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Analysis of Electricity and Natural Gas Security. A Case Study for Germany, France, Italy and Spain

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Abstract: This work aims to present an analysis of electricity and natural gas supply security in the four European Union countries with the highest level of consumption, namely Germany, France, Italy, and Spain. The goal of the study is to use and adapt a set of 22 indicators for estimating the level of energy security. The evaluation of an index called "Energy Security Level", measuring the overall energy security, is performed for the period 2006–2018 in order to compare its evolution in each of the analyzed countries. The application of the proposed indicator system demonstrates which measures weakened or strengthened energy security in the past. The analysis of the energy security level demonstrates that Germany and France perform better than Italy and Spain in terms of energy security assurance. The main factors for these differences are the rich energy mix for Germany and the massive presence of nuclear power in France. These two elements make German and French energy systems more resilient than the Italian and Spanish ones. The results of sensitivity and uncertainty analysis demonstrate that the initial values of indicator weights have low impact on the uncertainty of energy security level estimations.

Keywords: energy security; natural gas; electricity; indicators

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1. Introduction

Energy security is often referred to as a reliable and adequate energy supply at reasonable prices [1]. 'Reliable and adequate' means that the supply should be uninterrupted and capable of satisfying the demand of the corresponding region/country. 'Reasonable price' has a more complex meaning and, as highlighted in [1], there is no common convergence on its definition. From the economic point of view, a reasonable price is the result of the clearing between demand and supply.

Often, the concept of energy security is overlapped with that of energy independence, i.e., the ability of a country to be self-sufficient in addressing its energy needs without any imports. Initially, energy security was analyzed only from the energy dependence point of view and one of the first persons to highlight the importance of energy supply diversification was Winston Churchill [2].

According to more recent views, energy independence is only a dimension of energy security since internal sources of energy could be problematic as well. For example, if a country is largely based on renewables, there could be issues in terms of availability and reliability. Other dimensions influencing energy security can be the exercise of market power by suppliers, energy price volatility, threats to infrastructure, local reliability problems, environmental issues, etc.

The problem of energy security is also perceived in different ways according to the status of the analyzed country. As highlighted in [2], four main typologies of countries can be highlighted, namely, industrialized net importers, major hydrocarbon-exporting countries, emerging countries, and mid- to low-income energy importers. Table 1 highlights that the needs of each of these categories are different; therefore, the problem of energy security is addressed in different ways.

Table 1. Main issues of energy security based on the country's typology [2].

Country Typology	Issues
Industrialized net importers	To avoid supply disruptions, diversification of energy resources, security concerns related to infrastructures, technology development to reduce consumption
Major hydrocarbon-exporting countries	To develop long-term market with affordable prices, diversification of the exporting markets, financing fossil fuel extraction
Emerging countries	To ensure adequate supply for matching fast-increasing demand, to develop energy infrastructure, and technology development to reduce the energy consumption
Mid- to low-income energy importers	To guarantee an adequate energy supply to satisfy the basic needs of people, diversification of the supply sources, financing the development of infrastructures, to acquire technologies to reduce the energy dependence

The European Union (EU) can be considered an industrialized net-importer area; therefore, it has the problem of ensuring energy supply security in order to guarantee and improve its economic development. On the other hand, the EU relies on relevant fossil fuel imports, predominantly oil and natural gas; therefore, it is subject to third-country pressure. For example, in 2014 the crisis between Russia and Ukraine had a relevant effect on the EU in terms of energy supply [3] and it reopened the debate on European energy security. The previous crises of 2006 and 2009 were recalled and relevant concerns were raised, since in 2014 a real conflict between Russia and Ukraine was in the background [4]. On the other hand, the EU's natural gas system in 2014 was different than in 2009, as the North-Stream pipeline had been opened, the EU's national energy security plans were harmonized, and more LNG capacity was available [4].

As noticed in [5], after the 2014 Russian-Ukrainian crisis, the EU started to consider the problem of energy security with much more attention by taking some specific positions in its energy strategy. In particular, the lines of actions indicated by the EU are energy efficiency, market integration, optimization of indigenous resource exploitation and penetration of renewable energy sources (RES), development of innovative technologies, diversification of the supply, and common external energy policy.

In order to understand the current positioning of the EU with respect to energy security, it is mandatory to define quantitative indicators; however, there is no common view on the indicators to use, except for a few of them, such as fuel mix, concentration index, Shannon-Wiener index, etc., which offer only a partial view of the problem.

The goal of the present study is to use and adapt a set of indicators previously defined in [6] for the Baltic States in order to analyze the energy security, with specific reference to electricity and natural gas at the EU level.

Electricity and natural gas are pivotal in the EU energy context since the electrification of energy consumption is proceeding quickly and the development of e-mobility can boost it further. The role of natural gas is relevant as well because of its prominent position in the electricity generation mix and space heating. Besides, the concentration of the supply in a few countries makes it relevant from the strategic and geopolitical point of view.

To develop the analysis, the first four EU countries in terms of electricity and natural gas consumption were selected, namely Germany, France, Italy, and Spain. In each of these countries, the evolution of an index called Energy Security Level (ESL), measuring energy security, is estimated for the period 2006–2018 with reference to electricity and natural gas. The focus of the paper is to assess the energy security challenges of the considered focus countries rather than to test the ESL using these countries as sample sets.

To the best of the authors' knowledge, the present contribution is the first to address the issue of security of electricity and natural gas supply in Germany, France, Italy, and Spain with an extensive quantitative approach. Differently from other papers, the large set of indicators considered allows us to obtain a complete picture of all the factors influencing the energy security in these countries. Furthermore, the comparison among them allows us to analyze the impact that the different energy policies implemented in these countries had on energy security.

The paper is organized as follows: Section 2 presents a literature review, Section 3 illustrates the trend of natural gas and electricity consumption, Section 4 briefly describes the adopted methodology, Section 5 discusses the obtained results, and Section 6 summarizes the main results and conclusions of the study.

2. Literature Review

Many available papers provide various methods for assessing energy security performance. The most popular approach is to evaluate energy security using measurable quantitative indicators. Many studies have proposed methods to quantify energy security performance by employing an indicator approach, starting from Kruyt et al. [7], Vivoda [8], Jewell [9], and Sovacool [10,11] to Mansson et al. [12], Martchamadol and Kumar [13], Ang et al. [14], and many others [15–28]. In this paper, the goal of the literature review is to include those studies that provide the possibility to compare the analyzed countries (France, Germany, Spain, and Italy) with regards to energy security performance, especially by using indicators. It enables a comparison of the results presented in this paper with the results presented in previously published studies.

Energy security is one of the three core dimensions, together with energy equity and environmental sustainability, of the World Energy Trilemma Index (WETI), which is prepared annually by the World Energy Council (WEC) [29]. The WETI ranks energy systems of various world countries. According to the latest data of 2020 for the energy security dimension, Germany is ranked as 11th, France as 18th, Italy as 23rd, and Spain as 25th among 125 countries worldwide. However, the WETI does not provide values on the different dimensions but presents the country ranks only, which might be considered as the main disadvantage of this index.

Similarly, the ability to deliver secure, affordable, and sustainable energy is evaluated by the global Energy Architecture Performance Index (EAPI). The latest report provides results of the energy system performance of 127 countries using the EAPI scores on a scale of 0 to 1 [30]. According to the "energy access and security" sub-index, France and Germany have a score of 0.88, while Spain and Italy observed 0.87 and 0.84, respectively.

Instead, the Energy Security Risk Index is prepared annually by the Global Energy Institute [31], which ranks countries according to risk-based scores. The latest data of 2018 show that Germany is ranked as 14th, France as 15th, Spain as 19th, and Italy as 20th among 25 large energy-using countries.

Another aggregated index is proposed by Wang and Zhou, namely the Energy Security Index (ESI), to evaluate global national energy security [32]. The ESI is based on the integrated application of subjective and objective weight allocation methods. Nine subgroups including 162 countries were created according to energy security performance in different regions. All four analyzed countries were in the Good (I) group, or second best out of nine.

Energy security in EU countries based on diversity, import dependence, and supply risk was evaluated by Matsumoto et al. [33]. The Shannon–Wiener index (SWI) for France and Italy was approximately 1.5 and for Germany and Spain was approximately 1.6.

