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Master’s Thesis- Master Energy Science; Track System Analysis

Security of oil and gas supply in the European Union:

Has the EU’s energy security policy worked?

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Executive Summary

Due to the limited availability of and high dependence on oil and gas resources in the European Union (EU), energy security has been one of the priorities of the legislative agenda since its beginnings. To this end, the European Commission (EC) has issued several policy instruments to counteract the risks associated with oil and gas disruptions that can have long lasting consequences on EU's economy. However, no study has been conducted to determine whether or not the EC's policy has helped increase energy security of oil and gas in the region. Thus, the purpose of this study was to assess the policy's effectiveness by studying the evolution of oil and gas energy security in fifteen countries (EU15) from 1994 to 2016 by using five indicators: Liquidity in the oil and gas markets, oil vulnerability index (OVI), ESI price, share of zero carbon fuels (SOCZF) and supplier diversity. These indicators were chosen based on the methodology devised by the US Centre for Innovation and Impact, as well as by their characteristic to collectively cover all the elements provided in the definition of energy security (i.e. affordability, acceptability, accessibility and availability).

The results show that on a year to year basis (2016 vs 1994), the energy security in the EU15 has diminished meaning that their risk exposure to oil and gas disruptions has increased over time. The individual indicator results (2016 vs 1994) showed that: (i) The market liquidity of the oil and gas markets remained, for the most part unaltered (-0.4% in the oil market and -0.2% in the gas market) (ii) The OVI index increased 50%, which means that the EU15 increasingly allocate a bigger portion of their GDP to acquire oil in the international markets (iii) The ESI Price of Oil decreased 11.8% as a result of an increased reduction on the oil demand of the EU 15 Member States, diversification in oil suppliers and geopolitical stability in the supplying countries (iv) The ESI Price of gas increased 26.4% due to poor gas supplier diversification (v) The SOZCF increased 37.5% due to increased inclusion of renewable energy which means (according to this indicator) that oil and gas have become less socially acceptable (vi) The supplier diversity of oil has increased due to the inclusion of more oil suppliers but also due to a better distribution of the import shares among the supplying countries (vii) The gas supplier diversification has decreased 5.7% due to increased import dependency from the EU15 on Norway, the Netherlands and UK.
To understand the underlying reasons why the policies have proven ineffective, the study was complemented by a high level analysis of the content of the policies using a governance theory framework devised by Easton (1965). The results showed that only one out of the seven policies analysed (Regulation 994/2010), deals directly with energy security and establishes legally binding consequences for non-compliant countries, which limits the impact of these policies on energy security indicators. This lack of stringency is the result of the diverse interests present in the EU which ultimately leads to suboptimal policy outputs. Furthermore, it is difficult to establish causality between the indicator results and the measures embedded in the policies in question due to all the external factors that affect the international markets of oil and gas.

Going forward, the EC should continue its long term strategy to mitigate the risks associated to oil and gas disruptions through the strengthening of the internal energy market and the deployment of renewable energy capacity. Lastly, while this study showed that the policies issued by the EC did not seem to have an impact on the indicator results, there has been some progress in the field of energy security in the EU. Examples of this are the dissolution of energy conglomerates that hinder competition or the international cooperation mechanisms that have been implemented to counteract oil and gas disruptions. Thus, the role of the EC as an energy governance body should not be undermined.

UNITS AND ABREVATIONS

ABBREVATIONS:

APERC: Asia Pacific Energy Research Centre.

EC: European Commission.

EEC: European Energy Charter.

ECT: Energy Charter Treaty

EU 15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Spain, Sweden and United Kingdom.

Gas Directive: Directive 2009/73/EC

IEA: International Energy Agency.

Member State: Country belonging to the European Union.

ML: Market Liquidity

OVI: Oil vulnerability index.

RES: Renewable energy source.

TFEU: Treaty on the functioning of the European Union.

TPES: Total primary energy supply

USAID: The U.S. Centre for Innovation and Impact

SD: Supplier diversity.

SEA: Single European Act.

SOS: Security of supply.

SOZCF: Share of zero carbon fuels.

COUNTRY CODES:

AT:	Austria	**DE:**	Germany	**NL:**	Netherlands
BE:	Belgium	**GR:**	Greece	**PT:**	Portugal
DK:	Denmark	**IE:**	Ireland	**ES:**	Spain
FI:	Finland	**IT:**	Italy	**SW:**	Sweden
FR:	France	**LX:**	Luxemburg	**UK:**	United Kingdom

UNITS:

Ktoe: Kilo tonnes of oil equivalent.

Mtoe: Million tonnes of oil equivalent.

TABLE OF CONTENT

I.- Introduction

The Treaty on the Functioning of the European Union (TFEU) signed in 1957 by France, Italy, West Germany, Belgium, Netherlands and Luxemburg established the constitutional basis of the European Economic Community. This treaty marked the beginning of the integration of Europe and its objective was to establish a single and unified market for goods, labour, services and capital across the member states (Langsdorf, 2011). In order to strengthen this recently created market, the treaty gave several faculties to the Council such as deciding upon the measures appropriate to the economic situation if severe difficulties were to arise in the supply of certain products, especially in the area of energy. This marked the beginning of a collaborative European effort towards ensuring security of energy supply and has been an elemental principle in the European energy policy agenda ever since (Foreign and Commonwealth Office, 2008).

Even though the TFEU was considered the first step towards achieving energy solidarity in the region, the TFEU still allowed Member States to determine matters related to their internal energy policy such as their energy mix and the general structure of their energy supply. This meant that the Council members acted from a “self-serving” perspective, defending their national interests instead of acting as an integrated block (Nugent, 2003). It wasn’t until the oil crisis of 1973 that the block’s vulnerability was made evident by the inadequacy of the Member States (which by then, also included Ireland) on securing energy supplies. At the time the Member States opted for individual solutions to this crisis (Kirchner & Berk, 2010), but the immediate need to revise and adapt the legal framework was made apparent. These concerns were eventually addressed in the 1986 Single European Act (SEA), which emphasized the importance of the development of a free energy market as a way to strengthen the Union’s internal market (Commission of the European Communities, 1986). The SEA set the cornerstones for the 1990’s electricity and gas directives which, for the first time, established common energy law in the EU (European Parliament & EU, 1998). However, these directives lacked proper supervision instruments to ensure their implementation within Member States, an oversight that resulted from the strong opposition from some Member States (Langsdorf, 2011).

In 1992 the Maastricht treaty was signed by twelve Member States which established the structural pillars of the European Union and fostered cooperation of the Member States in the areas of foreign policy, military, criminal justice and judicial cooperation (European Commission, 1992). A chapter dedicated exclusively to common energy policy was dropped after the treaty’s negotiations due to the strong opposition from three energy producers, Germany, Britain and the Netherlands (Haaland-Matlary, 2007). None of the amendments to the Maastricht treaty have a chapter dedicated to energy, however they contain energy related legislation regarding the environment, supranational networks, difficulties in the supply of products, research and external relations.

Shortly after the Maastricht treaty, in 1994 the European Energy Charter (EEC) was signed by fifty countries including all EU members. Its purpose was to create a regime of energy management and international cooperation based on a mutual interest in security of energy supply and sustainable development (European Commission, 1994). To achieve this, legislation was established to ensure that companies were treated equally regardless of their country of origin and thus reducing conflict, improving reliability and security of supply (SOS) (Axelrod, 1996). The purpose of this regulation was to create an environment which fostered and facilitated investment across the region however, Member States still needed to implement additional measures to address the energy market's failures.

The energy policy in the beginning of the twenty first century has been largely shaped by the natural gas disruptions that occurred in 2006 and 2009 due to a dispute between Russia and Ukraine. These events made EU's import dependency and lack of supplier diversity evident and thus, opened a window of opportunity for the EC to push for additional regulation that fostered the interconnection and integration of the internal energy market with aims of increasing the SOS. This European-wide approach led to the publication of two Green Papers on energy in 2001 and 2006 (Piebalgs, 2006), a chapter dedicated to energy in the 2007's Treaty of Lisbon, the Commission's second strategic energy review in 2008 (European Commission, 2008) and the third energy internal market package in 2009. Additionally, the 2009 energy package also contains binding legislation to implement the so called 20-20-20 targets which are aimed towards reducing greenhouse emissions and primary energy use, as well as increasing the share of renewable energy sources. Collectively, these documents establish obligations and actions for the Member States to promote regional solidarity, bilateral assistance and coordination to implement mechanisms to reduce external disruptions of supply and climate change mitigation.

The most recent EC's legislation exclusively related to SOS was the 2014 the Energy Security Strategy which establishes short and long term measures to ensure stable SOS in the region. One of the most important takeaways of this policy were the results obtained from the execution of an energy security stress test. This exercise was conducted by thirty-eight European countries (including all EU's Member States) who simulated Russian supply disruption scenarios for a period of one or six months. The results showed that a prolonged supply disruption would have substantial impact on the EU and that cooperation among countries is needed to guarantee SOS in the region (European Commission, 2014).

Despite all the efforts done by the EC to counter the problem of energy insecurity and import dependency, there seems to be different opinions when it comes to determining whether or not their collective efforts have proven effective. Some sources look at the rising tendency in the energy import dependency from Member States which, is expected to rise from 54 percent in 2017 to 67 percent in 2030 (IEA, 2017) and argue that the Commission's measures have led to limited outcomes due to difficulties that arise when trying to introduce common policy that is beneficial for all states (Costantini, Gracceva, Markandya, & Vicini, 2007; Langsdorf, 2011; Lichwa, 2010; Maltby, 2013). Others authors, who focus on a more integrated approach of SOS that entails more that import dependency, mention that there is a positive trend in general that points to an overall increase in SOS across Member States (Doumpos, Andriosopoulos, & Matsumoto, 2018; Radovanović, Filipović, & Pavlović, 2017). However, none of the studies that where found, study the evolution of SOS in all Member States since the EU's formal establishment in 1994, in order to determine whether or not the Commission's policy has helped increase SOS. Therefore, in order to properly assess whether the SOS policy drafted by the Commission has proven effective, a time series quantitative analysis is necessary that centers around those countries who have been members of the EU since the beginning: The EU 15. These Member States have not only been subject to EC regulation for a sufficient period of time to experience the impact of the policies, but also collectively represent 84 per cent of the EU's annual GDP (Eurostat, 2018).

Consequently, the main research question of this study was: How has security of supply of oil and gas developed in the EU 15 Member States between 1994 and 2016 and to what extent can this be explained by policies issued by the European Commission? This work aimed to answer this question by: (1) The Identification of the main energy policies issued between 1994-2016 related to SOS in the EU15 and (2) A quantitative analysis of the evolution of SOS in the region and time period analysed (3) An Assessment of the overall effectiveness of the identified policies by using a governance framework.

RELEVANCE OF THE STUDY

It is certainly clear that SOS has been one of the main cornerstones of energy policy issued by the EC since its foundations and thus, it has been the main scope of several studies. However, no studies were found in literature that try to determine the effectiveness of these policies by using two approaches: a quantitative numerical approach that establishes indicators to study the evolution of oil and gas SOS in the EU 15 and a qualitative assessment of the content of the policies related to SOS whose foundations stem from governance theory. Collectively these two approaches provide a holistic overview of the evolution of oil and gas SOS in the EU 15 and the degree in which it has been influenced and shaped by policy devised by the EC. This study aims to contribute to the on-going energy dialogue on how to reduce EU's vulnerability to oil and gas disruptions, by identifying some of the underlying legislative reasons that have led to limited improvements in oil and gas SOS.

STRUCTURE OF THE PAPER

This paper is constituted by ten chapters whose content is briefly described below:

- **Chapter II** contains the theoretical framework which is divided in three different subsections: (i) Chapter 2.1 which relates to SOS (i) Chapter 2.2 which contains an overview of all the policies issued by the EC that relate to oil and gas SOS and (iii) Chapter 2.3 which briefly mentions the governance theory that exists to assess the effectiveness of a given policy.
- **Chapter III** details the methodology that was followed to conduct the quantitative analysis of oil and gas SOS (Chapter 3.1) and the effectiveness analysis of the oil and gas SOS policies (Chapter 3.2).
- **Chapter IV** contains the results of the indicator selection that were used to conduct the quantitative assessment of oil and gas SOS as well as a brief description of the data sources used.
- **Chapter V** has the results of the quantitative assessment of oil and gas SOS as well as the discussion of results per indicator
- **Chapter VI** consists of an assessment of the effectiveness of the policies issued by the EC that was carried out using a framework that stems from governance theory.
- **Chapter VII** includes a brief description of the limitations to which this study is subject to.
- **Chapter VIII** has the conclusions of this study
- **Chapter IX** contains the list of references that were used to carry out this study.
- **Chapter X** has all the appendixes which provide support material, namely: Appendix A- has an overview of all the indicators that were assessed, Appendix B- has the weighing of each indicator that helps justify their selection, Appendix C- Contains support graphs of the indicator results obtained for the EU 15, the line regression equations and R2 values, Appendix D – has the oil and gas TPES by EU 15 Member State from 1994 to 2016 and Appendix E –details how the individual Member State oil and gas SOS analysis was carried out.

II.- Theoretical Framework

2.1.- Security of Supply

2.1.1 Security of Supply Definition

To be able evaluate the performance of SOS and thus quantify it, a definition for it has to be given. Even though it is a widely used concept, there is no consensus when it comes to providing a definition as it appears to be dynamic and context dependant idea which interpretation differs widely. While some researchers focus only on the availability of energy and its price (Jamasb & Pollitt, 2008), others argue for a more integral definition that includes downstream benefits, such as societal and environmental effects (Pasqualetti & Sovacool, 2012; Vivoda, 2010). Furthermore, Ang. et al (Ang, Choong, & Ng, 2015), conducted a literature survey of over a hundred and four energy security studies which included journal, reports of national agencies, international organisations and associations and concluded that there are several key ideas across several definitions and identified seven major different elements or dimensions of SOS: (i) Energy availability (ii) Infrastructure (iii) Energy prices (iv) Societal effects (v) Environment (vi) Governance and (vii) Energy efficiency. They concluded that over the past few years the scope of SOS has expanded and now includes issues such as environmental concerns, governance and energy efficiency. This means that some of the dimensions were recently incorporated into the definition of SOS and thus weren't an issue that European Commission policy makers had in mind while implementing energy policies back in the 1990's. Additionally, this development has also implications on how SOS is quantified and thus requires the construction and evaluation of new indicators that properly assess the dimensions they are devised for. If the SOS of the EU's 15 members was to be assessed using this perspective, indicators to measure qualitative analysis of societal effects and governance would have to be created which is task that fell outside the scope of this study.

