-Pereira J. Analysis of energy security and sustainability in future low carbon scenarios for Brazil. Nat Resour Forum 2015;39:175–90. http://dx.doi.org/10.1111/1477-8947.12081.
[27] Brown SPA, Huntington HG. Energy security and climate change protection: Complementarity or tradeoff? Energy Policy 2008;36:3510–3. http://dx.doi.org/10.1016/j.enpol.2008.05.027.
[28] Röpke L. The development of renewable energies and supply security: a trade-off analysis. Energy Policy 2013;61:1011–21. http://dx.doi.org/10.1016/j.enpol.2013.06.015.
[29] Tishler A, Newman J, Spekterman I, Woo CK. Cost-benefit analysis of reforming Israel's electricity industry. Energy Policy 2006;34:2442–54. http://dx.doi.org/10.1016/j.enpol.2004.08.021.
[30] de Nooij M, Koopmans C, Bijvoet C. The value of supply security. The costs of power interruptions: economic input for damage reduction and investment in networks. Energy Econ 2007;29:277–95. http://dx.doi.org/10.1016/j.eneco.2006.05.022.
[31] Bauen A. Future energy sources and systems-acting on climate change and energy security. J Power Sources 2006;157:893–901. http://dx.doi.org/10.1016/j.jpowsour.2006.03.034.
[32] Correljé A, van der Linde C. Energy supply security and geopolitics: a European perspective. Energy Policy 2006;34:532–43. http://dx.doi.org/10.1016/j.enpol.2005.11.008.
[33] Costantini V, Gracceva F, Markandya A, Vicini G. Security of energy supply: comparing scenarios from a European perspective. Energy Policy 2007;35:210–26. http://dx.doi.org/10.1016/j.enpol.2005.11.002.
[34] Meade N, Islam T. Modelling European usage of renewable energy technologies for electricity generation. Technol Forecast Soc Change 2015;90:497–509. http://dx.doi.org/10.1016/j.techfore.2014.03.007.
[35] Jewell J, Cherp A, Riahi K. Energy security under de-carbonization scenarios: an assessment framework and evaluation under different technology and policy choices. Energy Policy 2014;65:743–60. http://dx.doi.org/10.1016/j.enpol.2013.10.051.
[36] McCollum D, Bauer N, Calvin K, Kitous A, Riahi K. Fossil resource and energy security dynamics in conventional and carbon-constrained worlds. Clim Change 2013;123:413–26. http://dx.doi.org/10.1007/s10584-013-0939-5.
[37] Martínez S, Koberle A, Rochedo P. Possible energy futures for Brazil and Latin America in conservative and stringent mitigation pathways up to 2050. Technol Forecast Soc Change 2015;98:186–210. http://dx.doi.org/10.1016/j.techfore.2015.05.006.
[38] Huang MY, Alavalapati JRR, Carter DR, Langholtz MH. Is the choice of renewable portfolio standards random? Energy Policy 2007;35:5571–5. http://dx.doi.org/10.1016/j.enpol.2007.06.010.
[39] Awerbuch S, Yang S. Efficient electricity generating portfolios for Europe: maximising energy security and climate change mitigation. EIB Pap 2007;12:8–37.
[40] Jansen JC, Seebregts AJ. Long-term energy services security: what is it and how can it be measured and valued? Energy Policy 2010;38:1654–64. http://dx.doi.org/10.1016/j.enpol.2009.02.047.
[41] Abolhosseini S, Heshmati A. The main support mechanisms to finance renewable energy development. Renew Sustain Energy Rev 2014;40:876–85. http://dx.doi.org/10.1016/j.rser.2014.08.013.
[42] Novacheck J, Johnson JX. The environmental and cost implications of solar energy preferences in Renewable Portfolio Standards. Energy Policy 2015;86:250–61. http://dx.doi.org/10.1016/j.enpol.2015.06.039.
[43] Scholten D, Bosman R. The geopolitics of renewables; exploring the political implications of renewable energy systems. Technol Forecast Soc Change 2016;103:273–83. http://dx.doi.org/10.1016/j.techfore.2015.10.014.