Radovanović et al. proposed the energy security index, which includes environmental and social aspects, and applied it to the energy security analysis of EU countries for the period 1990–2012 [19]. Spain and Italy reported scores of 62.87 and 51.24, respectively, in 2012 and were grouped into the first and second categories, respectively. Meanwhile, Germany and France reported +0.72 and −2.65 indexes, respectively, in 2012, going into the third category. However, the results are difficult to interpret as the index does not suggest any threshold values. In addition, the energy security index of France in 2012 is relatively low, which does not properly address the real energy security status.

Erahman et al. developed the energy security index based on five dimensions of energy security (availability, affordability, accessibility, acceptability, and efficiency) [17]. The index was applied to assess the energy security of 71 countries for 2008–2013. In 2013, the observed values of this index for the analyzed countries were very similar (from 0.717 to 0.770 on a scale of 0 to 1), while the average index value was 0.593. For comparison, the highest energy security index in 2013 was recorded for Norway (0.850).

The Risky External Energy Supply (REES) index was proposed by Le Coq et al. [34] to evaluate the security of the external energy supply in the EU for oil, natural gas, and coal. The value of this index for DE, FR, IT, and ES in the case of oil and natural gas was much better than the average, while in terms of coal, Italy reported a slightly higher risk than the average in 2006.

Delgado presented the Socioeconomic Energy Risk Index for the EU-25 countries [35]. The highest risk in 2009 among the four analyzed countries was determined to be in Spain (29.1), the lowest risk was in Germany (17.3), while the average value for the EU-25 was 28.9 out of 100.

Muñoz et al. proposed the Geopolitical Energy Supply Risk Index (GESRI), which aims to quantitatively estimate the geopolitical risk of energy supply [36]. A total of 122 countries were evaluated by the GESRI and the results were aggregated over the period of 2000–2010. Germany is ranked as 4th with a GESRI of 32.01, France is 8th with a GESRI of 33.43, Italy is ranked as 19th with a GESRI of 35.95, and Spain is 22nd with a GESRI of 36.34 on a scale from 0 to 100.

Badea et al. developed composite indicators for the energy supply security of EU countries in 2010 based on ordered weighted averaging [37]. In this study, Germany was ranked as 9th, France as 11th, Spain as 16th, and Italy as 22nd.

The composite index of vulnerability was estimated for the year 2003 for 37 countries by Gnansounou [38]. Analyzed countries were ranked according to the level of vulnerability. France performed as 8th, Germany as 19th, Spain as 23rd, and Italy as 34th.

The composite oil vulnerability index (OVI) was proposed by Gupta [39]. The OVI is computed as the weighted average of various indicators, where weights are derived using a multivariate technique of principal component analysis (PCA). Results for 2004 showed that the final values of OVI for Germany is 0.44, for France is 0.45, for Italy is 0.55 and for Spain is 0.70, while the average OVI of 26 analyzed countries is 0.64. The higher the value of OVI is, the higher is the observed vulnerability of the oil supply.

Cohen et al. proposed a country-specific diversification index (CDI) to measure the energy security of oil and natural gas supplies [40]. CDI is applied to provide the ranking of countries for the last sample year, which is 2008 for oil and 2007 for natural gas. In the analysis of CDI for oil, France is ranked as 4th, Spain as 6th, Italy as 10th, and Germany as 12th among 26 analyzed countries. In the analysis of CDI for natural gas, Italy is ranked as 4th, France as 5th, Spain as 7th, and Germany as 10th among 20 analyzed countries.

The energy security index based on 29 indicators, according to World Bank data, was calculated for a set of countries by Stavytskyy et al. [41]. The analysis period covers 1991–2020 and the 2020 index estimation for Germany is 0.937, for Spain 0.991, for France 0.858, and for Italy 1.013. The limits for the energy security index are not provided; however, it can be compared with the value of 1, which corresponds to the European average. If a country has an index greater than 1, it performs better than the European average in terms of energy security. If the index is lower than 1, it has lower energy security than the European average.

Azzuni and Breyer proposed the Global Energy Security Index and applied it on the national level to various countries worldwide [42]. The index is based on 15 dimensions of energy security and is measured on a scale of 0–100%. Germany is ranked as 1st with an index of 58.2%, France is 15th with an index of 53.4%, Spain is ranked as 20th with an index of 53.0% and Italy is 31st with an index of 51.3% among 228 countries.

The literature review demonstrates that energy security for the analyzed countries is evaluated in various ways emplesioying different methods, which results in quite different energy security estimates for these countries (Table 2). This paper contributes with a comprehensive analysis of the energy security performance of Germany, France, Italy, and Spain, which allows us to compare the dynamic of energy security level from 2006 to 2018.

Table 2. Summary of energy security estimates for analyzed countries. Source: own research.

Study [Reference]	Proposed Index	Latest Year of the Analyzed Period	Index Estimate (in the End of Analysis Period)				Measurement
			France	Germany	Italy	Spain	
WEC [29]	WETI	2020	18th	11th	23rd	25th	Rank (out of 125) (higher values demonstrate lower rank)
WEF [30]	EAPI	2017	0.88	0.88	0.84	0.87	(0; 1) (higher values demonstrate higher energy security)
Global Energy Institute [31]	Energy Security Risk Index	2018	15th	14th	20th	19th	Rank (out of 25) (higher values demonstrate lower rank)
Wang and Zhou [32]	ESI	Not specified	2nd	2nd	2nd	2nd	Nine sub-groups (higher values demonstrate lower rank)
Matsumoto et al. [33]	SWI [1]	2013	1.47	1.61	1.48	1.59	≥0 (higher values demonstrate higher diversity)
Radovanović et al. [19]	ESI	2012	−2.65 (3rd group)	+0.72 (3rd group)	+51.24 (2nd group)	+62.87 (1st group)	Four groups: (1) >+55; (2) (+15; +55); (3) (−25; +15); (4) <−25. (higher values demonstrate higher energy security)
Erahman et al. [17]	ESI	2013	0.770	0.764	0.756	0.717	(0; 1) (higher values demonstrate higher energy security)
Le Coq et al. [34]	REES	2006	1.7 (oil) 0.9 (natural gas) 0.5 (coal)	2.4 (oil) 5.5 (natural gas) 0.6 (coal)	3.3 (oil) 7.5 (natural gas) 1.8 (coal)	3.4 (oil) 3.3 (natural gas) 1.5 (coal)	≥0 (higher values demonstrate higher risk)
Delgado [35]	Socioeconomic Energy Risk Index	2009	28	17.3	22.5	29.1	(0; 100) (higher values demonstrate higher risk)
Muñoz et al. [36]	GESRI [2]	2010	33.43	32.01	35.95	36.34	(0; 100) (higher values demonstrate higher risk)
Badea et al. [37]	Composite indicator	2010	11th	9th	22nd	16th	Rank (out of 27) (higher values demonstrate lower rank)
Gnansounou [38]	Composite index of vulnerability	2003	8th	19th	34th	23rd	Rank (out of 37) (better rank demonstrates lower vulnerability)
Gupta [39]	OVI	2004	0.45	0.44	0.55	0.70	≥0 (higher values demonstrate higher vulnerability)
Cohen et al. [40]	CDI	2008	4th (oil) 5th (natural gas)	12th (oil) 10th (natural gas)	10th (oil) 4th (natural gas)	6th (oil) 7th (natural gas)	Rank (for oil out of 26, for natural gas out of 20) (better rank demonstrates higher diversity)
Stavytskyy et al. [41]	Energy security index	2020	0.858	0.937	1.013	0.991	≥0 (higher values demonstrate higher energy security)
Azzuni and Breyer [42]	Global Energy Security Index	Not specified	53.4	58.2	51.3	53.0	(0; 100) (higher values demonstrate higher energy security)

[1]. Values are estimated approximately since the study results are provided in the graphical form only. [2]. Values are aggregated over the period 2000–2010.

With respect to the reviewed literature, the paper offers a much more detailed description of the electricity and natural gas system since the focus is on four specific countries and not on a large group as presented in the reviewed literature.

3. Trend of Natural Gas and Electricity Consumption

The analysis of electricity and natural gas consumption patterns is relevant for understanding the trends in activities and support the interpretation of energy security indexes.

