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Is There a Trilemma of Energy Policy? A Theoretical and Empirical Approach

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Abstract
This paper is an attempt to shade a new light on the topic of the "energy policy trilemma". The idea of a partial incompatibility of the objectives of energy policy has taken a certain importance in the recent literature about energy and environment policies. This contribution is original in two aspects. First, the elaboration of our composite indexes follows the methodology given in OECD (2008) and is based on Principal Component Analysis. Second, we define the three objectives of energy policies in a different way from what has been done in the literature. In our approach, the three objectives are defined as energy security, energy sustainability and environmental protection. The study is conducted on eight European countries corresponding to the ten major energy companies in Europe.

Keywords: Energy Security, Energy Sustainability, Environmental Protection

JEL Classification: E61, O13, Q01, Q40, Q50

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1. Introduction

Over the past 50 years, the world is facing ecosystem degradation manifested, for example, by air pollution, ozone depletion, emissions of radioactive substances, decline in soil quality, increasing water scarcity, deforestation, or resource depletion. Ecological scarcity and social inequity are clear indicators of an unsustainable economy. As the economy and environment form mutually influential, interactive and interdependent systems, it is necessary for today's interdependent and globalized world to boost the green transformation of economic development. This is needed for ensuring the sustainable development of the economy, society and environment for future generations. Sustainable development is a widely discussed topic, which is reflected by innumerable literature. In spite of the fact that there is no commonly agreed upon definition of this term, the Brundtland Report's definition is the most widely accepted. They defined the sustainable

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development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43). That concept is the basis of 'green economy', which refers to a low-carbon, resource efficient, and socially inclusive economy that results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011, p. 16). In that economy, "growth in income and employment are driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services" (UNEP, 2011, p. 16). The main objective of a transition to the green economy is then to enable economic growth and investment while increasing quality of the environment and social inclusiveness.

Sustainable development is based on three core elements: environmental protection, economic and social development and there are many policy instruments (e.g. environmental taxes, regulations etc.) that put economies on the sustainable development path. Nevertheless, there are market failures that result in sustainable development problems and lead to trade-offs between aforementioned three pillars, respectively between the amount of protection and the economic costs that this level of protection will have (Vitalis, 2003). That trade-offs bring about different policy choices, particularly in energy policy that face manifold challenges.
Based on early preliminary research that led to the hypothesis that there is an energy trilemma consisting of three core partially contradictory aims of energy policy, this paper aims to answer whether such an energy policy trilemma does exist.

To answer this question, selected indicators assigned to the three energy objectives are examined through the Principal Component Analysis (PCA) and Energy Policy Indexes are constructed.

2. What is the trilemma of energy policy?

Policy makers face many energy and environmental challenges while setting targets of energy policy. They have to incorporate in their policy decisions global challenges as global climate change and ecosystem degradation manifested, for example, by air pollution, ozone depletion, emissions of radioactive substances, decline in soil quality, increasing water scarcity, deforestation, or resource depletion. The need to move environmental and energy issues to the forefront of political debates has even acquired an international dimension (e.g. UN Framework Convention for Climate Change, Kyoto Protocol, Paris Agreement, EU energy strategies etc.).

2.1. Diversity of objectives of an energy policy

Consequences of historical events and current challenges are to a greater or lesser extent reflected in energy and environmental policies of modern economies. Among the most discussed topics are energy security, energy dependence, energy efficiency, energy competitiveness, sustainable energy and related environmental protection.

Since the 1970s, the concept of energy security and more specifically, the security of energy supplies, has gained considerable importance. The consequence of the post-war strong and increasing dependence of developed countries on relatively cheap and plentiful Middle east oil led to the first oil crisis. This crisis occurred in 1973 as aftermath of Arab-Israeli war when the members of Organization of Petroleum Exporting countries (OPEC) imposed restrictions on oil production (Chester, 2010). As the result of the imposed embargo, the international price of crude oil almost quadrupled and triggered a panic on global markets that resulted in uncontrolled inflation, rising unemployment, a decrease in the turnover of firms, declining productivity etc. Energy-related vulnerabilities continued into the latter half of the twentieth century and the beginning of the twenty-first century with nuclear accidents (e.g. Chernobyl), fluctuating fortunes for coal and natural gas, increased energy demands, political disputes (e.g. Russian-Ukrainian gas dispute), political instability, and natural events (Bahgat, 2006; Chester, 2010; Umbach, 2010). In response to these issues, the security of energy supplies is occupying the political foreground. The run-up in oil prices over 2007-2008 has intensified the issue of energy security. Consequently, academics and policy makers have renewed interest in the topic (Cohen et al., 2011).

According to Löschel et al. (2010), the energy (in)security is currently discussed mainly in the political sphere rather than in the economic area inasmuch as the risk comes mainly from the core of uninterrupted energy supply and its basic component – energy imports/exports that could be used as a political weapon. Despite the fact that in the past energy security was more or less equated with security of oil and gas supplies (Chester, 2010; Löschel et al., 2010, Umbach, 2010), contemporary research reveals the multiple aspects and multi-dimensionality of energy security. Many security scholars have tried to determinate the general and widely accepted definition and they are in pursuit of finding a reputable method of its measurement.

There is a plethora of scholarly literature on energy security and varying definitions of the field. Ang et al. (2015) claimed that there is no broadly accepted definition of energy security, but some authors claim to intuit their explications of the term. Based on a literature survey covering 104 studies including 83 definitions, the conductors of the survey concluded that there is no widely recognized consensus on the definition of this term. Nonetheless, there are several authors providing a review of energy security literature. For instance, Winzer (2012) dealt with 36 definitions of energy security. In contemporary literature, there are numerous definitions of energy security, from the narrowest definitions referring to the issue of energy supply disruption to wider ones involving economic, environmental and political aspects (see literature overview of Ang et al, 2015; Chester, 2010; or Winzer, 2012).

The IEA (2014c, p. 13) defined the energy security as "the uninterrupted availability of energy sources at an affordable price". This definition has been adapted over time to its current form and therefore may seem similar to other authors' definitions (e.g. Le Cog and Paltseva, 2009). Among others, the IEA (2014c) put in evidence the link between energy insecurity and negative economic and social impacts of physical energy unavailability, or uncompetitive or overly volatile prices. The Asia Pacific Energy Research Centre study (2007, p. 4) defined energy security as "the ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner

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with the energy price being at a level that will not adversely affect the economic performance of the economy". Bohi and Toman (2006, p. 1) defined the energy security as "the loss of economic welfare that may occur as a result of a change in the price or availability of energy". This definition appears very frequently in papers related to energy security issues (e. g. in Chester, 2010; Labandeira and Manzano, 2012; or Winzer, 2012), but the difficulty of introducing of this definition into the measurements lead the authors to its simplification (e. g. Löschel et al., 2010). Narula and Reedy (2015, p. 148) introduced energy security as "security of supply and its physical availability by ensuring freedom from risk of supply disruption". A more simplistic definition comes from the European Commission (2014). It defined the energy security as a stable and abundant supply of energy and 'protected customers'. In contrast, Ang et al. (2015) employed a broad definition of energy security according to which it is necessary to observe its seven dimensions, namely energy availability, infrastructure, energy prices, societal effects, environment, governance, and energy efficiency, to ensure secure energy supplies. This broad concept is based on the common key ideas of 83 studied definitions of energy security. Nevertheless, Ang et al. (2015) in their pursuit of finding the widely-used definition pointed out that in the ever-changing energy field, the definition of energy security needs to be periodically revised in order to reflect changes in priorities and emerging threats. Selected energy security studies including their respective authors' definitions, energy dimensions/principles and number of indicators/metrics are listed in Appendix 1.