For the reasons mentioned above, the seven dimensions identified by Ang et al. (2005) were not a suitable definition for SOS to measure the Commissions energy policy since the 1990's. However, Cherp & Jewel (Cherp & Jewell, 2014) pointed out that even though the concept for SOS has widened over time, there are four elements that have be present in classical energy studies from earlier times (Deese, 1979; Yergin 1988): (i) Availability, which relates to the physical availability of the energy resource and (ii) Affordability which refers to the economic performance of the energy resource such as price level and volatility (iii) Acceptability linked to the environmental and societal concerns and (iv) Accessibility or geopolitical elements. These are the four elements of a classification scheme commonly referred to as the "4As" initially proposed by the Asia Pacific Energy Research Centre (APERC) who define SOS as the "ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy". Since the study's publication, several studies have been conducted using APERC's proposed framework. However, several contemporary scholars have argued that the concept of SOS has evolved since the publication of this study and it should be re-examined to include recent developments in the energy sphere (Chang, Leung, Wu, & Yuan, 2003; Chester, 2010; Von Hippel, Suzuki, Williams, Savage, & Hayes, 2011; Winzer, 2012). Regardless of the evolution of the concept, one thing remains certain: These four elements and definition have been considered by the European Commission when drafting and issuing energy policy as enshrined in Articles 2 and 6 of the TFEU (Foreign and Commonwealth Office, 2008). Since the purpose of this study was to assess the performance of the policies drafted by the EU, a SOS definition that is in line with the EU's energy policy cornerstones was deemed appropriate. Additionally, since the 4As framework was developed as a result of the proposed SOS definition of APERC, it's only natural to choose the same scope for the definition and for the framework for alignment purposes.

2.1.2 Measuring Energy Security

Over the recent years there has been a lot of attempts to devise quantitative methodologies to assess the level of SOS of a particular country or region. One of the most sought-after methodologies consists on an indicator-based assessment as it allows for the simultaneous evaluation of a wide range of issues that enables a comparison between the performance of an economy (or economies) over time (Ang et al., 2015). Nevertheless, to sufficiently cover all the aspects of energy security, several individual indicators were required and special attention should be given when selecting them (Kanchana & Unesaki, 2015). For this reason, some authors have devised frameworks and insights to aid in the selection of appropriate SOS indicators such as Kruyt et. al (Kruyt, van Vuuren, de Vries, & Groenenberg, 2009) who provide an overview of available indicators for the long-term SOS and classify them according to the previously reviewed 4As classification scheme. They argue that by doing so, they attempt to provide a useful tool to choose indicators based on the perspective of SOS they were designed for (Figure 1). One of the most important takeaways of their research, is that there is no one ideal indicator, as the notion of energy security is highly contect dependant and therefore multiple indicators should be applied to achieve a broader understanding.

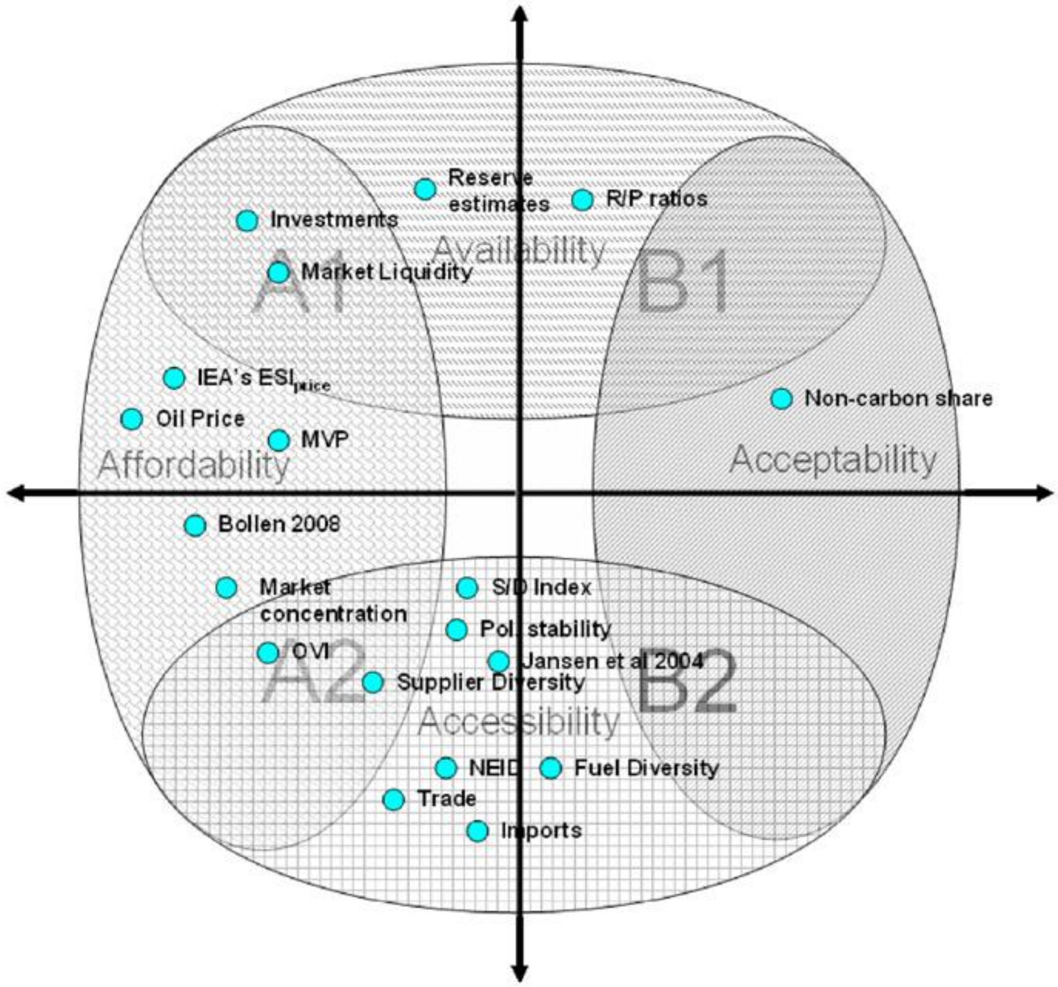

Figure 1.- Indicators considered in the study conducted by Kryut et. al (2009) and the elements of the energy security spectrum they focus on.

2.1.3 SOS Indicator Selection

Even though Kruyt et al. (2009) provide a useful tool that was used as a starting point for the identification of indicators as well as the perspective of SOS they are focused on, an appropriate indicator selection was required. The US Centre for Innovation and Impact (USAID) developed a guideline to adequately choose performance indicators as it requires careful thought, iterative refining, collaboration, and consensus building (USAID Center for Development Information and Evaluation, 1996). The suggested methodology consists on the following steps:

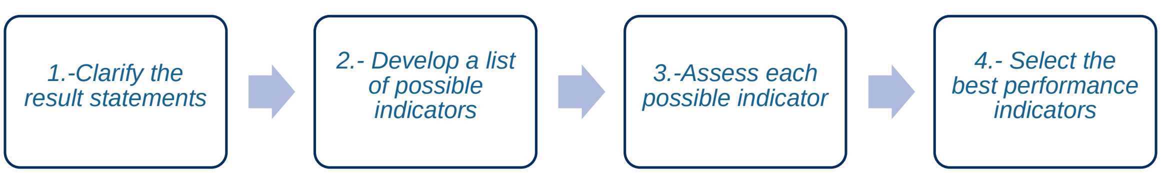

Figure 2.-Steps for the adequate selection of performance indicators as devised by the USAID.

Additionally, the USAID also includes seven criteria that should be considered when assessing and selecting performance indicators which consist on:

- *Direct:* The indicator should measure as closely as possible the result it is intended to measure. When a direct measure isn't possible (i.e. data unavailability) one or more proxy indicators might be appropriate.
- *Objective:* it shouldn't be ambiguous, there should be general consensus over how the results should be interpreted.
- *Adequate:* Collectively, a group of indicators should adequately measure the result in question. The amount of chosen indicators varies depending on: (i) The complexity of the result being measured (ii) The level of available resources and (iii) The amount of information needed to make confident decisions.
- *Quantitative, where possible:* The numerical precision associated to quantitative analysis allows for more consensus on how the results should be interpreted.
- *Disaggregated, where appropriate:* The disaggregation of information sometimes provides useful insights and trends that otherwise would be remain unnoticed.
- *Practical:* An indicator is practical if data can be obtained in a timely way and at a reasonable cost.
- *Reliable:* The data should be obtained from reliable sources.

2.2.- SOS Energy Policy

In general, there are two main sources of EU law: (i) Primary law: constituted by treaties which establish the legal framework of the EU and (ii) Secondary law: enacted by EU institutions in the exercise of powers conferred on them by the Primary Law. It is divided in legislative (e.g. regulations, directives and decisions) and non-legislative acts (delegated acts, implementing acts, recommendations and opinions). Additionally, there are other sources of EU law with lower hierarchy which can be recommendations and opinions or non-binding sources such as green papers, proposals, resolutions, communications, etc. (Borchardt, 2011).

When it comes to energy security, several legal instruments have been issued in the form of primary and secondary law. However, the literature research showed that there is no compilation of these laws available and tracing down all the SOS related regulation is a resource intensive task that requires significant knowledge of the legislative procedure of the EU. For this reason, this section provides an overview of all of the SOS related primary law and only the most important instruments of secondary law as identified by Lagnsdorf (2011) and Maltby (2013). In consideration of the discrepancy between the date of publication of the mentioned studies and the time scope of this work, primary and secondary law enacted between 2013 and 2016 was also included. The result of this compilation can be found in this chapter where each legal instrument is discussed. At the end of this chapter a table summarizing the main issues addressed in each law can be found.

2.2.1 Energy Charter Treaty - 1994

The end of the Cold War in the early 1990s brought an unprecedented opportunity for cooperation between the East and West to foster the development of the energy sector. Russia and many of the surrounding countries were rich in resources but lacked the economic capabilities to exploit them, while the West had an increasing interest in diversifying their energy sources. Upon this global landscape, the ECT was created with the main objective of creating a multilateral framework for energy cooperation and consequently building a legal foundation for global security of supply based on the principle of open and sustainable markets (Energy Charter Secretariat, 2004).

The treaty was signed in December 1994, however since it is a legally binding multilateral agreement that requires a transition period for the countries involved, it only came into force in April 1998. Since then it has been signed by fifty-two countries, including all of the EU 15 Member States who agreed on the following five broad areas: (i) Protection and promotion of foreign energy investments (ii) Free trade in materials, products and equipment related to energy subject to the guidelines set by the Word Trade Organization (WTO) (iii) Free energy transit through pipelines and grids (iv) Energy efficiency improvement to reduce the negative environmental impact of the energy production systems (v) Mechanisms for dispute resolution between investor and states. In addition to these provisions, the ECT has launched several programs that are aimed towards fostering dialogue and cooperation between signing countries such as the Development of Best-Practice Guidelines on Energy Market Restructuring or the Analysis of Natural Gas Markets in the Eurasian Area (Energy Charter Secretariat, 2004).

There are opposing views when it comes to assessing the outcomes of the ECT. While some scholars argue that this treaty has failed to address the main issues hindering the improvement of global energy security, other authors mention that it has proven effective. Selivanova (Selivanova, 2012) for example, argues that trade activities are conducted under the WTO guidelines which have been mostly designed to remove import barriers which in the energy sector are not as common as the export ones. Similarly, Kyomin (Klyomin, 2008) states that the ECT has failed to address its main political objective which originally was to lay down the fundamental rules of “joint” possessing and managing of the Russian gas[1]. Other authors argue that despite its shortcomings, the ECT has a unique role as the only energy specific multilateral agreement that covers all major aspects if international energy turnover (i.e. trade, transit, investment and energy efficiency) that collectively tackle the main issues related to ensuring security of supply (Peters, 2018).

2.2.2 EU Green Paper: Towards a European Strategy for the Security of Energy Supply - 2001

The dramatic rise in oil prices in the late 1990s revealed the EU’s structural weaknesses regarding energy supply, namely the EU’s growing import dependency. At the time, they estimated that if measures were not taken promptly, the EU’s gas import dependency in 2010 would be 40% and 66% or more by 2020 (Maltby, 2013). Moreover, increasing environmental concerns mostly driven by the Kyoto Protocol, made evident the need to diversify energy sources.

Consequently, the European Commission issued in 2001 the EU Green Paper – Towards a European Strategy for the Security of Energy Supply. The document is divided in three main parts: (i) Basic facts about energy in the European Union – Highlights the energy requirements with special emphasis on scarcity of conventional energy sources in the region (ii) A new reference framework for energy – Discusses the main issues of climate change and identifies the main obstacles that the energy market has to overcome and (iii) Securing the future: outline of energy strategy – Identifies the main risks associated to energy security and talks about the future prospects and developments in the energy field (European Commission, 2001).

[1] Russia until this day has not ratified the EEC even though they signed it. This has led to international disputes over the seizing of assets by the Russian government without any kind of indemnification for the companies involved. The most notable example is the ongoing dispute between Yukos and the Russian government.

Following its publication, the Commission invited members from the EU Parliament Commissions of Industry, External Trade, Research and Energy to participate in a public debate where main concerns were addressed. Six experts also participated in the hearing and exposed their recommendations for common energy policy in the EU. They concluded that the paper remained weak as it doesn't set quantitative objectives, provides poor information which can be extracted from the energy scenarios and most importantly doesn't advocate for the cooperation on energy with developing countries (Laponche B., Tillerson K., 2001). Moreover, the document is a Green Paper which means that it sets possible courses of actions in terms of policy but it's still at a formative state (House of Commons, 2010). This means that there it is not a legally binding document and therefore Member States were not forced to implement the provided recommendations.