Figure 1 reports the historical trend of gross domestic product (GDP) (Figure 1a), heating degree days (HDDs) (Figure 1b), electricity consumption (Figure 1c), and natural gas consumption (Figure 1d). GDP and HDDs support the understanding of electricity and natural gas consumption trends, since energy is a derived consumption and it is pushed by economic activities but also influenced by climatic conditions. Economic activities and climatic conditions are proxied with GDP and HDDs, respectively.

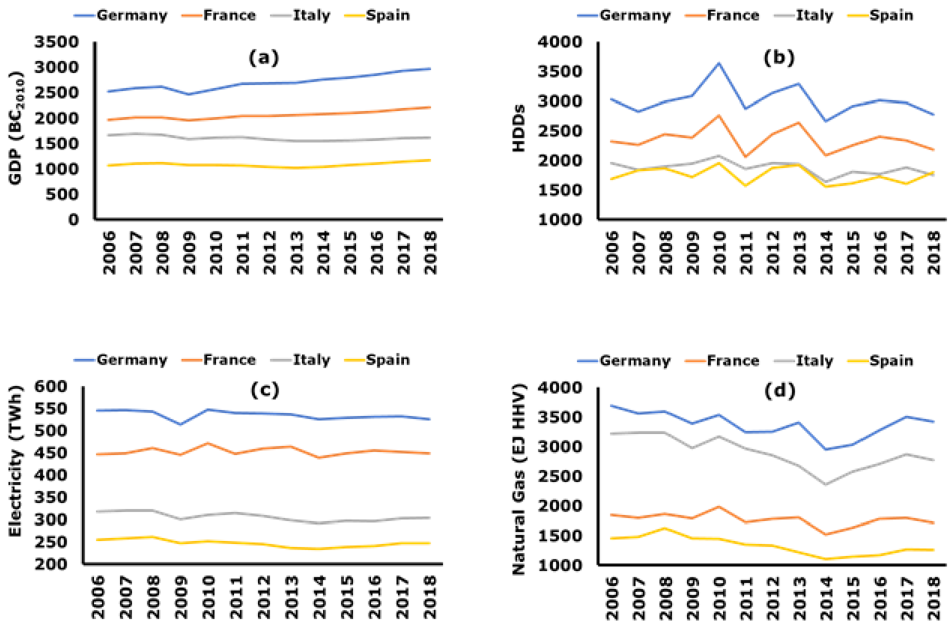


Figure 1. Trend of energy consumption and relevant explaining variables: (**a**) GDP, (**b**) HDDs, (**c**) electricity, and (**d**) natural gas. Source: [43].

As for the GDP trend, Figure 1a demonstrates that Germany has the highest values among the considered countries. GDP trends are similar; in particular, a relevant decrease is highlighted in 2009 vs. 2008 for all the countries, i.e., −6.0% in Germany, −3.0% in France, −5.6% in Italy, and −3.9% in Spain, caused by the global economic downturn. Afterward, a recovery is shown, but characterized by the different pace of growth for the different countries. In the period 2009–2018, Germany shows a compound annual growth rate (CAGR) of 1.9%, whereas France, Italy and Spain have respective CAGRs equal to 1.2%, 0.2%, and 0.8%. Germany is also characterized by the coldest climatic conditions (Figure 1b) with an average of 3012 HDDs in the considered period. France, Italy, and Spain have an average of 2350, 1868, and 1747 HDDs, respectively.

The trends of GDP and HDDs largely affect electricity and natural gas consumption patterns since GDP can be seen as a measure of the developed economic activities and they necessitate energy to be implemented. Furthermore, a substantial share of energy is used for space heating; thus, HDDs also influence the consumption.

Figure 1a,c highlight a certain degree of correlation between these two quantities; also, trends displayed in Figure 1b,d indicate a degree of relationship. To confirm these observations from a quantitative point of view, the linear correlation index among the considered variables is estimated and reported in Table 3. The correlation index between GDP and electricity for Germany, France, Italy, and Spain is respectively equal to −0.31,

−0.11, 0.92, and 0.44. The negative sign means that at the increase of GDP there is a decrease of electricity consumption. The correlation is strong for all countries, while only France shows a lower value. This is because in France electricity is also used for heating purposes; therefore, a noticeable share of the consumption cannot be ascribed to the economic development. The negative sign shown by Germany means that electricity and GDP have opposite trends in the considered period. In fact, electricity consumption passed from 545 TWh of 2006 to 525 TWh of 2018, whereas GDP was 2511 b€ in 2006 and 2962 b€ in 2018. This phenomenon is called energy decoupling and it highlights an increasing level of efficiency of the economy that uses less energy to generate more output.

Table 3. Correlation matrix for GDP, HDDs, Electricity, and Natural Gas for the investigated countries. Source: own research.

	Germany	France	Italy	Spain
GDP-Electricity	−0.31	−0.11	0.92	0.44
HDDs-Electricity	0.36	0.89	0.47	0.33
GDP-Natural Gas	−0.35	−0.41	0.87	0.20
HDDs-Natural Gas	0.37	0.78	0.66	0.46
Electricity-Natural Gas	0.52	0.75	0.91	0.93

Table 3 also highlights a substantial level of correlation between electricity consumption and HDDs because parts of the heating systems can be based on electricity. This is relevant in France, where the correlation index is particularly high, i.e., 0.89, which means that HDDs have a large influence on electricity consumption.

Similar observations can be proposed for natural gas. There is a substantial degree of correlation with both GDP and HDDs. In particular, the correlation between GDP and natural gas is negative in Germany and France. This means a reduction of natural gas utilization in economic activities, which may be ascribed to the implementation of energy efficiency measures or to the switching to other forms of energy. The correlation between HDDs and natural gas is quite strong and always positive; this means that at the increase of HDDs, i.e., colder climatic conditions, natural gas consumption increases because of more intensive utilization of heating systems.

Finally, the correlation between electricity and natural gas consumption is also analyzed, since in all the considered countries there is a large share of power plants fueled with natural gas. The results highlight that there is a strong positive correlation in all the countries. Consequently, when electricity consumption increases natural gas consumption grows correspondingly since it is used in the power plants. The correlation is very strong for Italy and Spain since they have a very large share of natural gas power plants in their generation mix.

4. Methodology

The approach applied in this paper to assess energy security is based on a previous methodology developed by the authors [6]. The backbone of the methodology is the so-called energy security level (ESL), which enables the quantitative evaluation of energy security for separate countries or specific energy systems. ESL is a composite measure represented by various indicators and their weights. The list of proposed indicators and calculation of ESL are later described in more detail.

4.1. Indicators

All the analyzed indicators are arranged into technical, economic, and socio-political blocks. These blocks of indicators are calculated for electricity and natural gas. The scheme of ESL and its division into blocks and indicators are displayed in Figure 2.

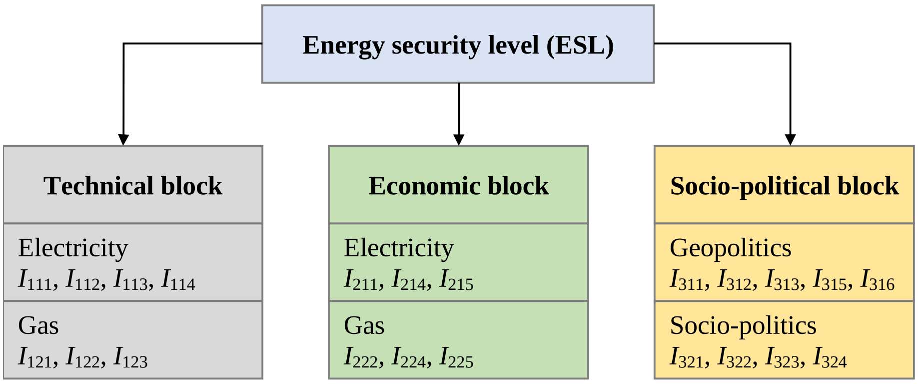


Figure 2. Composition of energy security level. Source: own research.

The list of indicators, their description, and their scale of measurement are given in Table 4. Max scale means that a higher value of the indicator reflects a higher level of energy security. Min scale means that a higher value of the indicator reflects a lower level of energy security. To be comparable for different countries, most indicators are expressed not as absolute values, but as relative values, e.g., ratios or shares. Thus, all indicator values are measured as a percentage.

Table 4. System of indicators.