Many policy makers tend to equate energy security with energy independence (Cohen et al., 2011; Winzer, 2012). Cohen et al. (2011) pointed out that despite the fact that most of policy makers equate energy security with energy independence, a multi-faced measure of energy security is needed. Anyway, energy independence is an important tool reducing energy supply insecurity and it remains at the forefront of interest for many researchers. Nonetheless, Parry and Anderson (2005) came to the conclusion that energy independence is unrealistic. Bahgat (2006) claimed that the globalized oil market's plan to become self-sufficient in energy is obsolete. He also highlights the fact that energy security is "an international issue that necessarily entails growing interdependence between major producers and consumers". Green (2010, p. 1620) argued that oil independence does not necessarily mean lessening of oil use or reduction in oil imports, but it is about "reducing vulnerability to oil dependence costs to an acceptable level". Zero energy independency is a questionable long term objective considering the current import dependency, natural resources endowment and potential of many countries.

The concept of energy efficiency is controversial. Despite the fact that there is no unequivocal definition of this term, unlike energy security, there is a broad consensus on this term. Authors of current scholarly literature on energy efficiency have interpreted the term in similar ways, even though these accepted definitions have evolved over time. An overview of diminutive literature demonstrates that fundamentals of this expression remain unchanged for years. Patterson (1996, p. 377) referred to the general concept of energy efficiency that is based on "using less energy to produce the same amount of services or useful output" and its broad definition that is captured as ratio of useful output of a process to energy input of a process. Department of Energy & Climate Change (2012, p. 3) described energy efficiency as "using either less energy to get the same level of energy services, or maintaining the same level of energy services, but using less energy". The IEA

(2014b, p. 17) uses a widely accepted definition based on Lawrence Berkeley National Laboratory that embraces energy efficiency as "using less energy to provide the same service". Schlomann et al. (2015, p. 97) agreed on widely accepted definition of energy efficiency as "a simple and cost-effective way to reduce energy consumption and greenhouse gas emissions". However, quantitative measurement of energy efficiency remains ambiguous, lacks clarification and in-depth discussions of essential aspects or dimensions (Harmelink et al., 2007; Schlomann et al., 2015). Divergent cultural contexts and different approaches to energy efficiency policies represent another drawback in the search for a widely used measurement method. Data availability and security are also salient issues (Harmelink et al., 2007; Schlomann, 2015; Tanaka, 2008).
Improving energy efficiency while simultaneously lowering the environmental impact of energy use is challenging. Energy efficiency can enhance security of energy supply and it can lead to the sustainable energy. Ang and Liu (2007) pointed out that Kyoto protocol and growing concerns about world climate change and sustainable development require, inter alia, increasing energy efficiency. While some literature considers energy efficiency as the part of energy security or energy sustainability (e.g. IEA, 2014a), some publications look at it as a separate process (e.g. Afgan et al, 1998). Energy efficiency used to be a separate goal of national energy policies (IEA, 2014a; Patterson, 1996). Its importance has been well recognized and nowadays, there are not many countries that would not have incorporated energy efficiency into their policies and long-term targets (Kejun, 2009; Patterson, 1996).

Another key concept related to energy is energy sustainability. As its denomination implies, it is the crucial element to sustainable development. Like the majority of energy related concepts, even this term is difficult to define. Tester et al. (2005) defined sustainable energy as "a living harmony between the equitable availability of energy services to all people and the preservation of the earth for future generations". Nevertheless, Prandecki (2014, p. 89) stressed that despite wide use and intuitive understanding of this concept, to provide the full definition is a tremendously complex issue. He concluded that "the sustainable energy must therefore be regarded as system of processing, transportation, distribution, and consumption of energy, which will be characterized by a constant, overwhelming reduction in consumption of non-renewable resources and environmental damage, while providing, at socially acceptable prices, universal access to energy". According to Rosen (2009), energy sustainability lies on two pillars – energy efficiency and renewable energy.

Sustainable energy used to be associated with the term energy transition that used to be described as the "change in the compositions (structure) of primary energy supply, the gradual shift from a specific pattern of energy provision to a new state of an energy system" (Smil, 2010). This definition may indeed be misleading and hence it is indispensable to avoid misuse by replacing sustainable energy with renewable energy (Prandecki, 2014). Many authors (e.g. Afgan et al., 1998; Moomaw et al., 2011) highlight the momentous role of energy in the development of human society and note that sustainable energy is an integral part of social and economic development that requires assured and affordable access to energy resources. The UNDP (2017, [online]) underlined that sustainable energy can be "an engine for poverty reduction, social progress, equity, enhanced resilience, economic growth, and environmental sustainability".

Afgan et al. (1998) propose a review of energy sustainability measurements and issues related to the sustainable energy in the form of prevention of energy resources depletion; efficiency improvements; development and use of better clean air technologies; intelligent energy systems and renewable energy sources; environment capacity for combustion products; and last but not least the mitigation of the nuclear power threat to the environment. The last of Afgan's measurements is rather controversial. While nuclear power plants are ecologically friendly insofar as they cause minimal pollution, they present as a potential enormous source of radioactivity. Examples of nuclear power plants that caused radioactive disasters include: Three Mile Island (1979), Chernobyl (1986), and Fukushima (2011). Another problem with nuclear power plants concerns methods for disposal of nuclear waste. This is managed relatively well, but new methods need to be developed to address high-level nuclear waste disposal because of its prolonged radioactivity remains unsolved (World Nuclear Association, 2012).

Finally, Energy policies are also linked with environmental protection. According to the United Nations (1997, p. 30) the term environmental protection refers to "any activity to maintain or restore the quality of environmental media through preventing the emission of pollutants or reducing the presence of polluting substances in environmental media". That may consist of changes in characteristics of goods and services, consumption patterns, production techniques, treatment or disposal of residuals in separate environmental protection facilities, recycling, and prevention of degradation of the landscape and ecosystems. The question of environment protection is linked with the existence of externalities. As environment can appear as a "free resource" for the firms, they are likely to overuse this resource, which lead to a socially suboptimal situation. This question must be distinguished from the question of sustainability, which refers to a trade-off between the present and the future. Sustainability means that the present growth shouldn't be a threat for the future growth and welfare, while environment protection refers to the necessary intervention of regulatory authorities in order to avoid the overuse of the environment. For instance, the use of a non-polluting but non-renewable resource would create a sustainability problem, but not an environmental problem. Reciprocally, noise pollution is an environmental issue without any sustainable aspect.

Regarding the presented concepts and taking in consideration the specificities and natural endowment of individual countries, we assume that policy makers have to search for trade-offs between aforementioned concepts while setting the targets of energy policy. For example, setting target on energy independence (e.g. using domestic coal) can increase in energy security, but it can result in energy unsustainability (e.g. coal is exhaustible natural source) and ecosystem degradation (e.g. burning of fossil fuels cause air pollution).

2.2. Trilemmas in economic policy

Use of policy trilemmas has become a phenomenon. In most of the cases, these trilemma models have their basis in policy dilemmas. But we can also encounter policy quadrilemmas.
Mundell-Fleming trilemma model is likely to be the most known policy trilemma model. This trilemma is based on the assumption that a country cannot simultaneously maintain an independent

monetary policy, exchange rate stability and open capital movement, and on the principle, that you can pick up any two goals, but not all of the three policy goals.

Another form of trilemma: the political trilemma of the world economy, also known as globalization paradox, was introduced by Rodrik (2000). This trilemma consists of three elements: international economic integration (hyper-globalization), the nation-state (national sovereignty), and mass politics (democratic politics). The possible compatibility of Rodrik's trilemma was questioned by Stein (2016) who tried to refute the incompatibility of these three goals. According to Stein (2016), the inherent result of their incompatibility lies in forces aimed at constraining globalization, limiting democracy, and reducing sovereignty.

The compatibility of policy goals has become very popular and several of them have been introduced over the years, including energy and environmental area.
One of the most known energy trilemma was presented by the UN-accredited global energy body – World Energy Council (WEC). Since 2010, the WEC publishes annually World Energy Trilemma report that represents a comparative ranking of 125 countries' energy systems (WEC, 2017). The report provides information on performance of countries in three core dimension of energy sustainability: energy security, energy equity and environmental sustainability. These dimensions represent three goals constituting a trilemma that individual countries face while searching the trade-offs between each other when setting the targets of their energy policy.

IFO Institut (2012) that presented the economic analysis and assessment of potentials and options of the future of energy markets, came out with the conclusion that there can be a relationship between energy turnaround and trade-offs between the targets of the energy policy. The Institut assumes that the 'Energy Policy Triangle' is comprised of Environmental Compatibility, Supply Security and Economic Viability.