2.2.3 EU Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy - 2006

There were several geopolitical and economic factors that heightened Europe's sense of SOS vulnerability and consequently triggered the issuance of the 2006 Green Paper. The stability of oil supply from the Persian Gulf was questioned when geopolitical tension rose in Iraq due to internal ethnic and sectarian conflicts. In addition, the dispute between Russia and Ukraine raised doubts regarding Russia's reliability as a gas supplier. The oil and gas supply was also threatened by increasing energy demand of India and China which led to an increment in resource competition. Together, these factors led to higher oil and gas prices which exerted pressure on European economies who saw the need to push for additional common energy policy (Bahgat, 2006).

On March 8, 2006 the European Commission issued the Green paper which establishes six different areas as priority: (i) Completing the internal European electricity and gas markets (ii) Encouraging solidarity among member states (iii) Establishing a more sustainable energy mix (iv) Supporting an integrated approach to tackling climate change (v) Encouraging a strategic energy technology plan (vi) Creating a coherent external energy policy. In order to achieve these objectives, it proposed the following measures: (i) Diversification of Europe's energy mix (ii) Creating the necessary framework to stimulate adequate investment to meet growing energy demand (iii) Better equipping the EU to cope with emergencies (iv) Improving the conditions for European companies seeking access to global resources and (v) Ensuring that citizens and businesses have access to energy (Pielbags A., 2006). This document provided the groundworks for the Energy Package presented by the EC on January 2007 which builds upon these strategies (European Commission, 2007).

2.2.4 Treaty of Lisbon -2007

Several authors agree that up until this point, by virtue of respecting the sovereignty of the Member States, energy was mostly seen as a national responsibility (da Graça Carvalho, 2012). The Lisbon Treaty tried to change that by increasing stakeholder's accountability through the issuance of energy policy under primary law instead of secondary legislation as has been the case in previous policy instruments (Ringel & Knodt, 2018).

The Treaty delivered for the first time a contractual basis for energy policy within the European treaties and pushed for solidarity among Member States to (i) Ensure the functioning of the energy market (ii) Ensure security of energy supply in the Union (iii) Promote energy efficiency and energy saving and the development of new and forms of energy and (iv) Promote the interconnection of energy networks (Foreign and Commonwealth Office, 2008). It still however, allows Member States to determine the conditions for exploiting their energy resources, their choice among different energy sources and the general structure of their energy supply (Knodt M., 2017).

At the time of issuance, several scholars argued that the Lisbon treaty is not a change on the direction of EU energy policy but rather a codification of the policy-process that preceded it (van Vooren B., 2012). While some scholars focused on researching the consequences of the Treaty on the governance bodies of the EU (Braun, 2011) others focused on addressing the possible obstacles that could emerge later on. Most of these obstacles relate to the single market mindset established within the origins of the EU which pushed for the development of a common market offering free movement of goods, service, people and capital (European Union, 2018). The main drawback of this perspective in the energy field is that some countries prefer to have a bilateral relationship with energy suppliers which in turn affect the EU's move to act as a single unit. Furthermore, long term supply agreements are usually signed between Member States and other countries which explicitly prohibit resale to another country. This practice thwarts the objective of article 101 of the TFEU which prohibits territorial restrictions in order to stimulate the creation and of a liberalised market (Arinaitwe, 2014).

Despite its shortcomings, a breakthrough provision though was included in Art. 122 which stipulates that the Council on a proposal from the Commission, may decide upon measures appropriate to the economic situation, in particular if severe difficulties arise in the supply of certain energy products, notable in the area of energy (Foreign and Commonwealth Office, 2008). Even though this provision confirms the EU's competence to adopt preventive measures to avoid security threats, solidarity among Member States still remained weak since it didn't impose legal obligations. It did however, provide a political backing for more far-reaching preventive measures in the future such as regulation No.994/2010/EU which was proposed after the Russia-Ukraine dispute on natural gas (Braun, 2011).

2.2.5 The EU Gas Directive- 2009

Following a second significant gas supply disruption in the EU, the EC issued the third energy package which is comprised by three regulations and two directives which collectively aim to strengthen the internal gas and electricity market in the EU. The Gas Directive is part of this package and through articles five and six, imposes an obligation on Member States to promote regional and bilateral solidarity and cooperation to safeguard gas SOS through interconnections, mutual assistance and coordination of contingency measures (Maltby, 2013). More importantly, through its provisions the Directive aims to establish common rules for the internal market of natural a gas. Among the changes envisioned, the most significant are: (i) the adoption of a regulated access tariff (ii) the obligation of every Member State to establish an independent regulator for the gas industry and (iii) the unbundling of the transportation of gas and trading services (Andersen & Sitter, 2009).

The Gas Directive has had hits and misses. Among its successes, the Directive helped remove the legal monopolies and partially opened he market to competition by allowing large users to choose their suppliers (Lowe, Pucinskaite, Webster, & Lindberg, 2007). However, some scholars have identified persistent problems in the internal gas market that could not be resolved by the Gas Directive, such as (i) market illiquidity (ii) insufficient unbundling and (iii) lack of structural clarity (Dutton & Court, 2015).

2.2.6 Regulation 994 – 2010

This regulation mandates the implementation of measures for gas SOS. It fosters a higher degree of preparedness in Member States by (i) acknowledging that gas SOS is a shared responsibility among actors in the EU (ii) Obliging Member States to appoint a national competent authority who is responsible to carry out the measures envisioned in the regulation and (iii) Carrying out a risk assessment and establishing a preventive action and emergency plans. However, it achieves little regarding solidarity amongst the Member States beyond what could already be done on a voluntary, bilateral basis (Braun, 2011).

2.2.7 European Energy Security Strategy - 2014

The disputes between Russia and Ukraine in early 2014 triggered the issuance of several policy instruments that brought SOS back to the top of EU's foreign policy agenda. The European Energy Security Strategy (EESS) is the most important one of these policy instruments and is based on eight key pillars which collectively aim to reduce the vulnerability to disruption arising from political developments in non-EU countries. These are: (i) Immediate actions aimed at increasing the EU's capacity to overcome a major disruption during the winter 2014-2015 (ii) Strengthening emergency/solidarity mechanisms including coordination of risk assessments and contingency plans; and protecting strategic infrastructure (iii) Moderating energy demand (iv) Building a well-functioning and fully integrated internal market (v) Increasing energy production in the European Union (vi) Further developing energy technologies (vii) Diversifying external supplies and related infrastructure and (viii) Improving coordination of national energy policies and speaking with one voice in external energy policy (European Commission, 2014).

At the time of issuance, Youngs (2014) provided an insightful analysis of the instrument with special emphasis on the geopolitical changes that the EESS aimed to introduce. Up to this point, one of the main struggles faced by the EU's policy makers was finding common ground for enacting external energy security policy as Member States pursued their national interest. Since late 2012, the EU has tried to rectify this shortcoming through regulation such as granting the EC powers to assess the compatibility of Member States bilateral energy agreements with EU rules. The idea is to stop governments from undercutting common EU aims when they sign energy contracts with suppliers. Another critical geopolitical change introduced by the EESS was the remarkably open strategy to push back on Russia's influence. The key actions that they propose for this effect are focused mostly on improving and deploying infrastructure to diversify the sources of natural gas such as investing in liquefied gas terminals or exploring the possibility of extending the southern gas corridor pipeline through the inclusion of Iraq, Iran and Turkemenistan. This strategy however, is incoherent with the regulation previously enacted by the EC to combat climate change as it reinforces current natural gas infrastructure and makes it increasingly difficult to meet the EU's long term goal to transition away from fossil fuels (Strambo, Nilsson, & Mansson, 2015).

Lastly, Table 1 summarizes the main issued addressed in the energy policy instruments revised in this chapter.

Table 1.-Main issues addressed in primary and secondary law enacted by the European Union during 1994-2016

Year	Policy/ Green Paper	PL/SL**	Main issues addressed
1994	ECT	PL	-Energy Investments -Energy Trade -Energy Flow -Energy Efficiency -Mechanisms for Dispute Resolution between Investors and State
2001	Green Paper	SL	-Energy Trade -Climate Change -Market Failures -Diversification of Energy Sources - Risks Associated to SOS
2006	Green Paper	SL	-Climate Change -Market failures (Electricity and gas markets) -Diversification of Energy Sources -Cooperation among Member States -Research and Development -Coherent External Energy Policy
2007	Lisbon Treaty	PL	-Market failures -Security of Energy Supply -Energy efficiency -Diversification of Energy Sources -Energy Flow -Cooperation among Member States
2009	Gas Directive	SL	-Common rules for the internal gas market - Cooperation among Member States -Market failures
2010	Regulation 994	SL	-SOS - Cooperation among Member States
2014	European Energy Security Strategy	SL	-Response mechanisms to supply disruptions -Cooperation among Member States -Energy efficiency -Market failures -Increase energy production in the EU -Research and Development -Diversification of external supplies -Protect and diversify infrastructure -Improve coordination of national energy policies -Coherent External Energy Policy

** PL = Primary law, SL= Secondary law.

2.3.- Energy policy effectiveness

Models for measuring the effectiveness of energy policy have traditionally been developed using mainly two approaches: (i) Process analysis: Incorporates information on anticipated technological change in the energy system and in the economy and (ii) Econometrics: Describes aggregate economic activity and provides for the analysis of policy impacts on the overall level of economic activity (Hoffman et al., 1977). Along this lines, the majority of recent studies have been conducted to evaluate the energy policy effectiveness of energy policy. Carley, for example, analysed the effectiveness of US energy stage programs with an empirical evaluation of linkage between state renewable energy policy implementation and the percentage of renewable energy electricity generation across states (Carley, 2009). The main drawback about these approaches is that the devised methodologies just focus on the final impacts (indicator results) of the policy and not on the whole implementation process. By applying an approach that addresses this issue we not only learn whether the policies are successful or not, but also why they succeeded or failed and how can they be improved (Harmelink, Nilsson, & Harmsen, 2008). For this reason, a different approach for the assessment of energy policy needs to be devised.

Accordingly, a framework developed in the 1960's from governance literature can be used as the groundwork for measuring policy effectiveness. The framework distinguishes between output and outcome effectiveness, as proposed by Easton (1965, taken from Barkmeyer, Preuss, & Lee, 2014), and provides subcategories which allow for policy analysis with more detail. This framework was originally designed to be used in political science and consists on an input-output analysis about the maintenance of the political system and its need to adapt to technological and environmental changes, as well as changing demands in order to survive. To accomplish this, the system receives inputs (supports and demands) and converts these inputs into binding decisions (outputs) (Easton, 1965). Easton also includes impact as an important aspect of effectiveness.

Since the publication of his paper several academics have use his input-output analysis approach to study diverse systems which have led to a wide array of interpretation of the concepts of output and outcome. Aware of this problem, de Kruijf & de Vries (2017) conducted a literature review where they provide an overview of the several variations in their meaning. The table below summarizes their findings:

Table 2.-The seven dimensions of output versus outcome (de Kruif & de Vries, 2017)

Output	Outcome
System dynamics: Decisions and policies delivered by the system	System dynamics: Changes in demands to, and support for (input), the system
Cause: All purposeful action seen as means to achieve goals	Effect: All intended and unintended consequences related to such output.
System oriented: All decisions and policies delivered by the system	Context oriented: All developments of context of the system either related or unrelated to the output.
Time frame: The immediate effects	Time frame: Intermediate and long term effects.
Descriptive: What is actually done	Normative: The evaluation of what is done
Nature: Intentions, words, the broad decision or policy definition	Nature: Actual changes in behaviour, actual implementation (micro-output)

Several authors have used these definitions to analyse the effectiveness of different forms of governance by establishing different suitable indicators. The present study builds upon this theory and selects a set of appropriate indicators to measure the effectiveness of SOS policy. The methodology used for this purpose, can be found on Chapter 3.2.

III.- Methodology

3.1 Quantitative assessment of the evolution of SOS in the EU15 from 1994 to 2016

The following section is divided in three different subsections that contain detailed information about each methodological step. These are:

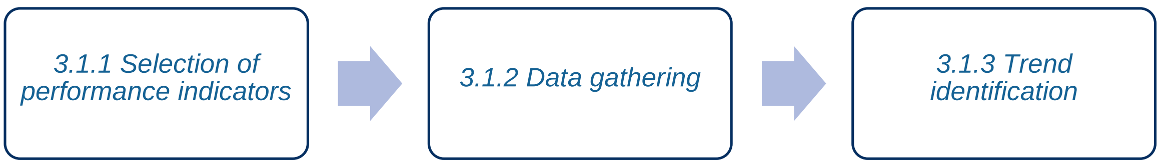

Figure 3.- Methodological steps for the quantitative assessment of the evolution of SOS in the EU15 from 1994-2016

3.1.1 Selection of performance indicators

In order to properly evaluate the performance of oil and gas SOS in the EU15, appropriate performance indicators need to be selected that are aligned with the chosen definition for SOS (4As Framework by APERC). For this purpose, the guidelines for performance indicator selection developed by USAID were used:

STEP 1: Clarify the results statements: The first step of their methodology consists on clarifying the results statements which means that a clear objective for the study needs to be established. This was achieved by appropriately formulating the research questions subject of this study.

STEP 2: Develop a list of possible indicators: The next step consisted on developing a list of possible indicators which were those identified by Kruyt et al. as they are aligned with the chosen definition for SOS, namely: (i) Reserves estimates (ii) R/P ratios (iii) Investments (iv) Market liquidity (v) IEA's ESI Price (vi) Oil price (vii) Mean Variance Portfolio (MVP) (viii) Non-carbon share (ix) Bollen's indicator (x) Market concentration (xi) Oil Vulnerability Index (OVI) (xii) Supplier diversity (xiii) Trade (xiv) Net energy import dependency (NEID) (xv) Imports (xvi) Political stability (xvii) Jansen's indicator (xviii) S/D index and (xix) Fuel diversity. A brief overview of this indicators is provided in Appendix A.

STEP 3: Assess each possible indicator: The next step consisted on an assessment of each possible indicator on the list based on USAID's seven basic criteria for judging and indicator's appropriateness and utility. For this purpose, USAID recommends creating a matrix to evaluate each indicator on a scale from 1-5 with the following criteria: 1- Very Poor, 2-Poor, 3-Fair, 4-Good, 5-Very Good. These ratings help to give an overall sense of the indicator's relative merit and help in the selection process.