Indicator		Description	Scale
1. Technical block			
Electricity			
I_{111}	Ratio of total installed capacity of electricity generators and connection lines to maximum electricity demand for capacity.	The indicator demonstrates the capacity of the system to satisfy the electricity demand. The installed capacity includes both own generators (capability of local generation) and connections with neighboring systems (capability of import).	Max
I_{112}	Ratio of the installed capacity of the largest unit to total installed capacity of the electricity system.	The indicator refers to the feature of distributed energy systems that encompass a diverse array of energy capacity. The higher energy security is assured when capacity is not concentrated mainly in one unit and is distributed across different smaller units.	Min
I_{113}	Share of the largest part of electricity production of one technology in total electricity production.	The indicator demonstrates the possible dominance of one type of energy source (e.g., gas, oil, wind, nuclear, or other) in the electricity production mix. The highest energy security is reached when shares are distributed equally among different generation technologies and one technology is not dominant.	Min
I_{114}	Share of renewable energy in gross final electricity consumption.	The indicator measures how extensive is the use of renewable energy in electricity consumption and to what extent RES contribute to the decarbonization of the energy system, which refers to higher energy security. The more a country uses RES (local resources are used), the less it depends on energy imports. According to [44], the indicator shall be calculated as the gross final consumption of energy from RES divided by the gross final consumption of energy from all energy sources, expressed as a percentage.	Max
Gas			
I_{121}	Ratio of total capacity of gas pipelines to final gas consumption.	The indicator demonstrates the capacity of the gas supply system (physical capacity of pipelines) to deliver gas to consumers and satisfy the gas demand. A higher value of the indicator refers to better assurance of energy security.	Max
I_{122}	Ratio of the capacity of the largest gas supplier to final gas consumption.	The indicator demonstrates the possible dominance of one gas supplier (e.g., company, country) in providing gas for final consumption. The more distributed gas supply is among different suppliers and if the dominance of one large gas supplier is avoided, then higher energy security is reached.	Min
I_{123}	Ratio of gas amount that can be stored in gas storages to final gas consumption.	The indicator measures the availability of gas storage facilities in the country to store gas by ensuring a reserve. The higher the ratio, the more resistant the gas supply system is to gas supply disruptions, which refers to assurance of higher energy security.	Max
2. Economic block			
Electricity			

Table 4. *Cont.*

	Indicator	Description	Scale
I_{211}	Ratio of the consumer's electricity price to the average electricity price in the EU.	The indicator measures if consumers pay more (indicator value > 100%) or less (indicator value < 100%) for electricity than the average electricity price of the EU countries. Higher energy security is reached when the ratio tends to decrease.	Min
I_{212}	Ratio of the amount of electricity that can be produced using fuel imported only from a single supplier to the total amount of produced electricity.	The indicator demonstrates the dependency on a single fuel supplier for electricity production. A high value of the indicator refers to the low diversity of fuel supply for electricity production. However, a low ratio would indicate that electricity production is diversified, which would result in higher energy security.	Min
I_{213}	Ratio of the amount of imported electricity to final electricity consumption.	The indicator shows the country's dependence on imported electricity. The more a country relies on electricity imports and lacks local electricity generation, the more it is vulnerable to electricity supply disruptions. A lower indicator value refers to higher energy security.	Min
	Gas		
I_{221}	Ratio of the purchase price of gas to the average gas price of the EU countries.	The indicator shows if consumers pay more (indicator value > 100%) or less (indicator value < 100%) for gas than the average gas price of the EU countries. A lower ratio ensures higher energy security.	Min
I_{222}	Share of the imported gas from a single supplier.	The indicator demonstrates the dependency on a single gas supplier. If the share in the analyzed country is high, the main reason might be the lack of gas market integration with other countries or the lack of infrastructure for diversification of gas supply. The higher value of the indicator leads to lower energy security.	Min
I_{223}	Ratio of the amount of imported gas to final gas consumption.	The indicator measures the country's dependence on imported natural gas. If a country does not have, or has very limited, resources of its own natural gas, it is highly dependent on gas imports. In this case, this would result in a high indicator value, which refers to lower energy security.	Min
	3. Socio-political block		
	Geopolitics		
I_{311}	Energy dependence.	The indicator demonstrates the extent to which a country relies upon energy imports to meet its energy needs. It is calculated as an amount of imported energy divided by final energy consumption and shows how strongly the country is dependent on imported energy resources. Lower energy dependence refers to higher energy security.	Min
I_{312}	Political risk factor of the country.	The indicator measures the risk factor of the analyzed country. It is based on Energy Security Risk Index [31], which takes into account the policies and other factors that contribute positively or negatively to energy security and is calculated annually using historical quantifiable data. The indicator is recalculated in such a way that a higher value of the indicator demonstrates higher energy security and lower energy security risk.	Max
I_{313}	Weighted mean (according to the size of import) of political risk factors of the countries from which energy resources are imported.	The energy security risk indicator I_{312} is measured as a mean for a group of countries from which energy resources are imported to the analyzed country. The indicator is weighted according to the total amounts of each imported resource.	Max
I_{314}	Weighted mean (according to the size of transit) of political risk factors of transit countries through which energy resources are imported.	The energy security risk indicator I_{312} is measured as a mean for a group of transit countries through which energy resources are imported to the analyzed country. The indicator is weighted according to the total amounts of each imported resource.	Max
I_{315}	Weighted mean (according to the size of connections) of political risk factors of the countries to which the electricity transmission network is connected.	The energy security risk indicator I_{312} is measured as a mean for a group of countries that have physical electricity connection lines with the analyzed country. The indicator is weighted according to the total capacities of electricity connections for each connected country.	Max
	Socio-politics		
I_{321}	Share of energy expenses per household in the total household expenses.	The indicator reflects energy poverty, which is one of the dimensions of energy security. As stated in [45], a household is said to be fuel poor if it needs to spend more than 10% of its income on energy. Higher energy security is maintained in the case of the share being as small as possible.	Min
I_{322}	Degree of undertaking the commitment with regards to share of renewable energy in final energy consumption.	The indicator illustrates the progress made by the countries with respect to their binding renewable energy targets for 2020 defined under the Renewable Energy Directive [44]. Indicator value $\geq$ 100% demonstrates that the target has already been reached or exceeded, which refers to higher energy security.	Max

Table 4. *Cont.*

Indicator		Description	Scale
I_{323}	Degree of following the commitment with regards to the reduction of greenhouse gas emission.	The indicator measures the effort made by the countries with respect to national GHG emission reduction targets for 2020 defined under Decision [46]. If the indicator value reaches 100% or more, then the target has been achieved and higher energy security is assured.	Max
I_{324}	Degree of undertaking the commitment with regards to EU energy efficiency target.	The indicator demonstrates to what extent countries are reaching their energy efficiency targets for 2020 defined under the Energy Efficiency Directive [47]. Indicator value $\geq$ 100% demonstrates that the target has already been achieved, which refers to higher energy security.	Max

4.2. Energy Security Level

Assessment of energy security level consists of four steps, as shown in Figure 3:

1. Normalization of indicator values. Since indicators have various dimensions and scales with different maximum values, they must be brought to a uniform measuring scale.
2. Identification of indicators' state according to their direction. Indicators are estimated in points from 0 to 100 using their factual values and are of two types: the first type—the higher value of the indicator refers to the higher degree of security (max scale); the second type—the smaller value of the indicator meets to the higher degree of security (min scale). Each indicator is characterized by pre-critical (separates normal and pre-critical states) and critical (separates pre-critical and critical states) threshold values. Pre-critical (*pctv*) and critical (*ctv*) threshold values for each indicator are evaluated using the expert assessment method, taking into account the state of the energy system of each investigated country. Pre-critical and critical threshold values differ for each indicator and can vary from 0 to 100 points. Using those two types of scales and threshold values, the value in points and state of each indicator is determined: the indicator is in a critical state when $I < ctv$ (max scale) and $I > ctv$ (min scale); indicator is in a pre-critical state when $ctv < I < pctv$ (max scale) and $pctv < I < ctv$ (min scale); and indicator is in a normal state when $I > ptv$ (max scale) and $I < ptv$ (min scale).
3. Determination of indicators, groups, and blocks weights. For modelling, it is assumed that all indicators in the group have the same weights. In this case, the sensitivity and uncertainty analysis of the indicators' weights is conducted to assess possible subjectivity. The group weight s_{ij} for the technical and economic blocks is determined as the share of gas and electricity final consumption compared to total final consumption. The group weights in the socio-political block were determined as equal. The weights for each of the technical, economic, and socio-political blocks are equal (1/3) since, in the modelling process, the assumption was made to put the same impact on the technical, economic, and socio-political dimensions of energy security.
4. Evaluation of integral characteristic of *ESL*. The integral characteristic of *ESL* is evaluated using Equation (1):

$$ESL = \sum_{i=1}^{3}\left(s_i \sum_{j=1}^{2}\left(s_{ij}\sum_{k=1}^{l_j} s_{ijk} I_{ijk}\right)\right) \quad (1)$$

where $s_{ijk} = 1/l_j$—weight of the *k*th indicator in the group, s_{ij}—the weight of the *j*th group in the block, $s_i = 1/3$—weight of *i*th block, i = 1, 2, 3; j = 1, 2; $k = 1, \ldots, l_j$. The integral characteristic of ESL is obtained in points and assigned to critical (0–33 points), pre-critical (34–66 points), or normal (67–100 points) state.