Heffron (2015), who highlighted the inseparability of energy law from energy policy, depicted the relationship between energy law and policy and three issues that try to pull the energy law and policy in their direction. Heffron's energy trilemma forms a triangle where the centre consists of energy law and policy and triangle arms are made of economics (finance), politics (energy security), and environment (climate change).

2.3. An original trilemma approach

Over the past 50 years, the energy and environmental issues related to the ecosystem degradation (e.g. air pollution, ozone, emissions of radioactive substances, increasing water scarcity, or resource depletion) and more recently, the necessity of developing in a sustainable way have become global issues that have been brought to the forefront of political debates. These debates have acquired an international dimension and resulted in the creation of many cross-border, both regional and international, initiatives and agreements, and regional policies.

Among the most known is the common framework for combating global warming by reduction of GHG emission: the United Nations Framework Convention on Climate Change (UNFCCC) from 1992 (United Nations, 1998) and its agreements: Kyoto Protocol and successor Paris Agreement. The Kyoto Protocol entered into force in 2005 and has set internationally binding emission reduction targets to its signatories. Within the first commitment period (2008–2012), 37 industrialized countries and the European Community committed to cut their emissions by at least 5% compared to 1990 levels. The Doha Amendment to the Kyoto Protocol (2012) revised the existing targets for a second commitment period (2013–2020) and committed Parties to reduce their GHG emissions by at least 18% compared to the same base year 1990. The Paris

Agreement, which should even accelerate and intensify the efforts of Parties to ensure a sustainable low-carbon future and which has entered into for in 2016, is currently in a process of ratification and detailed rules for its implementation are under negotiation.

For majority of the European countries, the EU is an important supranational body determining the energy and environmental policy orientation beyond their national interests. Additionally, the EU promotes global action against climate change at both EU and international level. At the EU level, an ambitious energy and climate change strategy has been set up. The Union's long-term plan is to achieve a low-carbon, secure, and competitive economy up to 2050. In respect to this strategy, three commitment periods with individual goals for each have been defined (2020, 2030 and 2050). For the current period that goes in the line with the Kyoto Protocol, the EU has committed itself to reach so-called 20-20-20 targets. Under these targets, all EU member countries pledged to reduce their GHG emissions by 20% of 1990 levels, decrease their energy consumption by 20% of projected 2020 levels by improving energy efficiency, and raise their share of renewables in final energy consumption by at least 20%. Besides these core targets, they have other minor targets like, for instance, achievement of 10% share of renewables used in transport sector. The attainment of these targets should mainly help the EU to combat climate change and air pollution, and decrease its energy dependence on fossil fuels while keeping the energy prices at affordable level for both, households and businesses.

To fulfil these very aspiring goals, the EU takes action in several areas. The 'flagship' of EU efforts in reduction of GHG emissions in a cost-effective way is the EU Emissions Trading System (EU ETS). This applies on the ETS sectors and covers around 45% of the EU's GHG emissions. Furthermore, the EU uses the Effort Sharing Decisions (ESD) that applies on non-ETS sectors such as transport, buildings, agriculture, or waste (European Commission, 2017). EU members also committed themselves to binding national targets for raising the share of renewable energy sources (RES) in their energy consumption. An integral part of the EU effort is also support of the development of low carbon technologies (e. g. carbon capture and storage), or energy efficient measurements. All the EU measurements are based on legislative acts such as Decision on the effort of Member States to reduce their GHG emissions (406/2009/EC), Directive on establishing a scheme for GHG emission trading system (2003/87/EC), Renewable Energy Directive (2009/28/EC), or Energy Efficiency Directive (2012/27/EU).

Based on the afore-mentioned EU policies, preliminary research of energy policies of selected EU countries[1], and theoretical framework set in this paper, an original energy policy trilemma approach is presented.

This energy policy trilemma is composed of three dimensions representing desired but partially incompatible goals of energy and environmental policies: energy security, energy sustainability, and environmental protection. Figure 1 depicts graphically the energy policy trilemma.

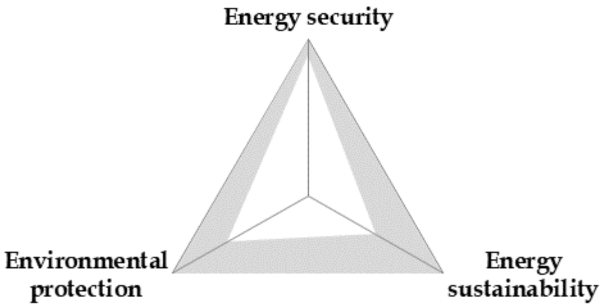

Figure 1 - Dimensions of Composite Index (source: Own processing)

This graphical capture looks the same as the one of World Energy Council (WEC) we evoked formerly, but the areas suggested in this paper differ from the ones of the Energy Trilemma Index. Unlike the Energy Trilemma Index, our approach:

- considers accessibility and affordability as a part of energy security;
- distinguish between 'energy sustainability' and 'environmental protection' that form two individual dimensions as the energy sustainability is an intertemporal concept while environmental protection is linked with concept of externalities (Energy Trilemma Index includes them under the dimension 'Environmental Sustainability').

The performance of countries in each dimension will serve as an indicator of countries' engagement in tackling existing global energy and environmental challenges. It will also serve as a tool for cross-country comparison. The structure of the composite index with its dimensions and individual indicators is captured in Table 1.

[1] Preliminary study of the environmental and energy polices of France (Sénat, 2016), Germany (Federal Ministry for Economic Affairs and Energy, 2016), and the Czech Republic (Ministry of Industry and Trade of the Czech Republic, 2015).

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Table 1 - Energy Policy Index Structure

Dimension	Indicator
Energy Security	Energy Dependence (%)
	Share of renewable energy in fuel consumption of transport (%)
	Electricity generated from renewable sources (%)
	Electricity prices: Medium size households (EUR per kWh)
	Electricity prices: Medium size industries (EUR per kWh)
Energy sustainability	Primary energy intensity of the economy (kg of oil equivalent per 1 000 EUR)
	Final Energy Intensity of the economy (kg of oil equivalent per 1 000 EUR)
	Gross inland energy intensity of the economy (kg of oil equivalent per 1 000 EUR)
	Implicit tax rate on energy (EUR per tonne of oil equivalent)
	Share of renewable energy in gross final energy consumption (%)
Environmental protection	GHG emissions per capita (tonnes of CO2 equivalent per capita)
	Emissions of sulphur oxides (SOx) (tonne per 1000 inhabitants)
	Emissions of nitrogen oxides (NOx) (tonne per 1000 inhabitants)
	Emissions of non-methane volatile organic compounds (NMVOC) (tonne per 1000 inhabitants)
	Urban population exposure to air pollution by particulate matter (Particulates <2.5µm) (micrograms per cubic metre)
	Urban population exposure to air pollution by particulate matter (Particulates <10µm) (micrograms per cubic metre)
	Urban population exposure to air pollution by ozone
	Shares of environmental taxes in total tax revenues from taxes and social contributions (%)

Source: Own processing, based on Eurostat data.

2.4. Definition of the relevant variables

The Energy Policy Trilemma is composed of three core dimensions and 17 indicators: 5 indicators composing the Energy security, 5 indicators composing the Energy sustainability, and 7 indicators composing the Environmental protection. All the indicators were collected from Eurostat Database (2018) and their description is based on the Eurostat metadata and rationale of the given indicator. Based on the literature review of existing energy concepts and indicator rationales, indicators were aligned in three categories (dimensions). Majority of the energy indicators used in this paper are Sustainable Development Indicators (SDIs) monitored under the new EU Sustainable Development Indicators (SDGs): mainly under the SDG 7: Affordable and Clean Energy; SDG 12: Responsible Consumption and Production; and SDG 13: Climate Action. For more details on SDI within the SDGs in the European Context, see Eurostat (2018, [online]).