To determine the rating for each indicator, a set of questions were prepared by using the following general construction:

How (USAID criteria *i*) does the (indicator *i*) assess the (SOS element) of oil and gas?

For example:

How directly does the Reserves estimates indicator assess the availability of oil and gas?
How disaggregated is the Oil Vulnerability Index assessment on the accessibility of oil and gas?
How disaggregated is the Oil Vulnerability Index assessment on the affordability of oil and gas?

It is important to mention that at least one indicator per SOS element was chosen in order to cover all aspects of SOS according to the chosen definition. In regards to the acceptability, only one indicator was identified for acceptability by Kruyt et al. Therefore, a review of the available literature was conducted to identify other possible indicators for this SOS elements. The analysis showed that acceptability is the least explored element of the 4A's and only one indicator has been proposed for it, which is also used by the European Commission to assess energy policy (Badea, 2010). Consequently, this indicator was used to assess the acceptability of oil and gas in the EU15.

3.1.2 Trend identification

Once the indicators results were obtained for every country and for every year, an arithmetic average for the EU15 Member States was calculated for every indicator. The resulting average of every indicator was plotted in a graph which also included a trend line (or regression analysis) and the value of R^2. The value of the slope served as a tool to assess whether the performance indicator had an increasing or decreasing trend and the value of R^2 served as a statistical method of how close the data was fitted to the trend line. This helped as an auxiliary tool to observe the overall trend in the analysis of the performance of the indicator of the EU15. It is important to mention that due to the variability in the indicator values of individual Member States, a case by case analysis was really difficult to conduct in certain situations. For this reason, the analysis centered around the trends observed for the EU15 (Appendix C) with a few exceptions where the individual results for Member States where considered to be of particular interest

3.2 Policy effectiveness assessment

The following section is divided in three different subsections that contain detailed information about each methodological step. These are:

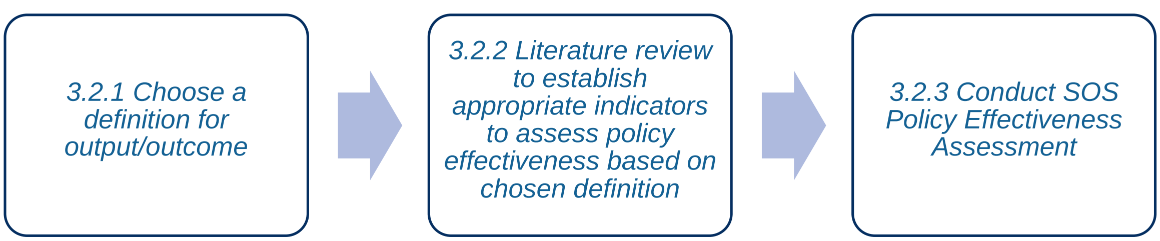

Figure 4.- Methodological steps for the effectiveness assessment of SOS energy policy in the EU15 from 1994-2016

3.2.1 Definition of Output/Outcome

A definition for output and outcome was chosen based on the appropriateness of the definition to the scope of this study. These were: (i) Output: System oriented perspective were the output are the decisions and policies delivered by the EC related to SOS during 1996 and 2016 and (ii) Outcome: Context oriented perspective were all the developments of context of the policies that can be either related or unrelated to the output.

Since Easton also includes impact as an important aspect of effectiveness, the results of the quantitative assessment of SOS described in Chapter 3.1 were used to provide a complete analysis of the effectiveness of these policies.

3.2.2 Chosen indicators for the assessment of policy effectiveness

The chosen indicators were chosen from a study by Kalfagianni & Pattberg (2013) who conducted a study on the effectiveness of transnational governance taking into account internal and external attributes by using a set of indicators. These were:

A) Output: As a description of the main SOS policies issued by the EC has already been provided, the analysis centered around the stringency of these policies. It is important to study this aspect of the policies because it refers to the extent to which the policies require actors to implement them. To evaluate the stringency Kalfagianni & Pattberg (2013) propose the following indicators:

- Policy's level of detail: a policy is considered stringent when it develops at least three indicators specifying each of the overreaching principles and criteria.
- Quantifiable targets: The policy includes quantifiable targets.
- Ambition: The policy goes beyond existing regulation.
- Performance: The policy includes targets that measure actual performance
- Management: The policy requires the development of management plans.

In the holistic evaluation of stringency, the following scaling was used: (i) High stringency: If all the indicators are satisfied (ii) Medium stringency: If four indicators are satisfied. (iii) Low stringency: If two or less indicators are satisfied.

A) Outcome: The chosen indicators to measure the outcome of the policies were:

(i) Policy uptake: Refers to the adoption of the policies by the EU15 Member States

(ii) Level of policy compliance: The extent to which the Member States actually comply with the standard.

The indicators that were left out from Kalfagianni & Pattberg's study were: (i) The quality of the audit which refers to the stringency of the instruments used by the organization to ensure that the target group conforms to the behavioral and performance standards and (ii) Access to decision-making venues and procedures which enquires into the type of actors included in the organizations' decision-making venues and procedures. These were left out of the indicator selection due to the unavailability of the required data. Moreover, understanding the process and assessing the quality of an audit by the EC, was outside the scope of this study.

3.2.2 SOS Policy Effectiveness Assessment

A literature review was conducted to perform assessment of SOS policy effectiveness. This review consisted on analysing the content of the policies to evaluate their stringency level. The degree of policy uptake as well as policy compliance indicators were also assessed through a literature review.

IV.- Security of supply evolution in the EU during 1994-2016

4.1 SOS Indicator Selection

Table 4 shows the results obtained for the assessment of each indicator using the methodology described by USAID. A detailed explanation with the reasoning behind each assigned rating can be found in Appendix B.

Table 4: Overview of the obtained results for the assessment of the performance indicators as recommended by USAID.

Indicator	SOS Element[1]	Direct	Objective	Adequate	Quantitative	Disaggregated	Practical	Reliable	Total
Reserves estimates	Availability	3	5	2	5	3	5	3	26
R/P ratios	Availability	3	5	2	5	3	5	3	26
Investments	Availability/Affordability	3	3	3	5	2	1	2	19
Market liquidity	Availability	5	3	5	5	3	5	4	30
	Affordability	2	2	2	5	3	1	3	18
IEA's ESI Price	Affordability	3	3	2	5	1	3	4	21
Oil & gas price[3]	Affordability	-	-	-	-	-	-	-	-
Mean Variance Portfolio	Affordability	2	2	2	5	2	1	2	16
Non Carbon Share	Acceptability	3	3	3	5	5	5	4	28
Bollen's Indicator [4]	Affordability	-	-	-	-	-	-	-	-
Market concentration	Affordability	3	4	3	5	3	3	4	25
	Accessibility[2]	-	-	-	-	-	-	-	-

Oil vulnerability index	Affordability	5	5	4	5	1	1	4	25
Supplier diversity	Accessibility/Affordability	3	3	3	5	3	5	4	27
Trade[3]	Accessibility	4	5	4	5	5	3	5	31
Net energy import dependency	Accessibility	4	4	2	5	2	1	4	22
Imports[3]	Accessibility	2	3	2	5	5	5	1	23
Political stability[3]	Accessibility	-	-	-	-	-	-	-	-
Jansen et al. indicator [5]	Accessibility	-	-	-	-	-	-	-	-
S/D [6]	Accessibility	-	-	-	-	-	-	-	-
Fuel diversity [7]	Accessibility	-	-	-	-	-	-	-	-

The following notes apply to Table 4:

1. According to Kruyt et. al (2009) Several indicators can evaluate more than one element of SOS (e.g. the Oil Vulnerability Index can be used to measure Accessibility and Affordability). Therefore, the suitability of these indicators was assessed for more than one element of SOS.

2. Since the formula to calculate the OVI with the methodology described by Gupta (Gupta, 2008) was deemed inappropriate it is not necessary to evaluate the suitability of this indicator in the two dimensions of SOS. The formula that was used for this purpose only evaluates one element of SOS (affordability).

3. These indicators provide a simplistic approach for studying a complex phenomenon as SOS and thus are frequently used as input parameters in more complex indicators. However, some of them due to their disaggregation help understand certain trends in more complex indicators. For this reason, some of these more simplistic indicators were used to analyze and discuss the trends observed in aggregated indicators.

4. This indicator requires the development of a MERGE model (Model for evaluating regional and global effects of GHG reduction policies). Since setting up a MERGE model is outside the scope of this study as building it is very resource intensive, this indicator will not be considered.

5. This indicator overlaps significantly with the other indicators listed in the table. Additionally, obtaining the required information for some of the indexes is a difficult task as there were no data sources available for the following input parameters: Depletion indexes, Extent of political stability in every country in a 0 to 1 scale which is arbitrarily determined and correction factors to be used in the equations.

6. For the calculation of this index a computer model has to be set up that represents the energy demand and supply structure of an EU Member State. Due to the complexity of the model and the lack of required information for the model's configuration, this indicator was left outside of the scope of this study.

7. Fuel diversity is frequently used in long term SOS studies. However, since the purpose of this study was to analyze specifically the SOS of oil and natural gas, a higher fuel diversity will impact negatively the subject study. Moreover, the share of non-carbon fuels measures the same phenomenon this indicator was devised for.

Based on the results above and the availability of the required data, the following indicators were chosen: (i) Availability: Market Liquidity for Oil and Gas (ii) Affordability: Oil Vulnerability Index, IEA's ESI Price and Market Concentration (iii) Acceptability: Non Carbon Share (iv) Accessibility: Supplier Diversity. A brief description of the selected indicators, the used equations and used data bases are provided in the following section. Additionally, other indicators mention by Kruyt et al (2009) were used to explain the tendencies observed in the results (e.g. trade, oil price, etc.)

4.2 Data sources used per indicator

Once the indicators were chosen, a literature review was performed to determine the quality and availability of the data required for every indicator. The data bases that were used to calculate the selected indicators are described below:

a) <u>British Petroleum Statistical Review of World Energy</u>: This yearly publication issued by British Petroleum contains detailed analysis and information on the key trends observed in the worldwide energy landscape. It provides useful information with a country breakdown of key indexes such as primary energy consumption by fuel type, oil and gas proved reserves and production figures, reserves/production ratios, crude prices, refining capacities, international trade, etc...(British Petroleum, 2018)
b) <u>The World Bank:</u> This international renowned financial institution has a robust data base available to the public with time series data by country on a variety of topics such as gross domestic product (GDP), political risk, government expenditures, sustainability indicators, etc. (World Bank, 2018)
c) <u>Eurostat- Energy Balance:</u> The energy balance is a matrix which contains a compilation on data of all energy products entering, exiting and being used in a country. It was created Eurostat which is the statistic office of the European Commission with the objective of showing the relationship between supply, inputs to the energy transformation process and their outputs as well as the actual energy consumption by different sectors of end-use. (Eurostat, 2018).
d) <u>Market Access Data Base issued by the European Commission:</u> The EU has created a database that gives historical information related to trade such as duties and taxes,

procedures and documents, statistics on trade flows between EU and non EU countries. In order to search the trade flows by product a specific identifier code is needed (i.e. 27111100 – Natural gas in gaseous state, 27112100 Natural gas in liquefied state, 27090010- Petroleum oils from natural gas condensates and 27090090- Petroleum oils and oils obtained from bituminous minerals, crude. (European Commission, 2018).

e) Comext: This data base contains detailed statistics on international trade. The data base is historical and recent data of countries within and outside the EU. Its compiled version is used by Eurostat (Comext, 2018).

The next chapter contains, alongside the results, the data sources use to calculate each of the variables embedded in every indicator.

V.-Analysis of results and discussion

5.1.-SOS Evolution

This section contains the results obtained for every indicator. First, the graphical results for each indicator are shown and accompanied by an analysis. At the end of this section a table summarizing the results can be found, as well as the equations for the line regression data and R^2 value. Chapter 5.2 provides an overview of the results as well as an analysis by Member State.

It is important to mention that the results obtained for some of the indicators show a high degree of variability and thus, reading and interpreting them may be a difficult task. Therefore, it is advised to analyse mainly the results obtained for the EU15. Appendix C contains the indicator graphs only for the EU15 as well as the equations for the line regression and R^2 value. Additionally, Table 5 aids with the interpretation of the graphical results obtained as it shows the impact on oil and gas SOS caused by either an increase or decrease on each indicator. This table and subsequent analysis of results were elaborated based on an analysis of how the indicator impacts oil and gas SOS since these fuels were the scope of the present study. However, a decrease or increase on a particular indicator might have different implications for the SOS in the energy matrix as a whole (e.g Increased SOZCF is beneficial for the energy matrix as a whole but not to oil and gas since it means that these sources have become less acceptable energy sources).

Table 5.- Impact of indicator's tendency on SOS

SOS Element	Indicator	Observed tendency	
		Indicator increase	Indicator decrease
Availability	Market Liquidity	SOS Increase	SOS Decrease
Affordability	Oil Vulnerability Index	SOS Decrease	SOS Increase
	IEA's ESI Price	SOS Decrease	SOS Increase
Acceptability	SOZCF	SOS Decrease	SOS Increase
Accessibility	Supplier Diversity	SOS Increase	SOS Decrease

Availability

5.1.1.- Market Liquidity

A) Indicator overview:

Since the EU 15 is an oil and gas net importing region due to low oil and gas proven reserves in the region (Figure 5 and 6) most of the indicators identified by Kruyt et al. (2009) to measure the availability of oil and gas were not suitable (e.g R/P ratios, Reserves estimates). Therefore, the Market Liquidity indicator was used to determine the availability of oil and gas in the EU 15.