A detailed analysis of the ESL evaluation method is presented in [6] and a description of the indicators is given in Table 4. All the indicators used in the proposed methodology are developed by the authors of the paper and are not taken from the literature. The selection of specific indicators in each block is grounded in [6].

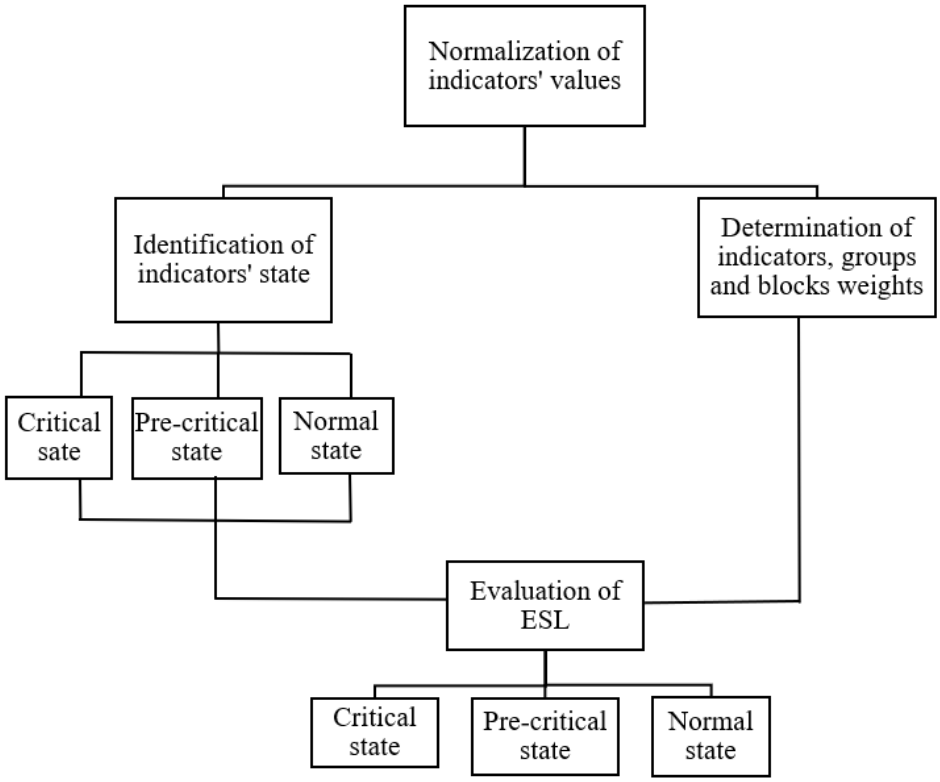


Figure 3. Assessment of energy security level. Source: own research.

5. Results and Discussion

For the construction of an indicator system consisting of 22 indicators, the methodology outlined in Section 4 is used. For each analyzed country, the indicator system is implemented separately. The evaluation of the ESL for Germany, France, Italy, and Spain is carried out for the period 2006–2018 by applying the methodology discussed in Section 4. Indicator values are determined for each year, as well as the ESL, which is the key outcome of the present analysis (Section 5.2). Primary data sources used in the analysis are discussed in Section 5.1.

5.1. Data

Statistical data for the indicator values during 2006–2018 were obtained to evaluate the ESL. Technical data, such as installed capacity, maximum demand, consumption of energy, reserves, RES share in gross final consumption, and others, have been collected from the European Statistical Office (EUROSTAT) [43], World Energy Statistical Analysis provided by the British Petroleum Company [48], and the European Network of Transmission System Operators of Europe (ENTSO-E) [49] databases. Economic data, such as purchased and market prices of energy sources and fuels, import dependency, and energy dependency indicators, were collected from the EUROSTAT database [43]. The country risk index for energy protection was identified by the Global Energy Institute [31]. The national RES, energy efficiency, and greenhouse gas emission reduction targets have been identified by the EUROSTAT database [43] and the EU Directives [44,47].

5.2. Results

5.2.1. Results of Energy Security Level

The obtained results demonstrate that general ESL in Germany is highest while ESL of Italy is the lowest during most of the years of the analyzed period (Figure 4). In recent years, the ESL of Germany and France falls under the normal state, while in Italy and Spain it is close to the normal state.

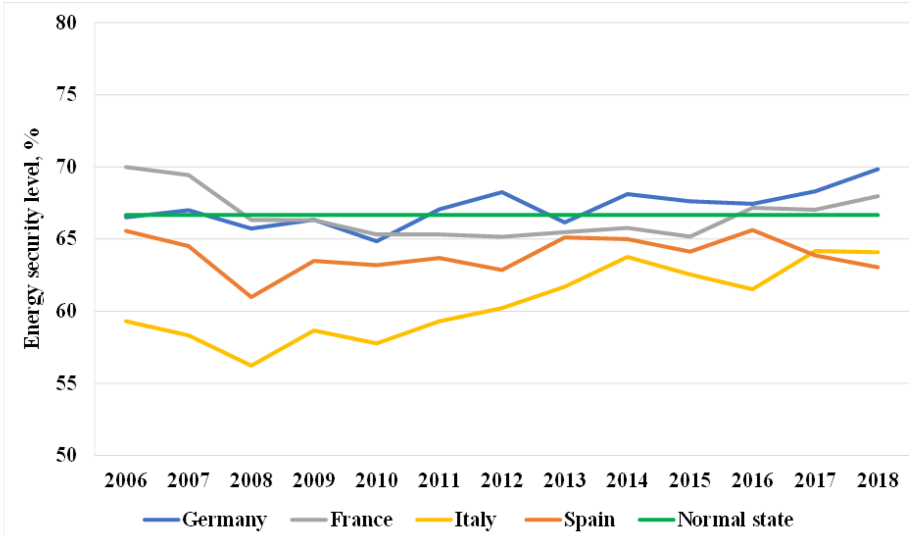
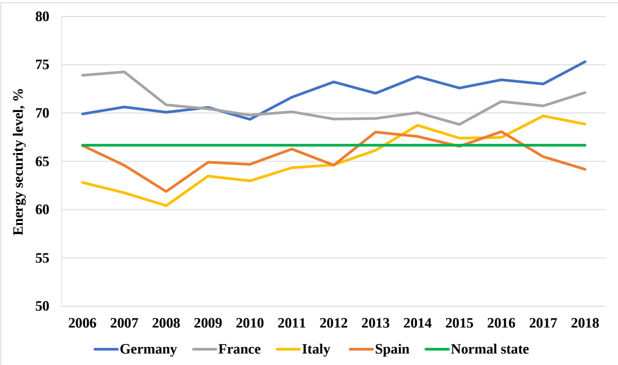


Figure 4. The dynamics of energy security levels in analyzed countries. Source: own research.