2.4.1. Energy security dimension

Energy security dimension is composed of 5 indicators (Energy dependence, Share of renewable energy in fuel consumption of transport; electricity generated from renewable sources; and Electricity prices for medium size households and medium size businesses) reflecting the multi-faced measure of energy security. Selection of these indicators is based on the assumption of uninterrupted energy supply that lies in the lowest level of the energy dependence, the highest possible level of energy self-sufficiency, and its affordable price.

Energy dependence is an indicator of energy security that shows the extent to which an economy relies upon imports in order to meet its energy needs. According to Eurostat, energy dependence is calculated as net imports divided by the sum of gross inland energy consumption plus international maritime bunkers. This indicator is also an SDI under the SDG 7.
Share of renewable energy in fuel consumption of transport indices the substitution of conventional fuels with renewable energy (e.g. ethanol and biodiesel) in transport. The use of renewable energy in fuel consumption contributes to the reduction of the oil imports dependence and thus to the security of energy supply and it has even other synergic effects as rural economic development. This indicator represents one of the goals of EU 2020 Energy Strategy (10% share of renewable energy in their transport sector).

Electricity generated from renewable sources (hydro plants excl. pumping, wind, solar, geothermal and electricity from biomass/wastes) shows the extent to which the electricity production does not rely on conventional fuels. Despite the electricity, generation from renewable sources has several environmental and social costs we considered this indicator to be an indicator of energy security.

Electricity prices are influenced by the cost of energy sources and the efficiency of the electricity markets. Energy market liberalization aims to bring the prices down for consumers and intensify competition. For this reason, this indicator is included in the energy security in relation to its affordable and competitive aspect.

2.4.2. Energy sustainability dimension

Energy sustainability is formed by 5 indicators (Primary energy intensity of the economy, Final Energy Intensity of the economy, Gross inland energy intensity of the economy, Implicit tax rate on energy, and Share of renewable energy in gross final energy consumption) that are related to the energy use and energy savings. Despite its multiple effect, for the purpose of this paper, we consider energy efficiency to be a part of energy sustainability as we agree with the definition of energy sustainability of Prandecki (2014) and Rosen's (2009) two pillars approach. Three out of five energy sustainability indicators are related to the energy consumption of the economy relative to the GDP: Primary energy intensity of the economy, Final energy intensity of the economy and Gross inland energy intensity of the economy (all expressed in kg of oil equivalent per 1 000 EUR). All the proposed indicators or their core elements are monitored within the set of SDIs under the new EU SDGs: Primary and Final energy intensity of the Economy (the core elements of this indicators: Primary and Final Energy Consumption under SDG 7, SDG 12 and SDG 13); Share of renewable energy in gross final energy consumption (SDG 7, SDG 12, SDG 13), Implicit tax rate on energy (a part of Environmental and Labour taxes under SDG 15: Partnership for the Goals). This reflects the undoubted sustainable aspect of these energy indicators.

Primary energy intensity of the economy is a ratio between primary energy consumption and GDP and this indicator measures the total energy demand of a country excluding all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals). It covers the energy consumption by end users such as industry, transport, households, services and agriculture, plus energy consumption of the energy sector itself, losses occurring during transformation and distribution of energy. Primary and Final energy consumption are indicators of energy savings that have positive effect across all the targets pursued (reduction of fuel import dependence, reduction of GHG emissions etc.) and are projected into one of the five headline targets of the EU 2020 Energy Strategy (reaching an overall increase of 20% in energy efficiency by 2020).

Final energy intensity of the economy comprises the total energy demand of a country, respectively energy consumed by end users (industry, transport, households, service and agricultures), excluding energy consumption of the energy sector itself, losses occurring during transformation and distribution of energy, and all non-energy use of energy carriers (e.g. natural gas used not for combustion but for producing chemicals).

Gross inland energy intensity of the economy measures the energy consumption of an economy and its overall energy efficiency. It is counted as a ratio of Gross inland energy consumption (quantity of energy consumed within the national territory of a country) and GDP. Gross inland energy consumption is fundamental to an understanding of many of the issues associated with climate change, its costs and negative effects to society and the environment such as security of supply, GHG emissions, air pollutant emissions and radioactive waste generation.
In order to have a better image of the difference between these three consumption-related energy indicators, Table 2 summarizes the way the indicators are counted and elements they are composed of.

Table 2 - Energy consumption-related indicators

Primary energy intensity of the economy	Final energy intensity of the economy	Gross inland energy intensity of the economy
(Total energy demand of a country – non-energy use of energy carriers)/GDP	(Total energy demand of a country – non-energy use of energy – energy consumption of the energy itself – losses occurring during transformation and distribution of energy)/GDP	(Primary production + recovered products + total imports + variations of stock – total exports – bunkers)/GDP

Source: Own processing, based on Eurostat data.

Implicit tax rate on energy expresses energy tax revenues in relation to Final energy consumption and is result of dividing the Energy Tax Revenues (sum of taxes on energy production and taxes on energy products used for both transport and stationary purposes) and Final energy consumption. This indicator allows quantifying the role of fiscal policy in shaping demand for energy and measures the development of the burden of taxes on energy consumption.

The Share of renewable energy in gross final energy consumption is an important indicator used for monitoring progress towards a resource efficient Europe (i.e. the implementation of the Europe 2020 Resource Efficient Flagship initiative) and EU 2020 Energy Strategy (target of increasing the share of renewable energies in Gross final energy consumption to 20% by 2020) and it shows the energy used-by end-consumers (Final energy consumption) plus grid losses and self-consumption of power plants.

2.4.3. Environmental protection dimension

Environmental Protection dimension comprises 7 indicators related to the emission and pollution intensity and their reduction: GHG emissions, Emissions of Sulphur oxides (SOx); Emissions of nitrogen oxides (NOx); Emissions of non-methane volatile organic compounds (NMVOC); Urban population exposure to air pollution by particulate matters (Particulates $<2.5\mu m$ and Particulates $<10\mu m$); Urban population exposure to air pollution by ozone; and Shares of environmental taxes in total tax revenues from taxes and social contributions.

GHG emissions[2] level is an important indicator related to the electricity generation, transportation and other forms of energy production and use. It is used to evaluate progress towards meeting GHG reduction commitments under the UNFCCC and the Kyoto Protocol. This indicator is a target of EU 2020 Energy strategy (20% reduction in the overall EU GHG emissions) and is also a SDI (under the SDG 7 and SDG 13).

Emissions of Sulphur oxides (SOx) tracks trends in anthropogenic atmospheric emissions of SOx that are emitted when fuels containing sulphur are combusted. It is a pollutant contributing to acid deposition, which can lead to potential changes occurring in soil and water quality. It can result in adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation, but this acidification can also damage buildings and cultural monuments.

Emissions of Nitrogen oxides (NOx) tracks anthropogenic atmospheric emissions of Nitric oxide (NO) and nitrogen dioxide (NO2) that occur largely through the combustion of fossil fuels. NOx contributes to acid deposition and eutrophication that can as well as Emission of SOx lead to potential changes occurring in soil and water quality with the same potential adverse effects. It is NO2 that is associated with adverse effects on human health, as at high concentrations it can cause inflammation of the airways. NO2 also contributes to the formation of secondary particulate

[2] Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF6).

aerosols and tropospheric ozone (O3) in the atmosphere – both are important air pollutants due to their adverse impacts on human health. NOx is therefore linked both directly and indirectly to effects on human health.

Emissions of non-methane volatile organic compounds (NMVOC) are emitted into the atmosphere from a large number of sources including combustion activities, solvent use and production processes. NMVOCs contribute to the formation of ground level (tropospheric) ozone. In addition, certain NMVOC species or species groups (such as benzene and 1,3 butadiene) are hazardous to human health.

Urban population exposure to air pollution by particulate matter (Particulates <10μm and Particulates <2.5μm) is an indicator that is tracked under the objective of prevention and reduction environmental pollution. Particulate matters can be carried deep into the lungs where they can cause inflammation and worsening the condition of people with heart and lung diseases. This pollutant can occur naturally (e.g. dust, sand) or by human activity by fuel combustion. Concentration of particulate matter smaller than 2.5μm is a part of SDGs 3: Good health and well-being, and SDGs 11: Sustainable Cities and Communities.