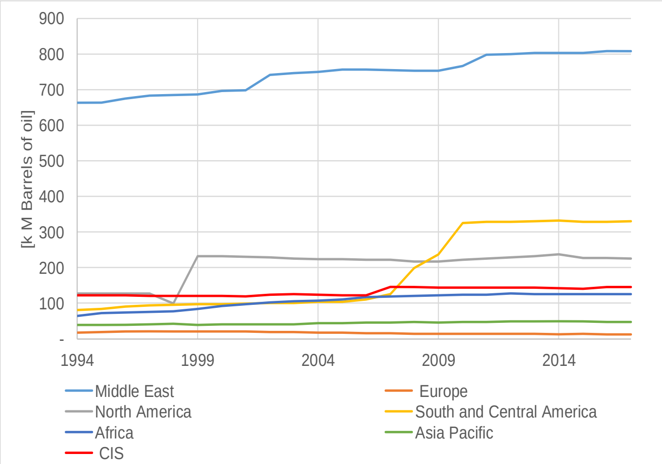

Figure 5: Proven reserves of oil from 1994 to 2017. (British Petroleum, 2018)

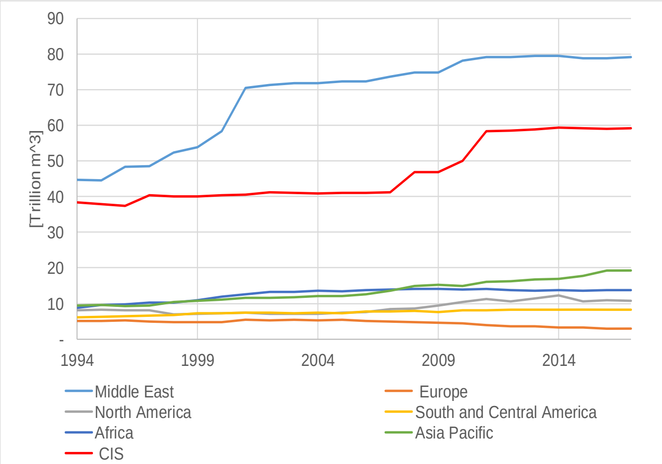

Figure 6: Proven reserves of gas from 1994 to 2017. (British Petroleum, 2018)

This indicator measures the capacity of markets to cope with fluctuations in supply and demand (i.e market's ability to purchase or sell an asset without affecting the price). For this purpose different actors have developed their own methodology to measure market liquidity such as the IEA who developed a methodology to measure market liquidity (Lefèvre, 2007). The theory behind this indicator dictates that a market is considered liquid when a balance between supply and demand exists. Under these ideal circumstances, the market is said to be in equilibrium and thus resilient to price fluctuations which is the reason why Kruyt et. al also catalogued this indicator as a measure of affordability (Gabrielsen, Marzo, & Zagagalia, 2011). In ideal circumstances, supply and demand would be in perfect equilibrium and therefore the ideal value of the indicator calculated through Equation 1 would be 2.72. Lower values entail lower market liquidities. The equations (Equation 1 and 2) that were used to calculate this indicator, as well as the data sources used and made assumptions are described below.

Equation 1:

$$ML_i = exp^{\left(\frac{Co_i}{FM_i}\right)}$$

Where:

ML_i = Market liquidity of fuel *i*, in country *i*, in year *i*

Co_i= Consumption of fuel *i*, in country *i*, in year *i [ktoe/year]*
FM_i= Total Availability of fuel *i* in EU 15 supplying countries, in year *i [ktoe/year]*

For calculating this indicator, the following assumptions were made: (i) The total fuel available in the market was considered to be the total yearly production of oil or gas in the countries that supply oil or gas to the EU 15 Member States. The oil and gas production in the EU 15 Member States was excluded. (ii) Annual changes of stock adjustments are taken into account (iii) For calculating the total consumption of fuel, () the following equation 2 was used:

Equation 2:

$$Co_i = P_i + I_i - E_i$$

Where:

Co_i= Consumption of fuel *i*, in country *i*, in year *i [ktoe/year]*
P_i= Production of fuel *i*, in country *i*, in year *i [ktoe/year]*
I_i= Imports of fuel *i*, in country *i*, in year *i [ktoe/year]*
E_i= Exports of fuel *i*, in country *i*, in year *i [ktoe/year]*

Table 5: Data sources used for the calculation of the oil and gas market liquidity indicator.

Indicator	Required information per EU15 country from 1994 to 2016	Symbol	Database**				
			a	b	c	d	e
Market liquidity	Country's consumption of fuel *i*				X		
	Total availability of fuel *i* available on the market		X				
	Production of fuel *i*, in country *i*, in year *i*				X		
	Imports of fuel *i*, in country *i*, in year *i*				X		
	Exports of fuel *i*, in country *i*, in year *i*				X		

** a) British Petroleum Statistical Review of World Energy b) The World Bank c) Eurostat-Energy Balance d) Market Access Data Base e) Comext.

b) Indicator results and discussion

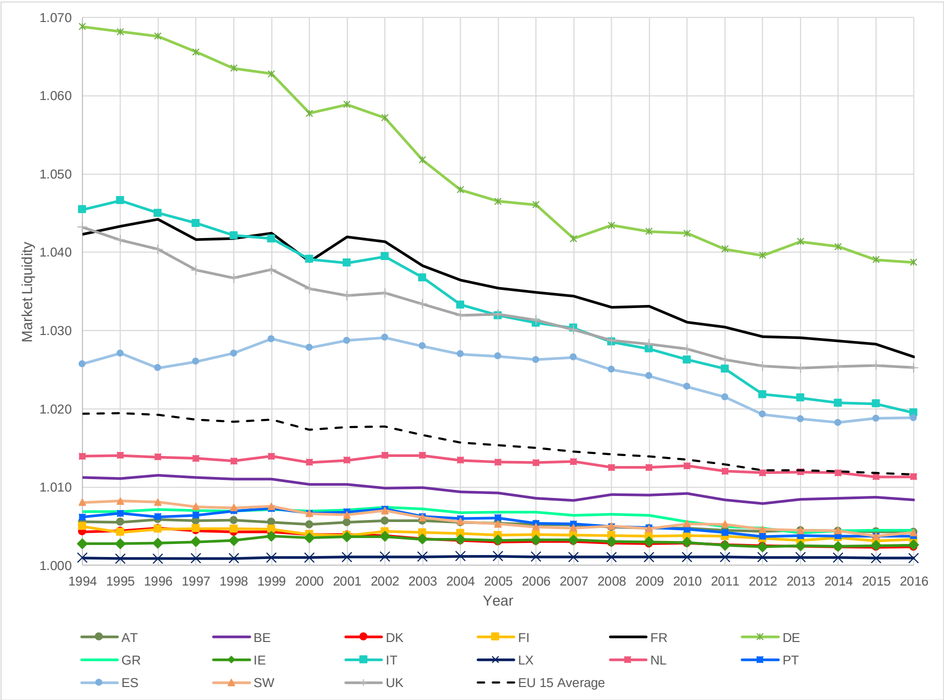

Figure 7a.- Oil Market Liquidity for the EU15 from 1994-2016. (Eurostat, 2018) (British Petroleum, 2018)

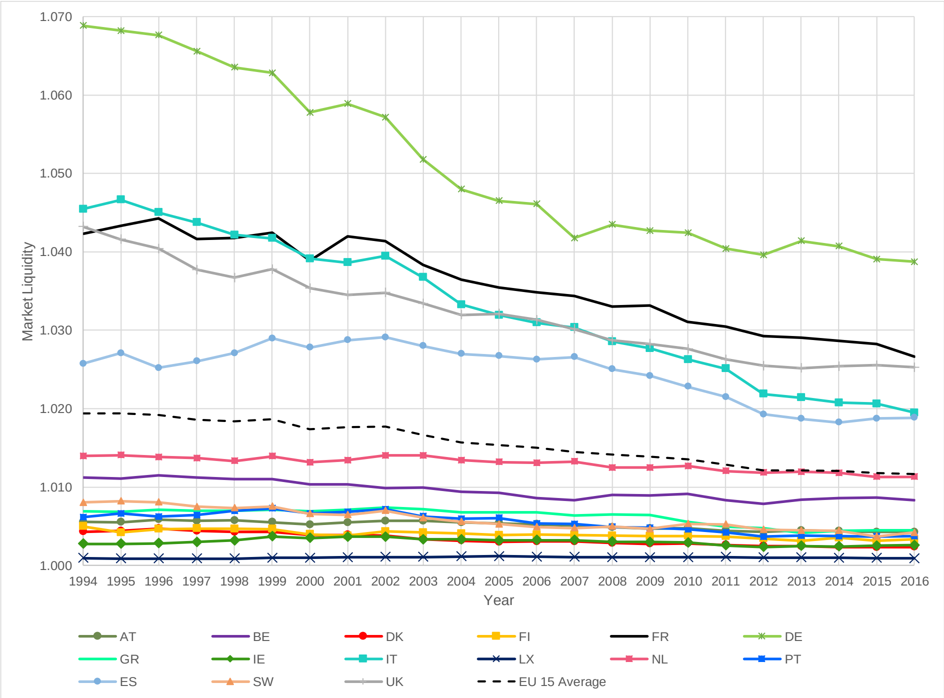

Figure 7b.- Oil Market Liquidity for the EU15 from 1994-2016. Axis adjusted for better data visibility. (Eurostat, 2018) (British Petroleum, 2018)

The results show that the liquidity of the EU15 oil market has decreased overtime (Figures 7a & 7b). This can be explained by looking at the supply and demand figures for oil during this period. On the supply side (Figure 8), there has been a steady increase on the worldwide production of oil from 1994 to 2016. Figure 8, also shows an increase in the total production of oil in the countries that supplied oil to the EU15 during 1994 to 2016, namely: Russia, Norway, Saudi Arabia, Libya, Iran, Nigeria, Algeria, Iraq, Kazakhstan, Azerbaijan, Syria, Mexico, Angola, Kuwait, Venezuela, Egypt, Brazil, Colombia, United Arab Emirates and Turkmenistan. Despite an increase in oil production there has been a reduction of oil demand in the EU15 since 2006 (Figure 9). The combined effect of an increased supply and a decreased demand has led to an overall decrease of the Market Liquidity of the EU15 Member States.

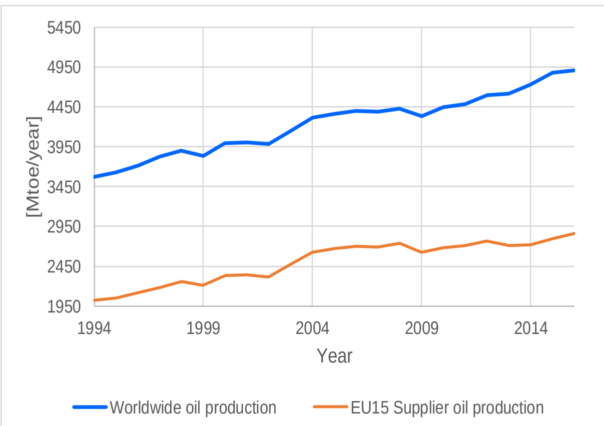

Figure 8.- Production of oil in the world and in the EU15 supplying countries from 1994-2016 (British Petroleum, 2018).

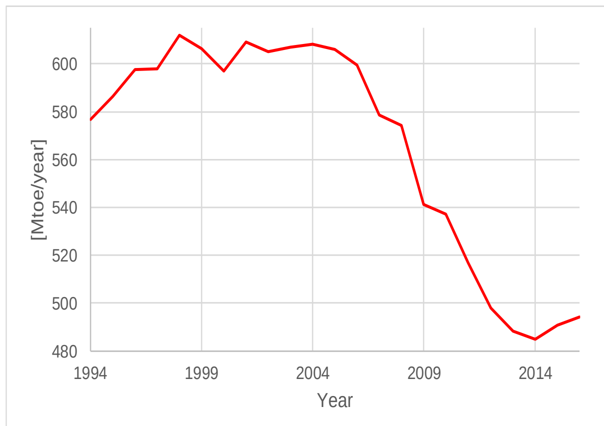

Figure 9.- EU15 Oil Consumption from 1994-2016 (British Petroleum, 2018).

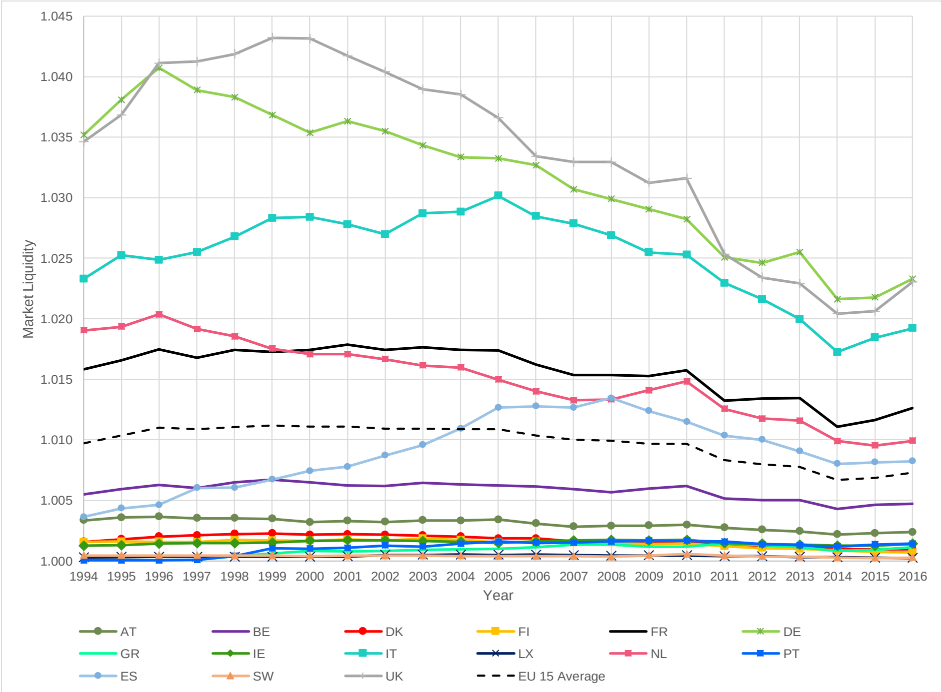

Figure 10a.- Gas Market Liquidity for the EU15 from 1994 to 2016. An overall decrease on the gas Market Liquidity can be observed which entails a decrease on oil SOS. (Eurostat, 2018) (British Petroleum, 2018)