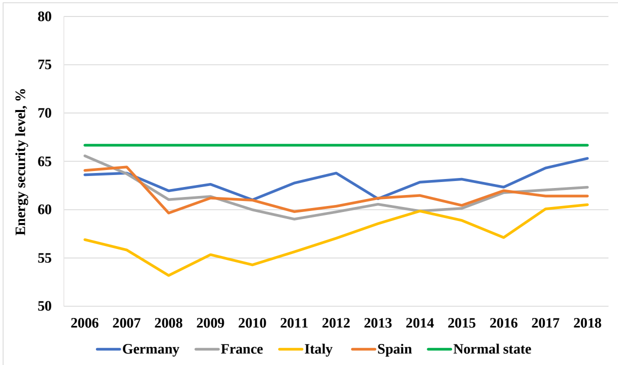
The main negative factor for the decrease of ESL in the period 2006–2008 for the analyzed countries was the index of energy security risk (this index includes measures of political and civil rights to gauge a country's political stability, and indirectly its reliability as an energy supplier and trading partner) [31]. It resulted in low values of indicators (from I_{313} to I_{315}) in the geopolitics group. The import of natural gas is mainly responsible for this negative sign and countries with a large amount of imports, such as Italy and Spain, are largely affected. It resulted in high values of indicators related to gas imports (I_{222} and I_{223}). Furthermore, natural gas is imported from countries with unstable political contexts; this is especially true for Italy, which directly imports natural gas through pipelines from Libya and Algeria [50]. The index has a decreasing tendency from 2006 onward and it was stabilized only around 2009–2010. This can be seen as an effect of an economic cycle rather than of an energy policy. In fact, in the period 2006–2007, there was an expansion of the economy and increasing consumption of natural gas. Oppositely, from 2008 onward, the economic downturn determined a decrease of consumption and a consequent reduction of imports. In fact, the values of the indicator related to dependency on gas and electricity imports were reduced. Furthermore, in that period a relevant development of renewable energy was initiated, and a corresponding increase of ESL is detected. This trend is common for all the considered countries; in fact, the RES share in the power mix in the period 2006–2018 passed from 8% to 32% in Germany, from 1% to 8% in France, from 3% to 22% in Italy, and from 10% to 25% in Spain. This resulted in a good performance of the indicators that measure the share of RES (I_{114}, I_{311} and I_{322}). Only in Germany was the trend a little bit different since the development of RES had already started in the previous years, whereas in France RES development was slower and, at the same time, the closure of some coal power plants determined a reduction of ESL. For all countries, this indicator moved from critical state to normal state.

When analyzing ESL for electricity and natural gas separately, two different situations are observed (Figure 5). ESL of electricity in recent years (2014–2018) for the analyzed countries falls into a normal state with a small exception for Spain. Instead, the ESL of natural gas during the analyzed period is in a precritical state, but it has the tendency to increase and in the last few years is close to normal state.

The macro-trends highlighted in Figure 5a show an increasing tendency of the electricity ESL, which is mainly due to the increase of the renewables share in generation and a reduction of the fossil fuel consumption share, especially oil and natural gas. Thus, the reduction of imports and the increase of local sources determine an increase of the overall security. It is to be noted that the ESL considers the negative effects caused by the volatility of RES generation; in fact, the interconnection capacity is an element determining the ESL value, i.e., see the definition of the I_{111} indicator. The higher the interconnection capacity, the lower the effect of volatility in RES generation since the supply can be stabilized by importing/exporting energy from/to neighboring countries. This is a fundamental principle of the EU energy security strategy, namely the interconnection of the different EU countries in order to tend to the establishment of one single EU electricity market. Overall, it can be said that the ESL in Germany and France is good; in particular, Germany showed an increasing trend during the last years. Italy and Spain present a similar situation. Both countries show an increase of the ESL especially caused by the RES development. Anyhow, Spain had a better starting point since the country has a more balanced power generation mix [51].



(**a**)



(**b**)

Figure 5. The electricity and natural gas security level in analyzed countries: (**a**) electricity, and (**b**) natural gas. Source: own research.

As illustrated in Table 5, general ESL is very well correlated with ESL of electricity, especially for France and Italy, where the correlation coefficient is close to 1. Such a trend for these two countries is observed also for the correlation of general ESL and ESL of natural gas. A different situation is detected for Spain. Though the correlation between general ESL and ESL of electricity is quite strong, the correlation between general ESL and ESL of natural gas is moderate and the correlation between ESL of electricity and ESL of natural gas is very weak.

Table 5. ESL correlations for analyzed countries. Source: own research.

	General vs. Electricity	General vs. Natural Gas	Electricity vs. Natural Gas
Germany	0.9076	0.8419	0.5451
France	0.9750	0.9650	0.8975
Italy	0.9762	0.9792	0.9132
Spain	0.8996	0.6261	0.2254

Currently, the French ESL for the power sector is at a safe level, but in the next years the situation could change substantially since most of the French nuclear power plants are approaching the end of their operating lives [52] and, at the moment, there are no concrete plans for their substitution. However, an extension of the operating life up to 60 years has been suggested. In conclusion, the French situation should remain stable for the next 20 years.

As for natural gas ESL, shown in Figure 5b, a more fluctuating trend is detected. This is due to the fact that natural gas consumption is influenced by weather conditions, which are random by definition. The general trend of ESL for all the considered countries is driven by the consumption pattern. In fact, a decreasing trend of consumption is highlighted in the period 2008–2014 (see Figure 1d), which determines an increase of the ESL since imports are reduced and, consequently, so is the market power of the main supplier.

In order to test whether the results of ESL for the analyzed countries have similar or the same tendency as the results of studies presented in the literature review and summarized in Table 2, a comparison, based on a relative country ranking according to estimates of energy security indicators, is carried out. The analyzed countries in each reviewed study were ranked from 1 to 4 based on the performance from the "best" to the "worst" available for the last year of the analyzed period. Country ranks in the presented study are based on the average value of ESL during the analyzed period 2006–2018. Table 6 reports the main results of the comparison of the countries' ranks.

Table 6. Comparison of country ranks considering estimates of energy security. Source: own research.

Country	France	Germany	Italy	Spain
Number of rank 1	8	10	3	2
Number of rank 2	7	4	2	4
Number of rank 3	1	3	7	7
Number of rank 4	3	2	7	6
Average rank of other studies	1.95	1.84	2.95	2.89
Ranks in the presented study	2	1	4	3

It can be concluded that the present study is in substantial agreement with the current literature; thus, the ESL can be seen as a valid energy security indicator. The best performer countries are Germany (10 times ranked as number 1) and France (8 times ranked as number 1), which have an average rank of 1.84 and 1.95, respectively. Instead, Italy and Spain have an average rank of 2.95 and 2.89, respectively, so they have a lower performance.

5.2.2. Results of Uncertainty and Sensitivity Analysis

To examine the effect of indicator weights on ESL, uncertainty and sensitivity analyses of these weights were carried out. The Monte Carlo method was used to randomly simulate indicator weights in the group. Uniform probabilistic distribution with parameters 0 and 1 was used for simulations. Then, in every group these random numbers were normalized to have the sum of the weights for a specific group to be equal to 1. A total of 100 cases were simulated by employing the Software for Uncertainty and Sensitivity Analyses (SUSA) created by Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH company (Germany) [53,54]. The ESL estimations for these simulations are presented in Figure 6. One hundred simulated cases are presented in black gray curves and the average of ESL calculated for the method with equal weights is presented in red curve.

As shown in Figure 6, the uncertainty analysis demonstrates similar results in terms of ESL spread across different simulations. To compare uncertainty results, the key descriptive statistics of ESL simulations were estimated (Table 7). Then the average ESL of the simulated weights method was compared with the ESL, which was obtained using the equal weights method.

It can be observed that the variations between the ESL estimated by considering equal weights and the average ESL determined with simulated weights method are within 0.21% for Germany, 0.27% for France, 0.81% for Spain, and 0.78% for Italy, as shown in Table 7. The dispersion of ESL simulations was also evaluated by estimating the relative standard deviation and the maximum values are 4.51% in 2009 for Germany, 4.08% in 2011 for France, 4.96% in 2008 for Spain, 6.03% in 2008 for Italy. The highest degree of uncertainties is estimated for Italy, 4.89% in average during the considering period, whereas the lowest value is shown by France with an average of 3.85% during the analysis horizon. The analysis demonstrates that the differences between constant and simulated weights are not significant.

In order to assess the impact of indicator weights on the energy security level, a sensitivity analysis using SUSA was carried out. Standardized regression coefficient (SRC) was used as a measure of the sensitivity of indicator weights. Higher absolute values of the coefficient indicate a higher impact of the indicator weight on the ESL. All the indicators for each analyzed country were ranked according to highest absolute values of SRC. The top five indicators that have the highest impact on ESL were selected for each analyzed country. Results of SRCs for these five indicators during the period of analysis are reported in Figure 7.