Urban population exposure to air pollution by ozone is an indicator that shows the population-weighted concentration of ozone to which the urban population is potentially exposed. Ozone is a strong photochemical oxidant, which causes serious health problems (rise to inflammatory responses and decreases in lung function) and damage to the ecosystem, agricultural crops and materials. It is not emitted directly in the air but it is created by chemical reactions of NOx and NMVOCs emissions from industrial facilities, electricity utilities, motor vehicle exhaust etc. (EPA, 2017).

Environmental tax revenues stem from four types of taxes: energy taxes, transport taxes and pollution and resource taxes that polluters pay for the damage they cause to human health and to the environment.

3. Empirical approach of the energy policy trilemma

The previous section served to the development of the structure of the composite index and rationale of its main components. In this section, we aim to analyze the policies of selected European countries. Our main tool will be Principal Component Analysis (PCA). We calculate the weights for each variable according to the method developed by OECD (2008) and Nicoletti et al. (2000) and we construct four composite indexes: three indexes will reflect individual dimensions of our analytical framework (namely, Energy Security, Energy Sustainability and Environmental Protection) and one will include all the variables together (hereafter called "global index"). We calculate then the scores of each country for each one of these 4 composite indexes. The scores for the 3 partial dimensions will permit us to draw triangle charts representing the choices of each country in the Energy Trilemma. Finally, the score of each country in the "global index" will allow us to make a ranking of the quality of energy policies of the countries of the sample. The choice made in this paper is to focus on a selected sample of countries. The country sample used for the purpose of this paper is based on the country of domicile of the top ten largest electricity producers in the EU according to their energy generation in TWh (see Figure 2) that is one of the most important indicators related to energy production. The sample consists of the following eight countries: Czech Republic, Finland, France, Germany, Italy, Portugal, Spain, Sweden. This group of countries manifests a great variety in terms of size of the economies, their geographical location, natural endowment, energy orientation, and historical background.

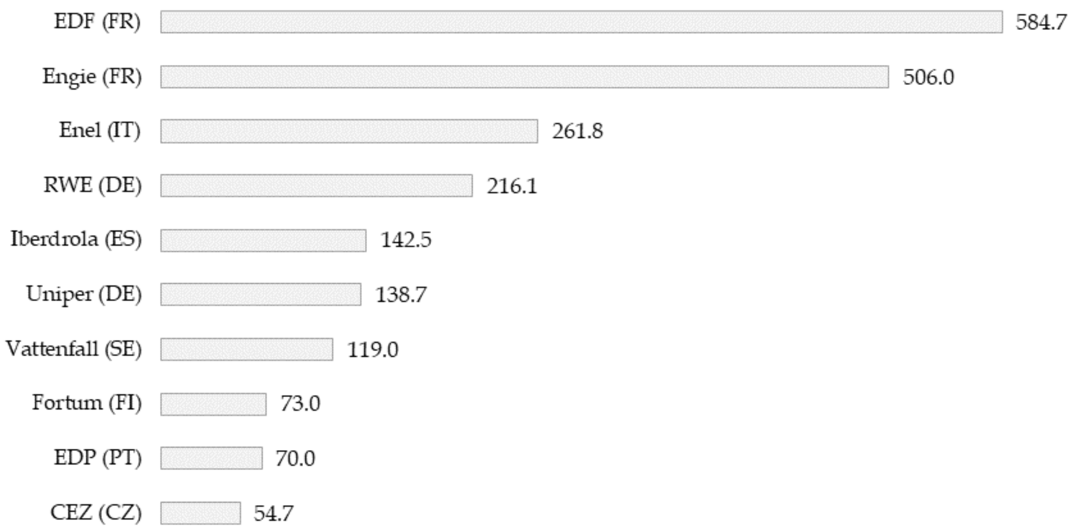

Figure 2 - Energy generation of the top 10 energy utilities in the EU in 2016 (in volume of TWh) (Source: Own processing)

3.1. Countries of the Sample in the "trilemma approach" of energy policy

In order to calculate an indicator for each country, we take the values of the corresponding variables (organized such as the higher the better, see Appendix 3) and we normalize these values from 0 to 1 by creating a new variable:

In order to calculate an indicator for each country, we take the values of the corresponding variables (organized such as the higher the better, see Appendix 3) and we normalize these values from 0 to 1 by creating a new variable:

$$y = \frac{x - \min(x)}{\max(x) - \min(x)} \tag{1}$$

where the variable *y* goes from 0 (x=min(x)) to 1 (x=max(x)). Then we weight each variable *y* by the weightings calculated with the PCA, as shown in Appendix 2. By computing those indicators (see Table 3), the "triangles" of energy choices for the 8 sample economies can be drawn.

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Table 3 - Scores of the Sample Countries in each Dimension of the Trilemma

	Energy Security	Energy Sustainability	Environmental Protection
Czech Republic	0.548963526	0.000555128	0.208099630
Germany	0.274315980	0.645902180	0.434375732
Spain	0.214224627	0.631147787	0.435279685
France	0.493699207	0.668356302	0.614872154
Italy	0.254776019	0.789634812	0.522660540
Portugal	0.327197491	0.597995521	0.642731129
Finland	0.617664403	0.415007059	0.615696070
Sweden	0.947350968	0.853337020	0.738591804

Source: Own processing.

3.1.1. Germany, Spain and Italy: strong focus on sustainability and environmental protection

Germany (Figure 3), Spain (Figure 4) and Italy (Figure 5) are very similar in their energy direction. They are strongly focused on the Energy Sustainability and Environmental Protection (where Sustainability is over Environmental Protection) that are in the forefront of their policies. We assume that these results are given by the significant representation of RES in energy use that among other positively affect countries' performance on Environmental protection.

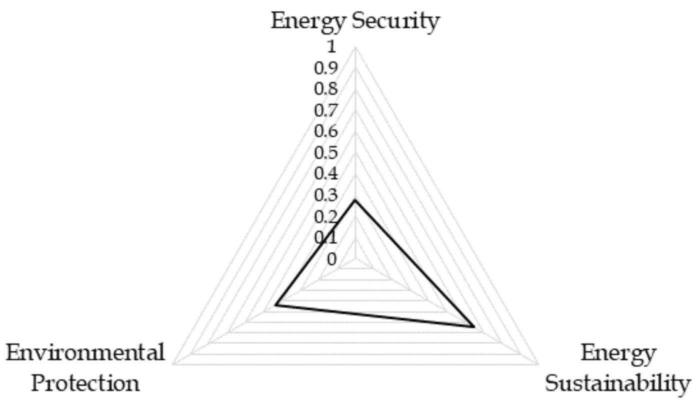

Figure 3 - Energy Triangle of Germany (source: Own processing)

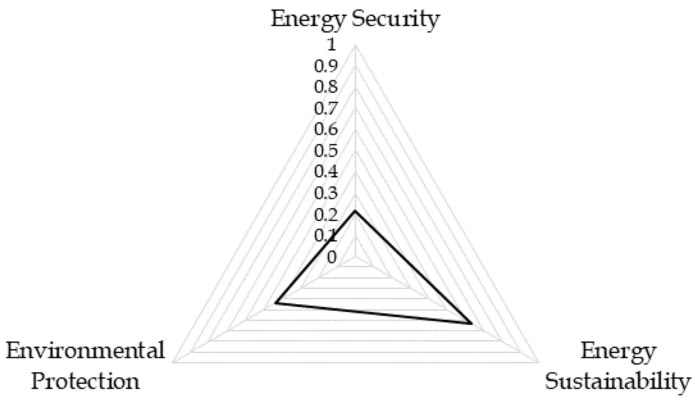

Figure 4 - Energy Triangle of Spain (source: Own processing)

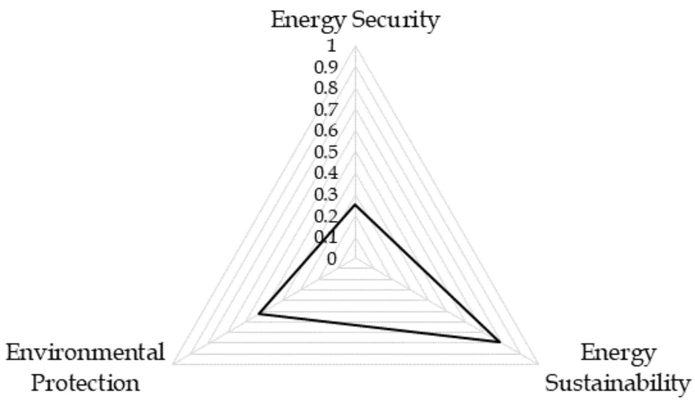

Figure 5 - Energy Triangle of Italy (source: Own processing)

3.1.2. Portugal: strong focus on environmental protection

Portugal's performance (Figure 6) on the three dimensions resembles above described Country Group (Germany, Spain and Italy), but the Environmental Protection dominates over the Energy Sustainability.