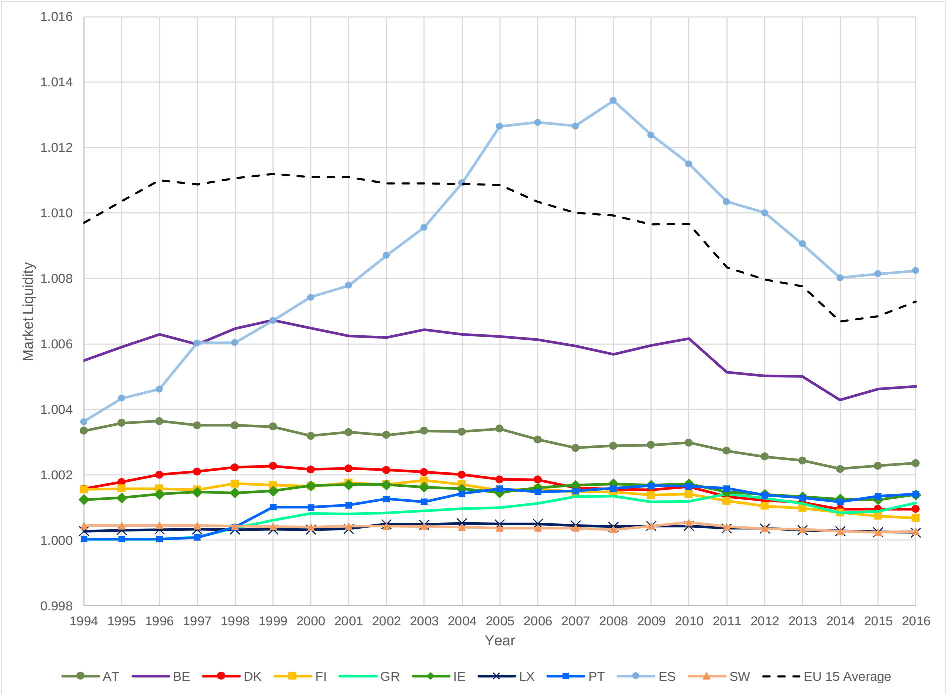

Figure 10b.- Gas Market Liquidity for the EU15 from 1994 to 2016. Axis adjusted for better data visibility. (Eurostat, 2018) (British Petroleum, 2018)

The results for the gas Market Liquidity for the EU15 also declined slightly over time (Figures 10a & 10b). Similarly, to the oil market results, the declining tendency in the Market Liquidity for the gas market can be explained by looking at the gas supply and demand. While the production of gas worldwide has been increasing (Figure 11), the demand for this fuel decreased after peaking in 2010 (Figure 12). Additionally, the results also show a sharp decline in 2014 due to a 14% decrease in gas consumption in 2014 (335 Mtoe in 2013 to 295 Mtoe toe in 2014). This finding is also consistent with the gas market analysis conducted by the European Commission who attribute this gas consumption decline to weather conditions, the slow recovery of the economic activity and the poor competitiveness of gas in the power sector (Market Observatory for Energy, 2014).

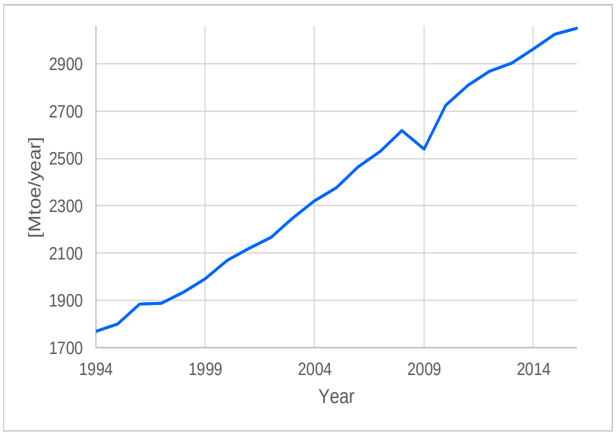

Figure 11.- World Production of gas from 1994-2016. (British Petroleum, 2018)

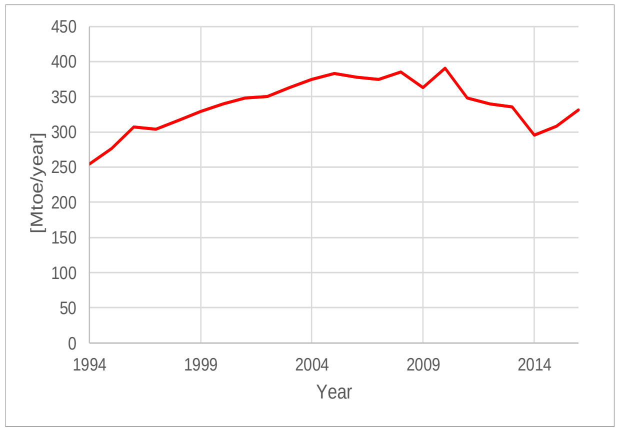

Figure 12.- EU15 Gas Consumption from 1994-2016. (British Petroleum, 2018)

In order for a market to be resilient to these price changes, States have to increase their Market Liquidity by addressing oil and gas market failures. The results obtained show that the policies issued by the EC to address oil and gas market failures to increase market liquidity, have proven ineffective.

The interpretation of the results of this indicator should be taken with caution due to the following explanation: According to this indicator, a decrease in market liquidity has a negative impact on oil and gas SOS because it means that there was either a surplus of fuel in the market or a decrease on their demand, which will offset the market equilibrium and drive a price change. While it is true that an overall reduction on the demand or an increase in the supply of oil (or gas) is beneficial for overall SOS, it might not be as beneficial for oil and gas SOS specifically. If there is a surplus of oil or gas in the market and the consumption levels stay the same, the price of oil and gas is likely to decrease. Likewise, a decrease on the demand will also trigger a price decrease.

Evidently, a price decrease is a favourable outcome since it increases the affordability of these energy sources, however, if the price drops significantly a lot of oil and gas infrastructure might be no longer financially viable as its profitability relies on a certain level for the price of these energy sources. If this infrastructure gets shut down, the physical availability of the oil and gas is at risk (Aoun & Cornot-Gandolphe, 2015). Additionally, if the price of oil and gas increases significantly, Member States will be more motivated to diversify their energy portfolio by including other cheaper sources. This will eventually reduce the amount of future investments that would increase the availability and reliability of oil and gas infrastructure and thus reducing oil and gas SOS. The outcome has far reaching consequences on the economy of a country since energy prices are intertwined to macroeconomic indicators, such as economic growth (GDP) and inflation (Ju, Su, Zhou, Wu, & Liu, 2016).

c) Limitations of the indicator

There are three main drawbacks of this indicator which limited the analysis of results:

1) The data unavailability related to gas, led to an unrealistic assumption: The total gas available in the market was considered to be the worldwide total yearly production of gas. It is unrealistic to assume that all the gas that is produced worldwide is available and accessible to the EU15 market. A data correction was attempted however no data base was found that contains the gas production profiles per supplier country from 1994 to 2016 with enough level of disaggregation. For example, Algeria, on average supplied 36% of the natural gas that is consumed in the EU15 from countries outside the EU 15. However, its yearly gas production figures are reported under “Others”.

2) The ML indicator is an over simplification of the energy system: While it is true that high levels of market liquidity provide more price stability against changes of supply and demand, the energy system and its impact on the economy are too complicated to be only assessed by the ML indicator devised by the IEA. Therefore, the conclusions and analysis that can be drawn based on these results are limited.

3) Kruyt et al. (2009) catalogued this indicator as SOS elements of availability and affordability. However, based on the level of analysis that the results allowed, the ML indicator is more suitable as an indicator of affordability since it relates to the ability of the market to cope with supply and demand fluctuations that affect the price.

A more suitable indicator for assessing oil and gas availability would take into account more variables that directly impact the physical deliveries of oil and gas to the EU15, such as (i) the utilization rate of the installed infrastructure to receive the physical deliveries of oil and gas or (ii) the evolution of the installed capacity through time (e.g. pipelines, LNG terminals, etc..). Aware of this downside, some scholars have developed more adequate indicators to measure the availability of oil and gas in a certain region in a specific year (Afgan, Carvalho, Pilavachi, & Martins, 2007; Le Coq & Paltseva, 2009). However, the use of these indicators in this present work is not applicable since the data required is not available for the time period analyzed.

d) Comparison to other SOS studies

The literature review conducted, showed that there are no long term studies of the evolution of market liquidity of oil and gas in the EU15. Moreover, while several sources mention the indicator devised by the IEA to measure ML (Axon, Darton, & Winzer, 2013; Islam, Hasanuzzaman, Rahim, Nahar, & Hosenuzzaman, 2014; Martchamadol & Kumar, 2012), there were no studies found that have used this indicator . Therefore, for comparison purposes, the ML of the oil and gas markets from the U.S.A were also calculated using the same methodology (Figure 13 and 14).

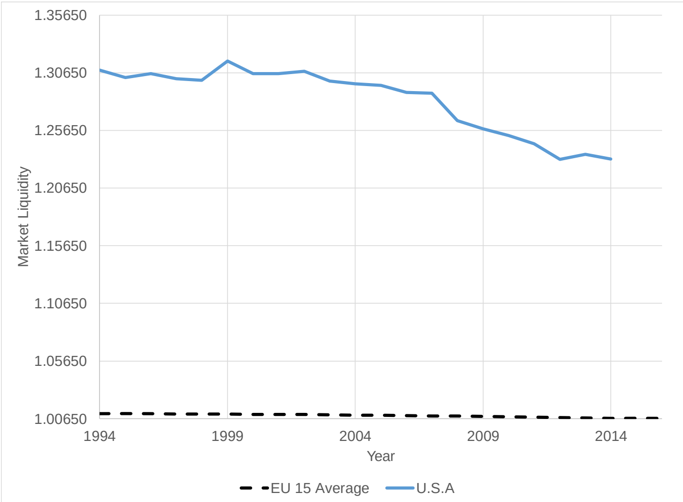

Figure 13.- Oil Market Liquidity of the EU15 and the U.S.A 1994-2016. (British Petroleum, 2018)

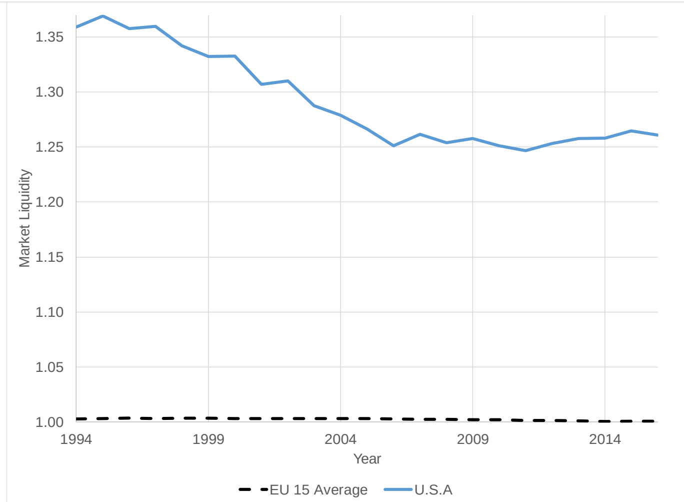

Figure 14.- Gas Market Liquidity of the EU15 and the U.S.A 1994-2016. (British Petroleum, 2018)

The graphs show that the ML of both regions and both fuels have decreased overtime, however these decreasing tendency has been more pronounced in the U.S.A than in the EU 15. An analysis of the input data indicates that the U.S has been decreasing their consumption of oil since 2005 causing a decline in the ML. The ML of the U.S.A gas market hasn't varied considerably since 2005. This can be explained by looking at the increase of gas consumption in the U.S.A which remained in the five hundred range until 2006 when it started increasing (Figure 15). This increased consumption didn't significantly increase the ML of the gas market because the production of gas around the world has been growing at faster rate.

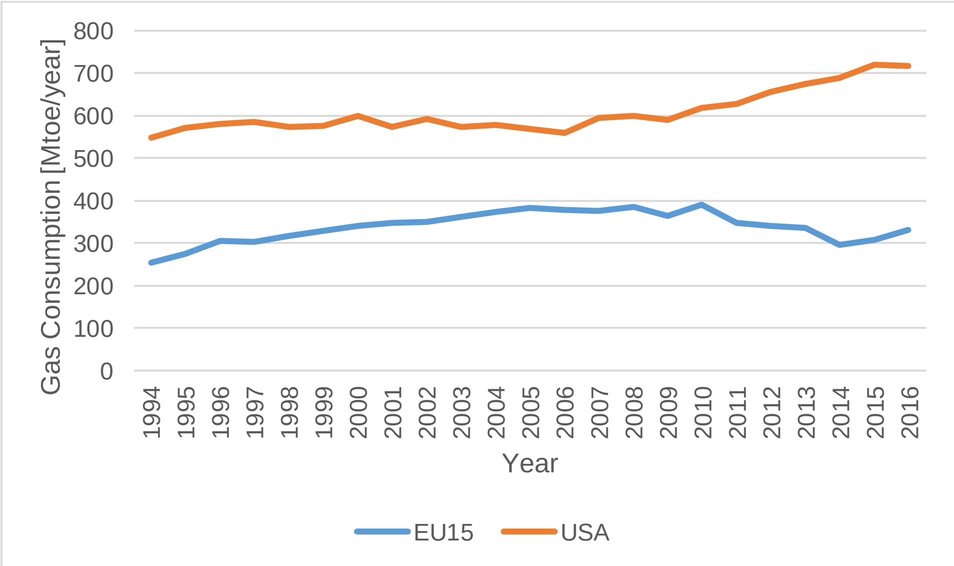

Figure 15: EU15 and USA gas consumption from 1994 to 2016. (British Petroleum, 2018)

Affordability

5.1.2.-Oil Vulnerability Index

A) Indicator overview:

The Energy Sector Management Assistance Program (2005) created an indicator to calculate an economy's exposure and thus vulnerability to oil disruptions which is calculated by Equation 3.