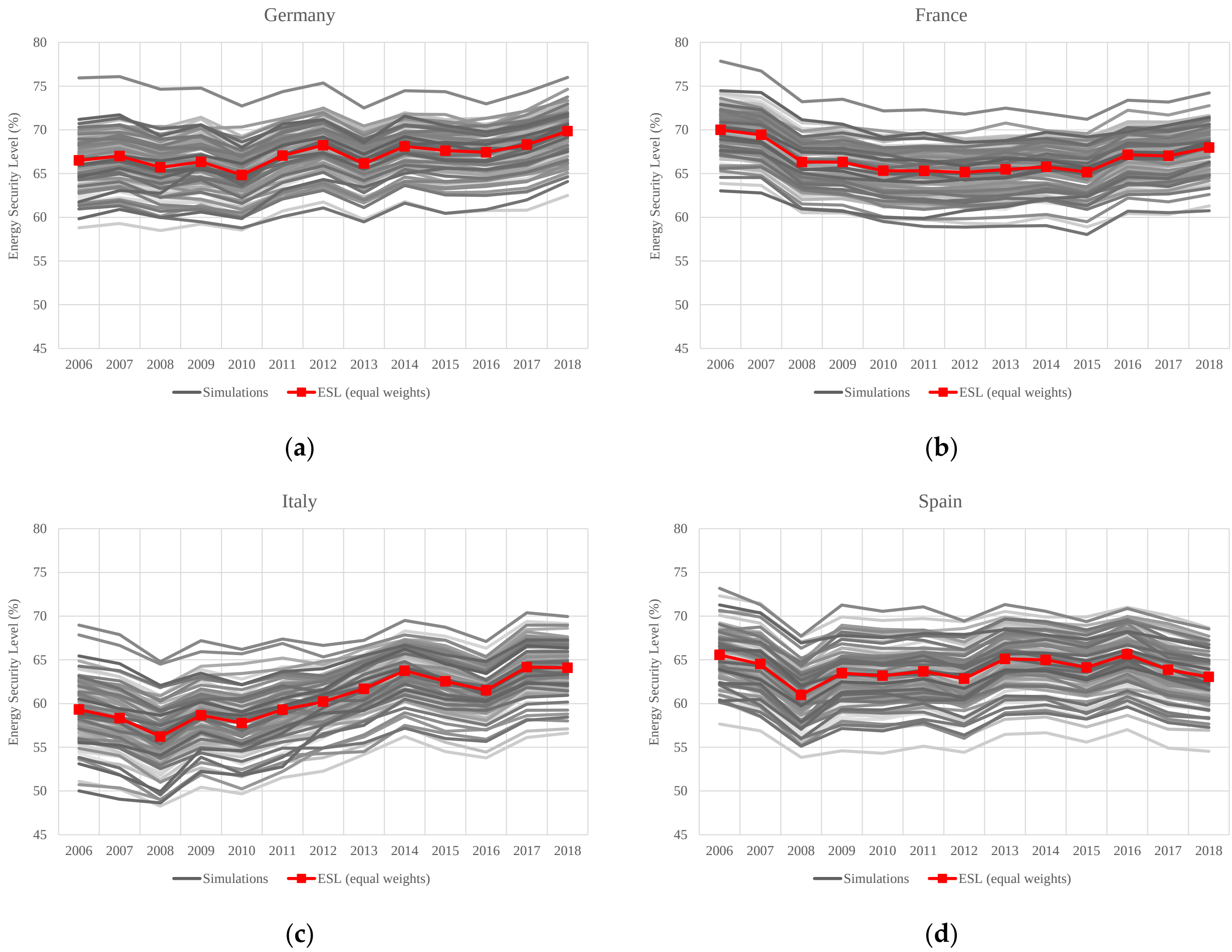


Figure 6. Simulated energy security level in the analyzed countries: (**a**) Germany, (**b**) France, (**c**) Italy, and (**d**) Spain. Source: own research.

The results of the sensitivity analysis demonstrate that indicators from the economic block contribute mostly to the uncertainty of the ESL, since absolute values of SRC for these indicators are the highest (see Figure 7). From the economic block, the same four indicators (two from the electricity group and two from the natural gas group) have the highest impact on ESL in all the considered countries. Indicator I_{222} (share of the imported gas from a single supplier) is ranked 1 in Germany, France, and Italy, while indicator I_{213} (ratio of the amount of imported electricity to final electricity consumption) is ranked 1 in Spain. This can be explained by the fact that natural gas in Germany and Italy is mainly supplied through pipelines and, therefore, there is a close connection between specific supplying countries. On the other hand, France has a limited amount of LNG terminals and other supply arrives from pipelines through other EU countries, e.g., Germany, Spain, United Kingdom, etc., which in turn are connected to specific countries. Spain is less sensitive to the market power of natural-gas-supplying countries since it has many LNG terminals and thus the degree of diversification is higher. Indicator I_{213} is more relevant for Spain, namely the net import of total electricity on the total is high. This ratio is linked with the market conditions on the Iberian Peninsula. In particular, there is a large availability of hydro generation in Portugal, which often exceeds the local demand and is exported to Spain. Portuguese hydro generation is more cost competitive and displaces local Spanish thermal generation by determining an increase of the net imports. Also, another two indicators, I_{211} (ratio of the consumer's electricity price to the average electricity price in the EU) and I_{223} (ratio of the amount of imported gas to final gas consumption), contribute to the uncertainty in ESL as well, and the strength of impact on ESL depends on the analyzed country. Electricity price changes according to the market conditions, which are different from country to country. Also in consideration is that in many European countries the electricity price for final consumers is subsidized. Similarly, final natural gas consumption and imported natural gas dynamically change with the market conditions; therefore, in a situation of economic instability as that of the period 2006–2018, this determines a high impact on the volatility of the ESL indicator. However, the results of sensitivity and uncertainty analysis demonstrate that initial values of indicator weights have low uncertainty in the ESL results.

Table 7. Results of uncertainty analysis for indicator weights. Source: own research.

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
						Germany							
ESL (equal weights)	66.50	67.00	65.72	66.34	64.84	67.06	68.24	66.15	68.11	67.62	67.44	68.30	69.85
Average ESL (simulated weights)	66.36	66.90	65.67	66.36	64.78	67.02	68.22	66.13	68.05	67.49	67.39	68.18	69.76
Mean difference, %	0.21	0.16	0.07	0.03	0.09	0.06	0.04	0.03	0.09	0.18	0.06	0.18	0.12
Relative standard deviation (simulated weights), %	4.38	4.26	4.28	4.51	4.12	3.96	3.95	3.86	3.61	3.77	3.60	3.71	3.63
						France							
ESL (equal weights)	70.00	69.43	66.32	66.31	65.32	65.31	65.16	65.47	65.77	65.16	67.15	67.03	67.97
Average ESL (simulated weights)	69.92	69.37	66.21	66.18	65.23	65.25	65.05	65.33	65.66	64.99	67.05	66.89	67.82
Mean difference, %	0.11	0.09	0.17	0.20	0.13	0.09	0.16	0.22	0.17	0.27	0.16	0.21	0.21
Relative standard deviation (simulated weights), %	3.82	3.63	3.68	3.79	3.90	4.08	3.90	3.98	3.86	4.01	3.77	3.77	3.79
						Italy							
ESL (equal weights)	59.31	58.32	56.22	58.66	57.76	59.30	60.21	61.69	63.76	62.54	61.52	64.17	64.09
Average ESL (simulated weights)	59.01	57.96	55.79	58.36	57.43	59.07	59.97	61.43	63.59	62.33	61.25	63.91	63.89
Mean difference, %	0.50	0.63	0.78	0.51	0.58	0.39	0.40	0.42	0.26	0.34	0.43	0.40	0.31
Relative standard deviation (simulated weights), %	5.88	5.95	6.03	5.28	5.49	5.21	4.36	4.40	4.16	4.40	4.06	4.23	4.10
						Spain							
ESL (equal weights)	65.57	64.51	60.98	63.47	63.18	63.68	62.84	65.11	64.99	64.13	65.62	63.87	63.05
Average ESL (simulated weights)	65.23	64.13	60.49	63.07	62.79	63.31	62.36	64.68	64.59	63.67	65.23	63.39	62.59
Mean difference, %	0.51	0.59	0.81	0.64	0.63	0.58	0.78	0.65	0.62	0.71	0.59	0.75	0.73
Relative standard deviation (simulated weights), %	4.46	4.72	4.96	4.82	4.74	4.62	4.85	4.49	4.26	4.41	4.28	4.49	4.24