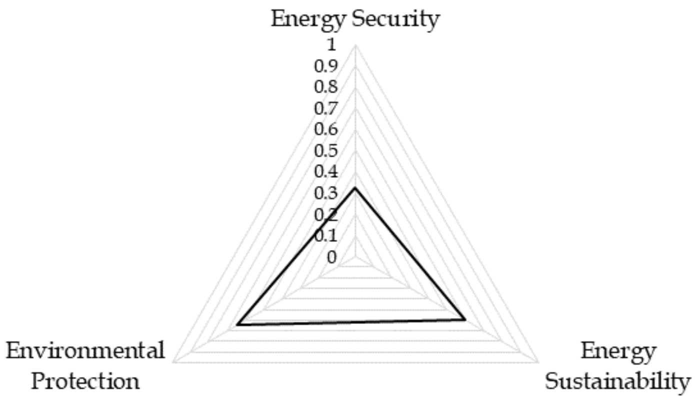

Figure 6 - Energy Triangle of Portugal (source: Own processing)

3.1.3. Czech Republic: energy security orientated country

The energy choice of the Czech Republic (Figure 7) is very different from the other economies of the sample, inasmuch as its energy orientation according to our index computation lies in targeting the Energy Security. The weakest point of the Czech energy choice is the Energy Sustainability that is significantly lagging behind other dimensions.

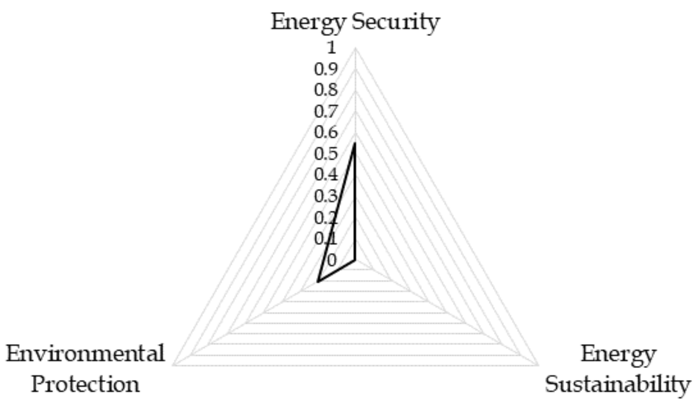

Figure 7 - Energy Triangle of the Czech Republic (source: Own processing)

3.1.4. Finland

Even if the share of renewable energy in gross energy consumption in Finland is high (the second highest after Sweden), Finnish energy intensity is also high (the 2nd highest after the Czech Republic) and its implicit tax rate on energy is low (the 2nd lowest after the Czech Republic). This results in a relatively low index of Energy Sustainability and dominance of the Energy Security and Environmental Protection (Figure 8).

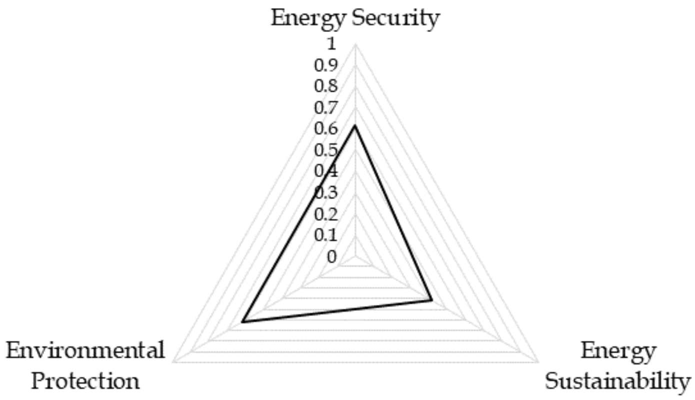

Figure 8 - Energy Triangle of Finland (source: Own processing)

3.1.5. France

Even if France (Figure 9) has a relatively good index of Energy Security (with the 4th highest score after Sweden, Finland and the Czech Republic) it seems that France is paradoxically less performing on Energy Security. Looking closely at its reason, it is mainly the consequence of a low Share of electricity generated from renewable sources, which is the 2nd lowest share after the Czech Republic.

Actually, the other components of the index show relatively good position of France in Energy Security: Energy independence is close to 50% that put France on the 4th position in the sample (higher energy independence is observed in case of Sweden, the Czech Republic and Finland), the Share of renewable in transport is the 2nd highest after Sweden, and electricity prices are among the lowest of the sample. The main problem related to the French Energy Security is therefore its choice of production of electricity that is based on nuclear power, with more than 75% of French electricity produced by nuclear, which is not a secure source inasmuch as it depends on importation of uranium.

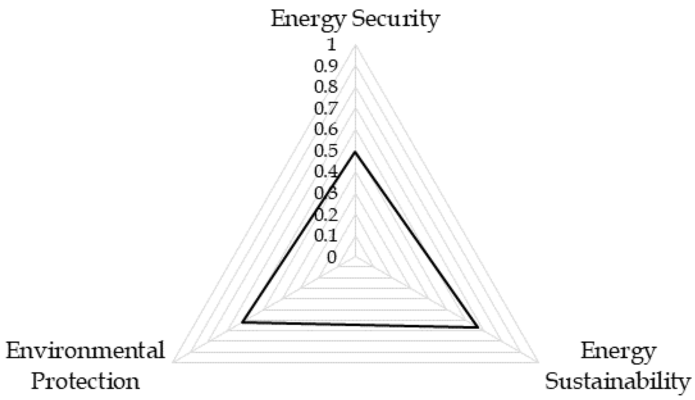

Figure 9 - Energy Triangle of France (source: Own processing)

3.1.6. Sweden: the impossible magic triangle?

In the selected country sample, Sweden performs the best on each dimension and its triangle has the largest surface (Figure 10) that is in line with our vision of the right direction of the energy policy.

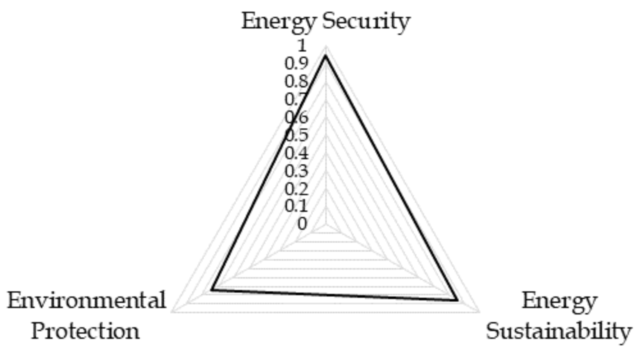

Figure 10 - Energy Triangle of Sweden (source: Own processing)

Nevertheless, it is necessary to take into account the different country potential, resources endowment and the last but not least, the country historical background can play an important role in determining the energy direction.

3.2. The overall ranking of countries

Finally, based on the overall indices for each country (see the calculations in Appendix 2), the final score and ranking for each country is provided (Table 4). This ranking reflects the above stated country energy choices characteristics.

Table 4 - Overall ranking of countries

	Score	Ranking
Sweden	0.83	1.
France	0.64	2.
Italy	0.57	3.
Portugal	0.54	4.
Finland	0.52	5.
Germany	0.51	6.
Spain	0.47	7.
Czech Republic	0.21	8.

Source: Own processing.