Equation 3:

$$V = \frac{NIV\$}{GDPC\$} = (P\$) * \left(\frac{NI}{OC}\right) * \left(\frac{OC}{EC}\right) * \left(\frac{EC}{GDPRL}\right) * \left(\frac{GDPRL}{GDPCL}\right) * \left(\frac{GDPLC}{GDPC\$}\right)$$

Where:
$V =$ Oil vulnerability index
$NIV\$$ = Net import value in dollars [USD]
$GDPC\$$ = Value of GDP in current U.S dollars [USD]
$P\$$ = Price of oil in current U.S dollars [USD]
NI = Volume of net oil and oil product imports in barrels per year [boe/year]
OC = Volume of consumption of oil products in barrels per year [boe/year]
EC = Total primary energy consumption [Y BTU/ year]
$GDPRL$ = Value of GDP in constant local currency [USD]
$GDPCL$ = Value of GDP in current local currency [USD]

The rationale behind this indicator can be deducted by analyzing the formula used to calculate this indicator, which suggests that as a Member State allocates a bigger proportion of their GDP to pay for their oil imports, the lower their oil SOS becomes. Under ideal circumstances, Member States should not have to allocate any of their GDP for acquiring oil in the international markets (meaning that the ideal value of the indicator would be 0%) because that could mean two things: (i) Either, a Member State has sufficient indigenous production of oil to satisfy their demand or (ii) The EU 15 market dynamics and production profiles are strong enough to allow individual Member States to satisfy their oil demand with the oil available within the EU 15.

The following considerations were made: (i) Due to simplicity and data availability, the left side of the equation was used. (ii) The GDP data used corresponds to the GDP at purchaser's prices calculated by the World Bank (iii) The net import value data was adjusted to remove the intra EU 15 trade operations.

Table 6: *Data sources used for the calculation of the oil vulnerability index*

Indicator	Required information per EU15 country from 1994 to 2016	Symbol	Database**				
			a	b	c	d	e
Oil vulnerability index	Net import value in dollars of oil						X
	Value of GDP in current U.S dollars			X			

** a) British Petroleum Statistical Review of World Energy b) The World Bank c) Eurostat-Energy Balance d) Market Access Data Base e) Comext.

b) Indicator results & discussion

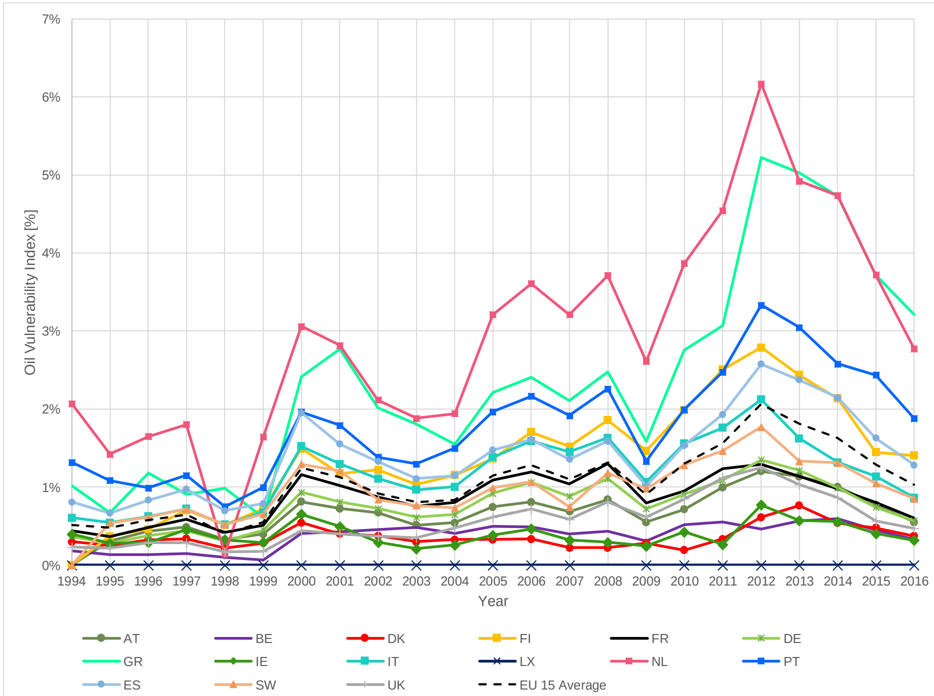

Figure 16a.- Oil Vulnerability Index for the EU15 from 1994 to 2016. An overall increase of the OVI can be observed which entails a decrease on oil SOS. (Comext, 2018) (The World Bank, 2018)

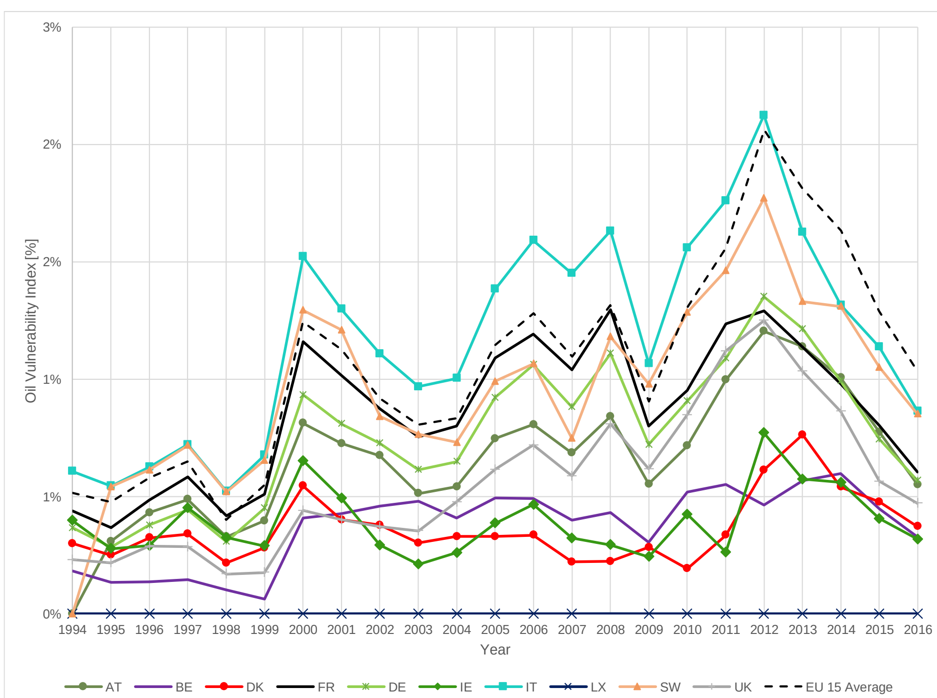

Figure 16b.- Oil Vulnerability Index for the EU15 from 1994 to 2016. Axis adjusted for better data visibility. (Comext, 2018) (The World Bank, 2018)

The results show that the OVI of the EU15 during the analysed period has increased overtime, reducing overall the SOS of oil (Figure 16a & 16b). This means that the countries have become increasingly dependent on foreign imports of oil and that they allocate a bigger proportion of their GDP to obtain them. Figure 16b also shows how in 2012 the OVI of the EU15 reached a peak value and has been steadily declining ever since. Evidently, the import value of crude is affected not only by the amount of oil demanded in the region but also by other variables such as the price of oil, economic recession, etc... Despite the reduced demand of oil in the region (Figure 9), the prices of oil have had a substantial impact on the net value of imports of oil. Figure 17, shows the close correlation that exists between the net import value of oil (left axis) and the price of oil (right axis). Additionally, a comparison between Figure 16a and Figure 17, also shows that all Member States seem to be equally affected by the price oil showing that the national policy they've drafted has not had a significant impact on the resilience of their vulnerability to oil.

The results also demonstrate that the EU Member States exhibit major differences relative to their dependence of oil. The most vulnerable countries are the Netherlands, Greece and Portugal who displayed an overall growth in the value of their oil imports from 1994 to 2012 as well and a GDP below the average of the EU15 Member States (Figure 18). These Member States (i.e. Greece, the Netherlands and Portugal) have high refining capacities which rely on the imports of oil from countries outside the EU 15 Member States.

On the other hand, the Member States that displayed the lowest OVI are Luxemburg, Denmark and Ireland. Denmark historically has been oil producing country who delivered between 2006 and 2016 more than 90% of their total oil exports to EU 15 Member States namely, Sweden, United Kingdom, Netherlands, Germany, Finland and France (Eurostat, 2018). Ireland and Luxemburg rely heavily on the oil imports from Norway and U.K therefore their OVI is relatively low since the data was adjusted to remove the trade transactions among the EU15 Member States.

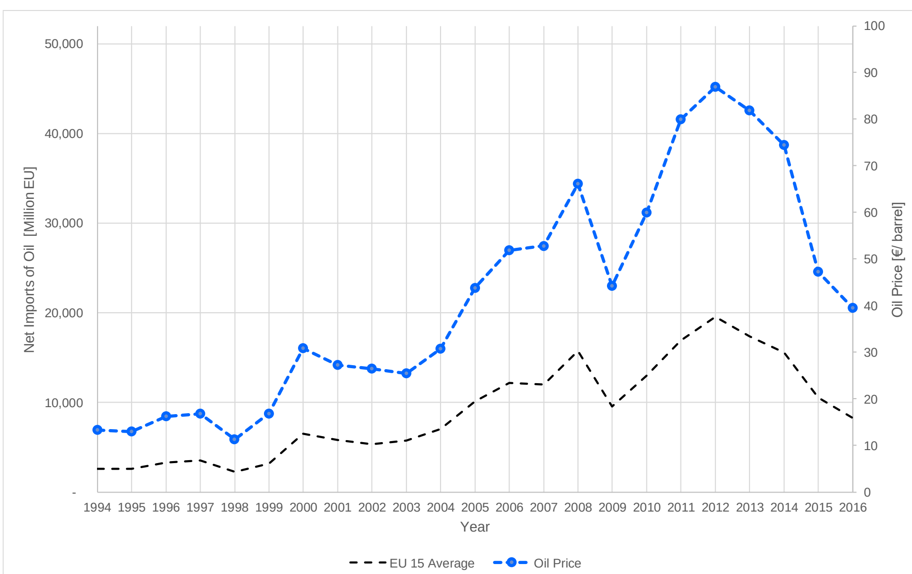

Figure 17.- Value of the Net Imports of Oil in the EU15 (left axis) and Brent Oil Price evolution (right axis) from 1994 to 2016. (Comext, 2018).

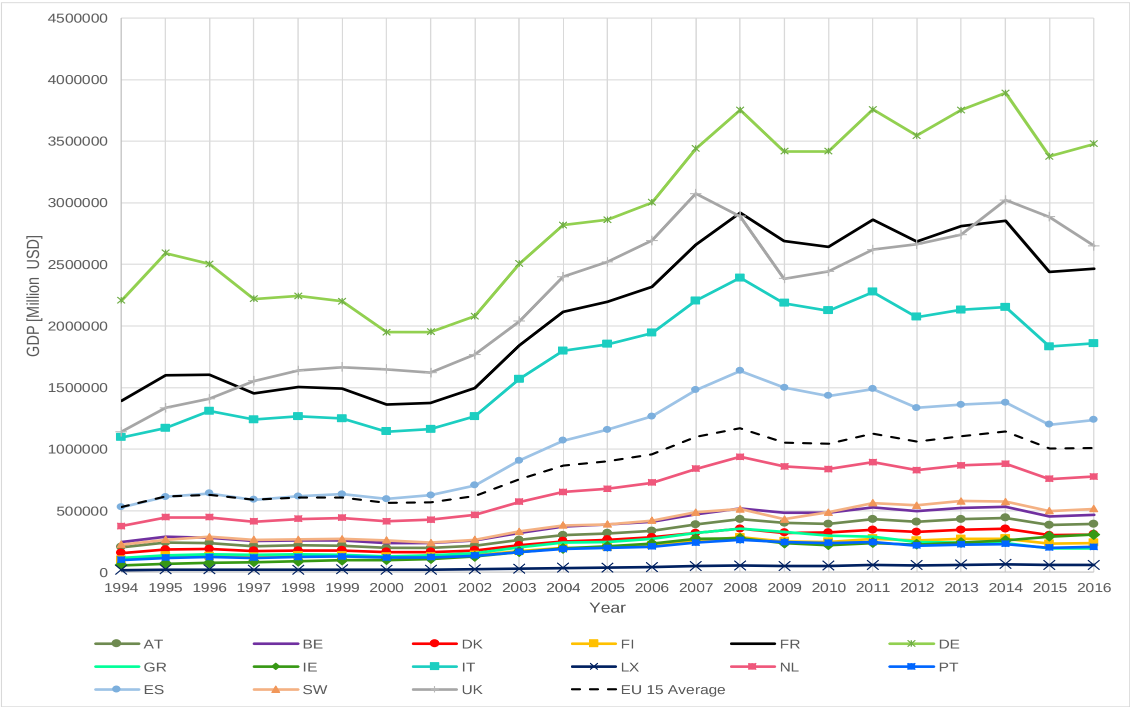

Figure 18: GDP of the EU15 from 1994 to 2016. (World Bank, 2018).

c) Limitations of the indicator

The chosen indicator was created to calculate an economy's exposure and thus vulnerability to oil disruptions, however as Gupta (2008) points out, there are several parameters that affect an economy's vulnerability to oil disruptions, such as: (1) the ratio of value of oil imports to GDP (2) oil consumption per unit of GDP (3) GDP per capita (4) oil share in total energy supply (5) ratio of domestic reserves to oil consumption (6) exposure to geopolitical oil supply concentration and (7) market liquidity. Therefore, the OVI indicator is a far too simplistic approach to assess the vulnerability of an economy to oil disruptions.

An attempt was made to use the formula proposed by Gupta (2009) to assess oil vulnerability, however this indicator is based on a statistical method called principal component analysis which transforms a number of correlated variables into a smaller number of uncorrelated variables called principle components. Furthermore, it requires a principal component analysis to express the results in a manageable scale from 0 to 1. Since this method requires a highly statistical and numerical analysis that is resource intensive, it was considered to be outside the scope of this analysis.

e) Comparison with other SOS studies

A similar study measured the OVI of the EU with the use of more complex indicators and found similar results. Roupas et al. (2009) developed an index to measure the oil vulnerability of the EU27 from 1995 to 2007 and observed an OVI increase during this period for all countries. This index is a combination of some of the indicators chosen for this present paper, as it uses the geopolitical risk, the market liquidity, the net energy import dependency and the diversification of primary energy demand. The study also forecasted the evolution of OVI up to 2030 and concluded that oil vulnerability in the EU 27 is expected to increase due to (i) Higher energy prices due to competition for oil sources and (ii) Decrease of Europe's oil indigenous production (Roupas, Flamos, & Psarras, 2009).