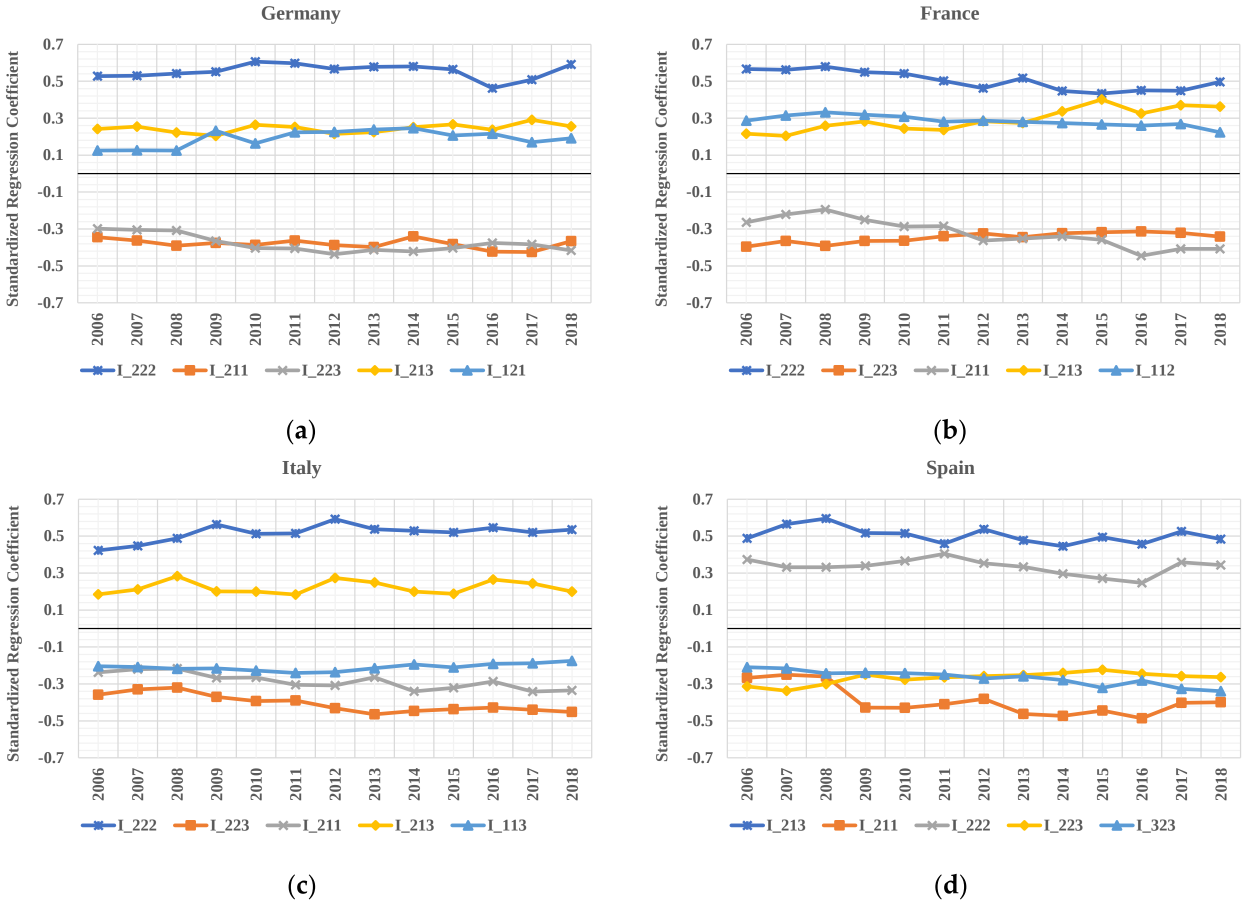


Figure 7. Results of sensitivity analysis for indicators that have the highest impact on ESL for: (**a**) Germany, (**b**) France, (**c**) Italy, and (**d**) Spain. Source: own research.

6. Conclusions

In this paper, an analysis of electricity and natural gas security of supply for four EU countries (Germany, France, Italy, and Spain) is presented. A total of 22 indicators per each country are considered and merged in one synthetic index, namely the Energy Security Level (ESL), which measures the overall performance of a country. ESL can be used to analyze which factors affect the security level in a given country and its evolution can be seen as a useful indicator for energy policy purposes.

The results of ESL in the period 2006–2018 indicate that, on average, Germany is the best-performing country among those analyzed in terms of energy security. The average ESL for Germany and France is 67.17% and 66.65%, respectively, while Spain and Italy recorded 63.92% and 60.58%, respectively.

The highest energy security levels are observed in 2018 (69.85% for Germany), in 2006 (70% for France), in 2016 (65.62% for Spain), and in 2017 (64.17% for Italy). Germany recorded the lowest energy security level in 2010 of 64.84%. France was lowest in 2012 with 65.16%, while Spain and Italy in 2008 recorded 60.98% and 56.22%, respectively.

Germany and France were the best-performing countries in the period 2006–2018, mainly because Germany has a rich energy mix, not unbalanced on a specific source, whereas France has a massive amount of nuclear power plants that in the middle period makes it very resilient with respect to energy security since it is less subject to imports and the related consequences than Italy and Spain. France's status may change in the long term since a large number of nuclear power plants are approaching the end of their operating lives.

Italy has the worst situation since its energy mix is unbalanced toward natural gas and, therefore, the country relies on imports from countries with unstable political contexts.

Also, electricity generation is based on natural gas power plants, so the natural gas supply also influences the power market. The situation improved from 2008 onward since there was a relevant development of renewables and also a decrease of consumption caused by the economic downturn.

The Spanish situation is a little bit better in comparison to the Italian context since the energy mix of the power sector is richer. In fact, there is nuclear generation and a higher share of renewables. Also, in terms of the natural gas supply, the Spanish system can rely on a large share of LNG and, therefore, the diversification of suppliers is higher with respect to Italy, which mainly imports natural gas through pipelines from Algeria and Libya.

The main factors that positively affected the ESL in the analyzed countries were an increase in the share of RES (indicators I_{114}, I_{311}, and I_{322}), a reduction of fossil fuel consumption, and lower dependency on gas and electricity imports (indicators I_{212}, I_{213}, I_{222}, and I_{223}). The main negative factors for the decrease of ESL were the unstable political contexts of countries supplying natural gas (indicators from I_{313} to I_{315}) and the extremely high dependency on the imported gas (indicators I_{222} and I_{223}).

The results of sensitivity and uncertainty analysis demonstrate that initial values of indicator weights have low uncertainty in the energy security level. However, indicators mostly contributing to the uncertainty of ESL are related to economic factors and depend highly on the amounts of natural gas and electricity imports and prices (indicators I_{222}, I_{213}, I_{211}, and I_{223}).

The three main energy policy indications can be obtained by the proposed analysis, namely:

- Diversification is a key, both in terms of power generation technologies and sources of fuel supply. A diversified energy mix is much more resilient to changes in geopolitical context, climatic conditions, etc. Oppositely, the concentration on one technology or one energy increases the risk. This is demonstrated by the results of Germany, which is the best performer in this analysis.
- Interconnections will be a relevant pillar of EU energy policy since, because of climatic reasons and availability of local resources, diversification in a RES-dominated context is difficult to achieve. On the other hand, a relevant development of interconnections can overcome this issue. In fact, power flow from Southern Europe may support Northern Europe, or power generated by wind energy in the north can be transported to the south. Synergic exploitation of RES can support the increase of the energy security level. A similar approach is also valid for the development of natural gas pipelines, which allows the exploitation of different sources of supply within the EU.
- Adequate long-term planning and energy policy choices are necessary to guarantee security levels in the future. For example, the present analysis demonstrates that France currently has a solid position in terms of energy security because of a large amount of nuclear power available in the country, which results in the precise energy policy choices taken during the 1970s and 1980s. In contrast, the upcoming future is uncertain since nuclear power plants are approaching the end of their operating lives and there are no precise plans for their substitution or for alternative measures. This could compromise the future energy security level of the country.

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