4. Conclusion

This paper represents a new contribution in the "trilemma approach" tradition. Even if this approach has already been applied to energy and environmental policy, our originality is twofold. First, the three targets of the Energy Policy are defined as Energy sustainability, Energy Security and Environmental Protection. Second, the composite indexes used are based on the PCA. Our future researches will go in two directions. One will consist in a comparison between our results and the results of competing approaches, as the one developed by the WEC. The second direction will consist in a comparison between the policies of the countries we analyzed, and the corporate policies of the major energy firms of these countries, such as they appear in their sustainability reports.

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Appendix 1: List of selected energy security studies and their energy dimensions/principles and number of indicators/metrics (Source: Own Processing)

Author (year)	Energy dimensions/principles	Number of indicators/metrics
APERC (2007)	Energy resource availability; accessibility barriers; environmental acceptability; investment cost affordability	4
Chester (2010)	Absolute (availability, adequacy of capacity) and relative (affordability, sustainability)	-
Cohen et al. (2011)	Security of external supply (crude oil; natural gas)	4
European Commission (2014)	Energy efficiency; energy security; energy sustainability	-
IEA (2014b)	Affordable/competitive supply; reliable/uninterrupted supply; accessible/available supply	30
Institute for 21st Century Energy (2013)	Global fuels; fuel imports; energy expenditures; price & market volatility; end use intensity; electric power sector; transportation; environmental	29
Kruyt et al. (2009)	Availability; affordability; acceptability; accessibility	16 (simple) + 5 (aggregated)
Le Coq and Paltseva (2009)	Security of external supply (oil; gas; and hard and brown coal)	15
Martchamadol and Kumar (2013)	Social; environment; economic	25
Ren and Sovacool (2014)	Availability; affordability; acceptability; accessibility	24
Sovacool (2011)	Availability; dependency; diversification; decentralization; innovation; investment; trade; production; price stability; affordability; governance; access; reliability; literacy; resilience; land use; water; pollution; efficiency; greenhouse gas emissions	200
Sovacool (2012)	Availability; affordability; technology development and efficiency; environmental sustainability; regulation and governance	20
Sovacool and Mukherjee (2011)	Availability; affordability; technology development and efficiency; environmental and social sustainability; regulation and governance	320 (simple) + 52 (aggregated)
Vivoda (2010)	Energy supply; demand management; efficiency; economic; environmental; human security; military-security; domestic socio-cultural-political; technological; international; policy	44
Von Hippel (2011)	Energy supply; economic; technological; environmental; socio-cultural; military-security	25
Winzer (2012)	Source of risk; scope of the impact measure; severity of impacts	9
Yergin (2006)	Diversification; resilience against markets shocks; recognition of the integration of worldwide energy system; the importance of information	-

Appendix 2: Calculating weightings using the PCA

The calculation of weights using the PCA were based on the method developed by OECD (2008) and Nicoletti et al. (2000). This method follows the following steps:

Step 1: Making a PCA on selected data and retaining the factors according to the following criteria:

I. Each factor must be associated to eigenvalue larger than one;
II. It must contribute individually to the explanation of overall variance by more than 10%; and
III. All the factors retained must contribute cumulatively to the explanation of the overall variance by more than 60%.

Step 2: Rotating the selected factors using a Varimax rotation, which maximises the variance of the normalized squared loadings of the selected factors. Thanks to this rotation of factors, which gives loading either close to one or close to zero, each variable can be associated to one factor.

Step 3: The weight of each variable in the composite index will be the normalized value of the multiplication of the normalized squared loading of the variable in the associated factor, by the normalized variance of each factor after rotation.

Hereafter, the detailed calculation of the (1) Index of Environmental Protection and other indexes are calculated in an analogue manner.

After the PCA, the following latent factors are obtained:

	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	3.155	2.345	1.497	0.562	0.322	0.11	0.01
Variability (%)	39.436	29.311	18.713	7.027	4.026	1.37	0.12
Cumulative %	39.436	68.747	87.461	94.488	98.514	99.88	100.00

According to the step 1, we select the 3 first factors.

Then we make a varimax rotation on these 3 factors, which gives the following values:

	D1	D2	D3	F4	F5	F6	F7
Variability (%)	38.141	28.958	20.361	7.027	4.026	1.37	0.12
Cumulative %	38.141	67.099	87.461	94.488	98.514	99.88	100.00

Then we calculate the normalized squared loadings of each variable in the rotated factors.
Factor loadings after Varimax rotation:

	D1	D2	D3
GHG Distance to Max	0.116	0.936	-0.152
Sulphur oxides (SOx) Distance to Max	0.059	0.932	0.139
Nitrogen oxides (NOx) Distance to Max	-0.514	0.545	0.411
NMVOC Distance to Max	-0.525	-0.033	0.727
Pollution particulate (Particulates < 2.5µm) Distance to Max	0.879	0.350	-0.107
Pollution particulate (Particulates < 10µm) Distance to Max	0.954	0.156	0.049
Population exposure to pollution ozone Distance to Max	0.875	-0.358	0.066
Shares of environmental taxes in total tax revenues (%)	-0.209	-0.013	-0.933

We calculate the squared factor loadings and we normalize them to unity:

	D1	D2	D3
GHG Distance to Max	0.44%	37.80%	1.42%
Sulphur oxides (SOx) Distance to Max	0.11%	37.46%	1.19%
Nitrogen oxides (NOx) Distance to Max	8.66%	12.81%	10.39%
NMVOC Distance to Max	9.05%	0.05%	32.44%
Pollution particulate (Particulates < 2.5μm) Distance to Max	25.33%	5.30%	0.71%
Pollution particulate (Particulates < 10μm) Distance to Max	29.85%	1.05%	0.15%
Population exposure to pollution ozone Distance to Max	25.12%	5.53%	0.27%
Shares of environmental taxes in total tax revenues (%)	1.44%	0.01%	53.44%
	1	1	1

We then associate each variable to one factor, and we calculate the weighting of this factor by multiplying the normalized squared factor loading of the variable in the associated factor by the normalized variance of the factor in the PCA after rotation. In this case the normalized variances of the rotated factors will be:

D1: 38.141 / 87.461 = 43.61%

D2: 28.958 / 87.461 = 33.11 %

D3: 20.361 / 87.461 = 23.28 %

Multiplying these figures by the squared factor loadings and normalizing to unity, we obtain the following result, corresponding to the weights of each variable in the composite indicator:

GHG Distance to Max	14.87%
Sulphur oxides (SOx) Distance to Max	14.74%
Nitrogen oxides (NOx) Distance to Max	5.04%
NMVOC Distance to Max	8.97%
Pollution particulate (Particulates < 2.5μm) Distance to Max	13.12%
Pollution particulate (Particulates < 10μm) Distance to Max	15.46%
Population exposure to pollution ozone Distance to Max	13.01%
Shares of environmental taxes in total tax revenues (%)	14.78%
	100.00%

Following the above-mentioned reasoning, we obtained the following results for other two dimensions and overall index:

(2) Index of Security

- Factors before rotation:

	F1	F2	F3	F4	F5
Eigenvalue	2.707	1.667	0.424	0.146	0.056
Variability (%)	54.147	33.339	8.485	2.918	1.111
Cumulative %	54.147	87.486	95.971	98.889	100.000

- Factors after varimax rotation:

	D1	D2	F3	F4	F5
Variability (%)	52.669	34.817	8.485	2.918	1.111
Cumulative %	52.669	87.486	95.971	98.889	100.000

- Calculation of the weightings:

	D1	D2	Weights
Independence	35.03%	0.73%	23.00%
Renewable energy in transports	7.96%	43.08%	18.70%
Electricity from renewable	1.79%	50.76%	22.03%
Electricity price household (distance to max)	26.39%	3.32%	17.33%
Electricity price firms (distance to max)	28.83%	2.11%	18.93%
			100.00%

(3) Index of Sustainability

- Factors before rotation:

	F1	F2	F3	F4	F5
Eigenvalue	3.507	1.055	0.405	0.029	0.004
Variability (%)	70.149	21.090	8.091	0.583	0.087
Cumulative %	70.149	91.239	99.330	99.913	100.000