[44] Zhao Y, Tang KK, Wang L. Do renewable electricity policies promote renewable electricity generation? Evidence from panel data Energy Policy 2013;62:887–97. http://dx.doi.org/10.1016/j.enpol.2013.07.072.
[45] Kilinc-Ata N. The evaluation of renewable energy policies across EU countries and US states: an econometric approach. Energy Sustain Dev 2016;31:83–90. http://dx.doi.org/10.1016/j.esd.2015.12.006.
[46] Carley S. State renewable energy electricity policies: an empirical evaluation of effectiveness. Energy Policy 2009;37:3071–81. http://dx.doi.org/10.1016/j.enpol.2009.03.062.
[47] Sanyal P, Ghosh S. Product market competition and upstream innovation: evidence from the us electricity market deregulation. Rev Econ Stat 2013;95:237–54. http://dx.doi.org/10.1162/REST_a_00255.
[48] Gan L, Eskeland GS, Kolshus HH. Green electricity market development: lessons from Europe and the US. Energy Policy 2007;35:144–55. http://dx.doi.org/10.1016/j.enpol.2005.10.008.
[49] Chien T, Hu JL. Renewable energy: an efficient mechanism to improve GDP. Energy Policy 2008;36:3035–42. http://dx.doi.org/10.1016/j.enpol.2008.04.012.
[50] Kruyt B, van Vuuren DP, de Vries HJM, Groenenberg H. Indicators for energy security. Energy Policy 2009;37:2166–81. http://dx.doi.org/10.1016/j.enpol.2009.02.006.
[51] Johansson B. Security aspects of future renewable energy systems-A short overview. Energy 2013;61:598–605. http://dx.doi.org/10.1016/j.energy.2013.09.023.
[52] Sovacool BK, Saunders H. Competing policy packages and the complexity of energy security. Energy 2014;67:641–51. http://dx.doi.org/10.1016/j.energy.2014.01.039.
[53] Change D of E& C. Energy Markets; 2009.
[54] International Energy Agency I. Toward a sustainable energy future. Paris; 2001.
[55] Mabro R. On the security of oil supplies, oil weapons, oil nationalism and all that. OPEC Energy Rev 2008;32:1–13. http://dx.doi.org/10.1111/j.1753-0237.2008.00139.x.
[56] Milov V. Global energy agenda. Russ Glob aff 2005;3:60–8.
[57] Bazilian M, Nakhooda S, Van de Graaf T. Energy governance and poverty. Energy Res Soc Sci 2014;1:217–25. http://dx.doi.org/10.1016/j.erss.2014.03.006.
[58] González-Eguino M. Energy poverty: an overview. Renew Sustain Energy Rev 2015;47:377–85. http://dx.doi.org/10.1016/j.rser.2015.03.013.
[59] Natorski M, Surrallés AH. Securitizing moves to nowhere? The framing of the European Union's energy policy J Contemp Eur Res 2008;4:71–89.

[60] European Commission. Communication from the Commission to the Council and the European Parliament: European energy security strategy "In-depth study of European Energy Security", Commission Staff Working Document, SWD(2014) 330 final/3. Brussels; 2014.
[61] European Comission. Member states' energy dependence: An indicator-based assessment. Brussels; 2013.
[62] Huang MY, Alavalapati JRR, Carter DR, Langholtz MH. Is the choice of renewable portfolio standards random? Energy Policy 2007;35:5571–5. http://dx.doi.org/10.1016/j.enpol.2007.06.010.
[63] Chester L. Conceptualising energy security and making explicit its polysemic nature. Energy Policy 2010;38:887–95. http://dx.doi.org/10.1016/j.enpol.2009.10.039.
[64] United Nations Development Program U. World energy assessment: overview 2004 update. New York; 2004.
[65] Yergin D. Ensuring energy security. Foreign Aff 2006;85:69. http://dx.doi.org/10.2307/20031912.