- Factors after varimax rotation:

	D1	D2	F3	F4	F5
Variability (%)	70.084	21.155	8.091	0.583	0.087
Cumulative %	70.084	91.239	99.330	99.913	100.000

- Calculation of weightings:

	D1	D2	Weights
Primary energy intensity / distance to Max	27.45%	0.73%	21.51%
Final energy intensity / distance to Max	27.17%	0.00%	21.29%
Gross inland energy intensity / distance to Max	27.89%	0.03%	21.86%
Implicit tax rate on energy	17.47%	7.72%	13.69%
Share of renewable in energy consumption	0.02%	91.53%	21.65%
	100.00%	100.00%	100.00%

(4) General Index (all variables):

- Factors before rotation:

	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	6.628	5.555	2.415	1.481	0.867	0.861	0.194
Variability (%)	36.821	30.859	13.415	8.228	4.815	4.783	1.079
Cumulative %	36.821	67.680	81.095	89.323	94.138	98.921	100.000

- Factors after varimax rotation:

	D1	D2	D3	F4	F5	F6	F7
Variability (%)	35.444	27.855	17.796	8.228	4.815	4.783	1.079
Cumulative %	35.444	63.299	81.095	89.323	94.138	98.921	100.000

- Calculation of weights of each variable in the overall index:

	D1	D2	D3	Weights
Independence	2.86%	0.60%	23.72%	6.49%
Renewable energy in transports	1.80%	7.13%	11.36%	3.11%
Electricity from renewable	3.14%	13.16%	0.44%	5.64%
Electricity price household (distance to max)	5.23%	0.21%	7.00%	1.92%
Electricity price firms (distance to max)	0.88%	1.54%	19.01%	5.20%
Primary energy intensity / distance to Max	13.69%	0.41%	0.94%	7.47%
Final energy intensity / distance to Max	15.00%	0.00%	0.04%	8.18%
Gross inland energy intensity / distance to Max	14.37%	0.08%	1.16%	7.83%
Implicit tax rate on energy	9.00%	1.15%	1.24%	4.91%
Share of renewable in energy consumption	0.04%	16.84%	3.15%	7.22%
GHG Distance to Max	8.96%	2.61%	0.05%	4.89%
Sulphur oxides (SOx) Distance to Max	14.39%	0.53%	0.15%	7.85%
Nitrogen oxides (NOx) Distance to Max	5.82%	4.09%	3.52%	3.17%
NMVOC Distance to Max	0.53%	13.99%	2.66%	6.00%
Pollution particulate (Particulates < 2.5µm) Distance to Max	0.51%	15.20%	0.41%	6.51%
Pollution particulate (Particulates < 10µm) Distance to Max	0.05%	13.53%	4.54%	5.80%
Population exposure to pollution ozone Distance to Max	3.23%	8.37%	5.18%	3.59%
Shares of environmental taxes in total tax revenues (%)	0.48%	0.55%	15.44%	4.23%

Appendix 3: Overview of indicators and data used in the paper

This section provides an overview of indicators and data used in the paper. All data was downloaded from online Eurostat database and refers to the year 2016 (where indicated, the data for 2015). Some indicators were adjusted for the purpose of this paper.

(1) Energy Security data

	Energy Dependence (%)	Energy Independence (%)	Share of renewable energy in fuel consumption of transport (%)	Electricity generated from renewable sources (%)	Electricity prices: Medium size households (EUR per kWh)	Electricity prices: distance to Max / households	Electricity prices: distance to Max / firms	Electricity prices: Medium size industries (EUR per kWh)
Czech Republic	32.8	67.2	6.4	13.6	0.142	0.155	0.033	0.072
Germany	63.5	36.5	6.9	32.2	0.297	0.000	0.026	0.079
Spain	71.9	28.1	5.3	36.6	0.219	0.078	0.000	0.105
France	47.1	52.9	8.9	19.2	0.169	0.128	0.034	0.071
Italy	77.5	22.5	7.2	34.0	0.241	0.056	0.021	0.084
Portugal	73.5	26.5	7.5	54.1	0.235	0.062	0.011	0.094
Finland	45.3	54.7	8.4	32.9	0.154	0.143	0.044	0.061
Sweden	31.9	68.1	30.3	64.9	0.189	0.108	0.044	0.061
Value	the higher the worse	the higher the better	the higher the better	the higher the better	the higher the worse	the higher the better	the higher the better	the higher the worse

(2) Energy Sustainability data

	Primary energy intensity of the economy (kg of oil equivalent per 1 000 EUR)	Primary energy intensity / distance to Max	Final Energy Intensity of the economy (kg of oil equivalent per 1 000 EUR)	Final energy intensity / distance to Max	Gross inland energy intensity of the economy (kg of oil equivalent per 1 000 EUR)	Gross inland energy intensity / distance to Max	Implicit tax rate on energy (EUR per tonne of oil equivalent)	Share of renewable energy in gross final energy consumption (%)
Czech Republic	226.0	0.0	140.5	0.0	239.0	0.0	138.4	14.9
Germany	94.1	131.9	68.8	71.6	111.1	127.9	203.2	14.8
Spain	104.8	121.2	73.8	66.7	110.5	128.5	205.3	17.3
France	105.6	120.4	66.0	74.4	117.2	121.8	266.4	16.0
Italy	88.3	137.7	69.0	71.5	98.4	140.6	384.0	17.4
Portugal	119.3	106.6	86.9	53.5	133.1	105.9	206.0	28.5
Finland	153.4	72.6	116.8	23.7	181.5	57.5	159.4	38.7
Sweden	101.2	124.7	70.1	70.4	116.2	122.8	227.5	53.8
Value	the higher the worse	the higher the better	the higher the worse	the higher the better	the higher the worse	the higher the better	the higher the better	the higher the better

(3) Environmental Protection data

note: emissions for 2015	GHG emissions per capita (tonnes of CO2 equivalent per capita)	Emissions of sulphur oxides (SOx) (tonne per 1000 inhabitants)	Emissions of nitrogen oxides (NOx) (tonne per 1000 inhabitants)	Emissions of non-methane volatile organic compounds (NMVOC) (tonne per 1000 inhabitants)	Urban population exposure to air pollution by particulate matter (Particulates < 2.5µm) (micrograms per cubic metre)	Urban population exposure to air pollution (Particulates < 10µm) (micrograms per cubic m)	Urban population exposure to air pollution by ozone (micrograms per cubic metre day)	Shares of environmental taxes in total tax revenues from taxes and social contributions (%)
Czech Republic	12.2	11.7	15.6	13.2	19	27.7	3407	6.07
Germany	11.3	4.3	14.5	12.4	15.1	20.3	3074	4.77
Spain	7.5	5.9	19.5	12.6	11.1	25.8	4850	5.54
France	7.1	2.3	12.5	9.3	12.6	20.7	3573	4.89
Italy	7.3	2.0	12.6	13.9	17.5	26.8	5464	8.21
Portugal	7.0	4.8	17.4	17.4	9.9	20	2947	7.54
Finland	10.5	7.7	25.5	16.0	8.4	13.7	1473	7.05
Sweden	5.7	2.0	13.2	16.6	7.2	14.3	2569	5.05
Value	the higher the worse	the higher the worse	the higher the worse	the higher the worse	the higher the worse	the higher the worse	the higher the worse	the higher the better
Czech Republic	0.0	0.0	9.9	4.2	0	0	2057	
Germany	0.9	7.4	11.0	5.0	3.9	7.4	2390	
Spain	4.7	5.8	6.0	4.9	7.9	1.9	614	
France	5.1	9.4	12.9	8.1	6.4	7	1891	
Italy	4.9	9.6	12.9	3.6	1.5	0.9	0	
Portugal	5.2	6.9	8.1	0.0	9.1	7.7	2517	
Finland	1.7	4.0	0.0	1.4	10.6	14	3991	
Sweden	6.5	9.7	12.3	0.8	11.8	13.4	2895	
Value	the higher the better	the higher the better	the higher the better	the higher the better	the higher the better	the higher the better	the higher the better	