[66] International Energy Agency I. International energy agency. Paris; 2008.
[67] Jaforullah M, King A. Does the use of renewable energy sources mitigate CO_2 emissions? A reassessment of the US evidence Energy Econ 2015;49:711–7. http://dx.doi.org/10.1016/j.eneco.2015.04.006.
[68] Neff TL. Improving energy security in Pacific Asia: diversification and risk reduction for fossil and nuclear fuels. Pacific Asia Regional Energy Security Project; December 1997.
[69] Grubb M, Butler L, Sinden G. Diversity and security in UK electricity generation: the influence of low carbon objetives. Energy Policy 2006;34:4050–62.
[70] Percebois J. Dependance et Vulnerabilite: Deux Façons Connexes Mais Differentes D'aborder les Risques Energetiques. Montpellier; 2006.
[71] Internaational Energy Agency. Energy Security and Climate Policy-Assessing Interactions. Organisation for Economic Co-operation and Development, 2007.
[72] Sovacool BK. Rejecting renewables: The socio-technical impediments to renewable electricity in the United States. Energy Policy 2009;37:4500–13. http://dx.doi.org/10.1016/j.enpol.2009.05.073.
[73] Bird L, Bolinger M, Gagliano T, Wiser R, Brown M, Parsons B. Policies and market factors driving wind power development in the United States. Energy Policy 2005;33:1397–407. http://dx.doi.org/10.1016/j.enpol.2003.12.018.
[74] Chatterjee S, Hadi AS. Regression analysis by example, Wiley; 2006, http://dx.doi.org/10.1002/0470055464.
[75] Wooldridge JM. Econometric analysis of cross section and panel data. ; http://dx.doi.org/10.1515/humr.2003.021.
[76] Pesaran MH. General diagnostic tests for cross section dependence in panels. SSRN Electron J 2004:1229.
[77] Friedman M. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. J Am Stat Assoc 1937;32:675–701. http://dx.doi.org/10.1080/01621459.1937.10503522.
[78] Frees EW. Assessing cross-sectional correlation in panel data. J Econom 1995;69:393–414. http://dx.doi.org/10.1016/0304-4076(94)01658-M.
[79] Baltagi BH, Wu PX. Unequally spaced panel data regressions with AR(1) disturbances. Econom Theory 1999:15. http://dx.doi.org/10.1017/S0266466699156020.
[80] Beck N, Katz JN. What to do (and Not to Do) with time-series cross-section data. Am Political Sci Rev 1995;89:634–47. http://dx.doi.org/10.2307/2082979.
[81] Karakosta C, Pappas C, Marinakis V, Psarras J. Renewable energy and nuclear power towards sustainable development: characteristics and prospects. Renew Sustain Energy Rev 2013;22:187–97. http://dx.doi.org/10.1016/j.rser.2013.01.035.
[82] Al-Mulali U, Fereidouni HG, Lee JY, Sab CNBC. Examining the bi-directional long run relationship between renewable energy consumption and GDP growth. Renew Sustain Energy Rev 2013;22:209–22. http://dx.doi.org/10.1016/j.rser.2013.02.005.
[83] Ohler A, Fetters I. The causal relationship between renewable electricity generation and GDP growth: a study of energy sources. Energy Econ 2014;43:125–39. http://dx.doi.org/10.1016/j.eneco.2014.02.009.
[84] Vielle M, Viguier L. On the climate change effects of high oil prices. Energy Policy 2007;35:844–9. http://dx.doi.org/10.1016/j.enpol.2006.03.022.
[85] Kiriyama E, Kajikawa Y. A multilayered analysis of energy security research and the energy supply process. Appl Energy 2014;123:415–23. http://dx.doi.org/10.1016/j.apenergy.2014.01.026.
[86] Franza L. Long-term import contracts in Europe. The evolution in pricing mechanism. CIEP Working Paper. The Hague, The Netherlands; 2014.
[87] EIA, Annual Energy Outlook 2015. U.S. energy information administration. April 2015 DOE/EIA-0383(2015).