5.1.3.-IEA's ESI Price

a) Indicator overview

The IEA devised an indicator of the price component of energy security which measures the market concentration in each international fossil fuel market (ESCM). For countries in particular, it weights the relative importance of ECSM based on the exposer of the country to each fuel (IEA, 2007). It also accounts for the political risk rating which refers to the risk faced by several actors (e.g investors, governments, corporations) that political decisions or certain events, could affect the profitability of a certain project. The rationale behind this indicator (Equation 4) lies on the following premise: the more a country is exposed to high concentration markets, the lower energy security.

Equation 4:

$$ESI_{price} = \sum_{f}\left[\left(\sum_{i} r_i\, S_i^2\right)\frac{C_f}{TPES}\right]$$

Where:
ESI_{price} = ESI price of country *i* in year *I [1]*
r_i = political risk rating of country *i* in year i
S_{if} = Share of supplier *i* in total fuel supplied in country *i* in year *i* [%]
$C_f/TPES$ = Share of fuel *f* in total primary energy consumption [%]

For calculating this indicator, the following assumptions were made: (i) The data was adjusted to remove all the intra EU15 trade operations (ii) The data for the political risk rating for the following years was not available: 1994, 1995, 1997,1999 and 2001. In this case, the value for the political risk rating of the following year was used, as no significant variations on year to year basis were observed (iii) The PRS group issues political risk ratings for the following categories: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law and control of corruption. For the purpose of this study, an arithmetic average of these categories was used since it is the common practice and all these issues impact the overall political stability of a country (iv) There was no political risk rating data for Benin, Azerbaijan, Turkmenistan, Kazakhstan and Georgia. Since the geopolitical risk rating is determined using the criteria previously mentioned (i.e. voice and accountability, political stability, etc..) it was difficult to determine similarities between countries whose data was missing and countries who had the required data (e.g. Which country had similar geopolitical characteristics to Benin from 1994 to 2016). Moreover, a really small percentage (less than 0.1%) of the EU15's imports came from these countries and thus, were not taken into account.

Table 7: Data requirements and data sources used to calculate the IEA's ESI Price.

Indicator	Required information per EU15 country from 1994 to 2016	Symbol	Database*				
			a	b	c	d	e
IEA's ESI Price	Political risk rating			X			
	Share of supplier country in oil and gas market					X	
	Share of fuel *f* in total primary energy consumption.				X		

** a) British Petroleum Statistical Review of World Energy b) The World Bank c) Eurostat-Energy Balance d) Market Access Data Base e) Comext.

b) Indicator results and discussions

This indicator deals with price risks stemming from supply market concentration which is assessed by a Herfindhal-Hirschman index. Additionally, the political stability is also included by giving extra weight to political unstable countries. The supply concentration measure for each fuel market is weighted according to the fuel's share in primary energy supply to assess a country's vulnerability to these concentration risks (Sovacool K., 2010). Accordingly, a higher ESI Price implies a lower level of SOS since it means that either: (i) A large percentage of the total primary energy consumption comes from either gas or oil ii) That their supplier diversification is low and/or (iii) The geopolitical risk of these countries is high. Consequently, a lower level of ESI Price implies that a country has energy source diversification and supplier diversification and despite their dependence on foreign oil and gas supply they fulfil their demand with supply from geopolitical stable countries. The results of this assessment are shown in Figures 19a & 19b:

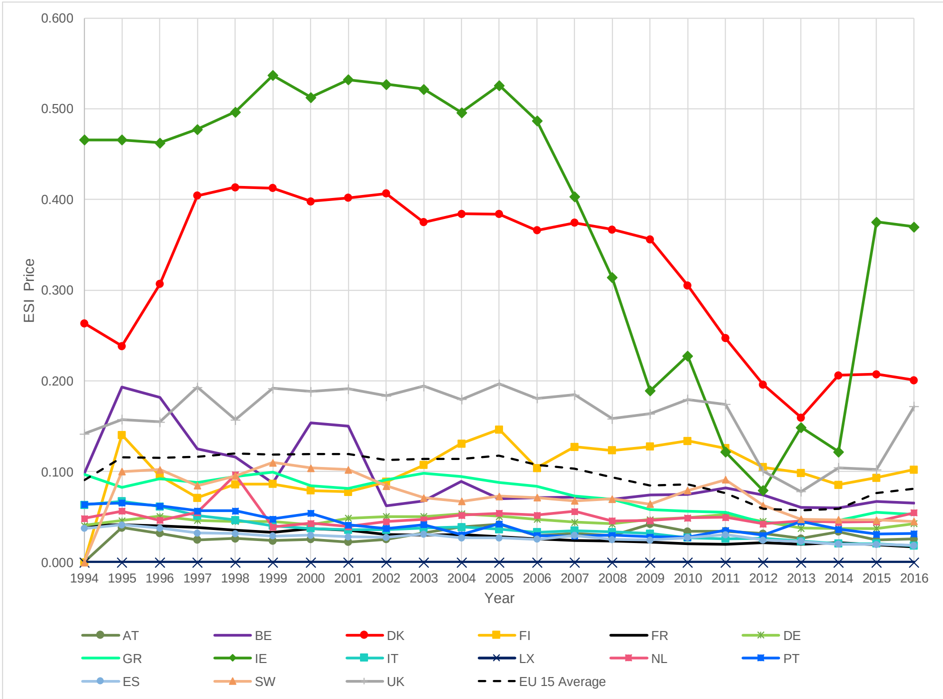

Figure 19a.- Oil ESI Price for the EU15 from 1994 to 2016. An overall decrease of the ESI Price can be observed which entails an increase on oil SOS. (World Bank, 2018) (European Commission, 2018) (Eurostat, 2018)

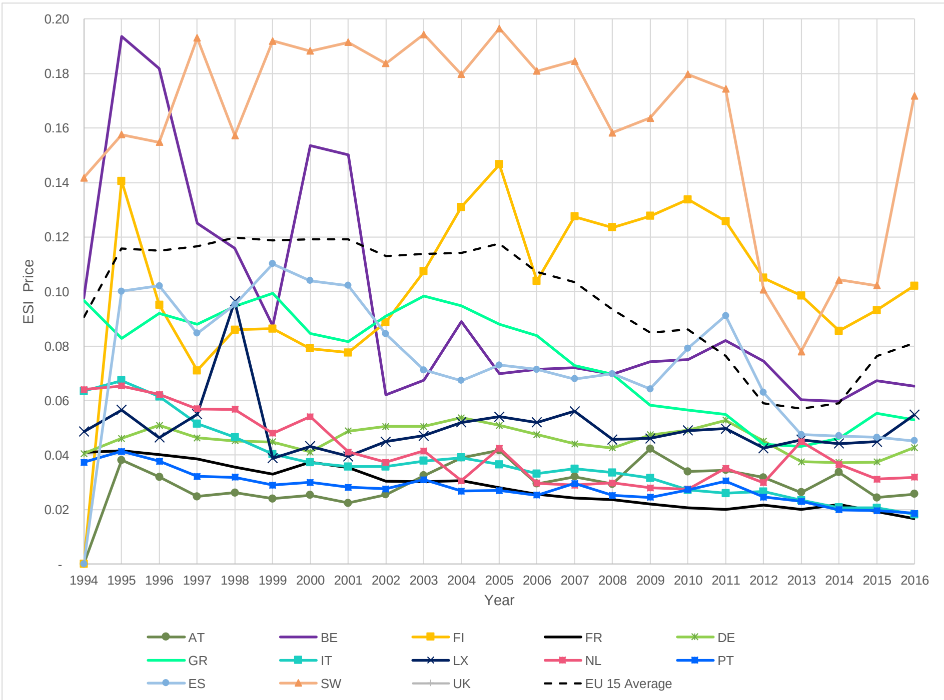

Figure 19b.- Oil ESI Price for the EU15 from 1994 to 2016. Axis adjusted for better data visibility. (World Bank, 2018) (European Commission, 2018) (Eurostat, 2018)

The results for the oil ESI Price show an overall decrease from 1994 to 2016 which according to this indicator, implies a higher level of SOS. The main driver for this development was the reduction on the consumption of oil of the EU 15 (Figure 9) since 2006. The share per oil supplier and its associated political risk, which are the other variables involved in the ESI Price calculation, didn't have a significant impact on the indicator results. The reason for this is due to the fact that the EU15 Member States have relied on the oil imports of Norway and Russia (Figure 20) whose geopolitical stability remained relatively steady. Other importing countries during these period were: Albania, Algeria, Angola, Azerbaijan, Benin, Brazil, Cameroon, Colombia, Czech Republic, Egypt, Estonia, Georgia, Indonesia, Iran, Kazakhstan, Korea, Kuwait, Libya, Mexico, Nigeria, Pakistan, Romania, Slovakia, Syria, Tunisia, Turkmenistan, United Arab Emirates, Venezuela, Saudi Arabia and Yemen. The EU15 oil import share per country is shown in Figure 21. In this graph, it can be appreciated that Russia has been slowly positioning itself as the main source of oil imports from the EU15 at the expense of Norway's decreasing import share and other minor market players. Iraq has also managed to position itself as a relevant oil supplier to the region, after a significant set-back from 2003 to 2014 where they didn't play a significant supplying role in the region due to the outbreak of the war led by the U.S coalition. The war was characterized by attacks on the oilfields with affected not only the production equipment but also caused damaged to the reservoirs which will have long lasting consequences (Oil and Energy Trends, 2006). A similar phenomenon is also observed in Libya, whose supplier share has declined since the civil war started in 2014. These two particular events highlight the importance of relying on the imports of geopolitical stable countries such as Norway or Saudi Arabia (Figure 20).

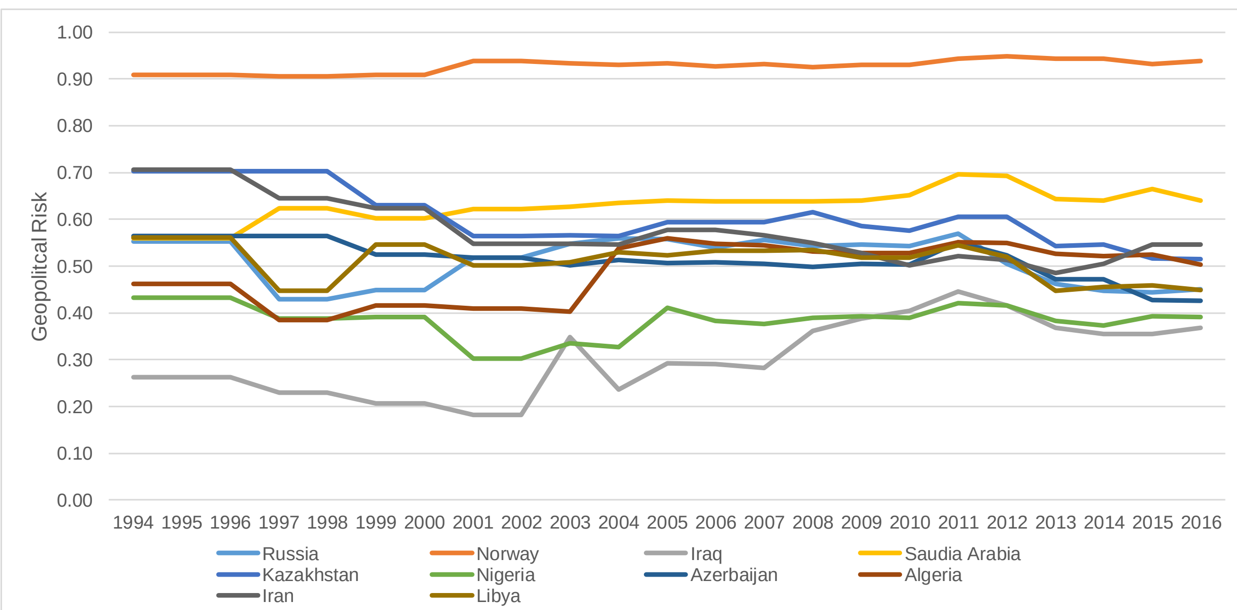

Figure 20: Geopolitical risk evolution of the main EU15 oil suppliers. (World Bank, 2018)

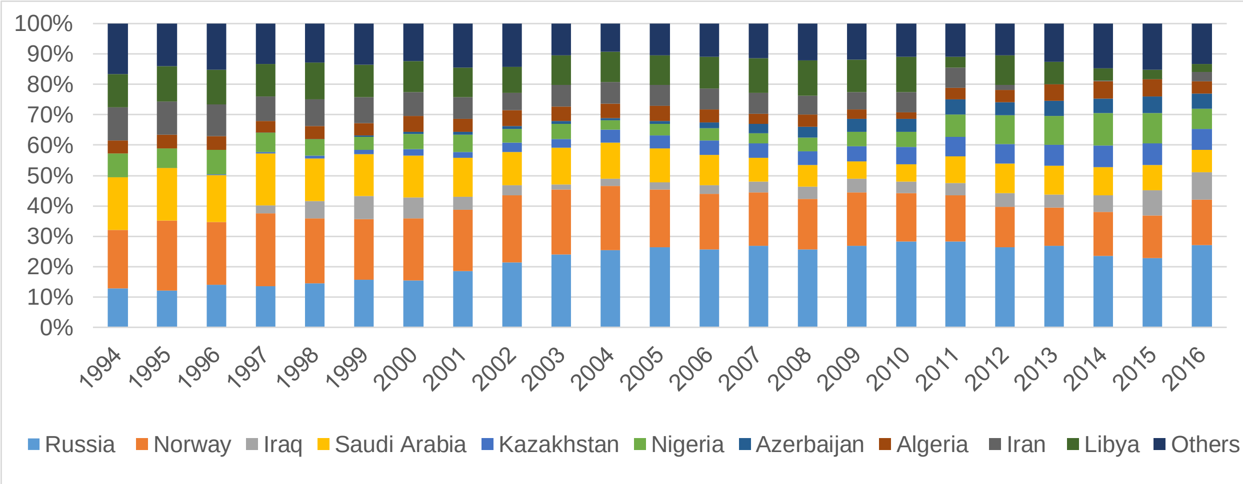

Figure 21: Share of EU15 oil imports per importing country. Trade movements amongst EU15 countries were omitted. (Comext, 2018)

From an individual Member State perspective, two countries display a significant decrease on their oil ESI Price and thus oil SOS: Ireland and Denmark. Ireland's ESI Price decrease from 2005 to 2012 which is explained by the increased supplier diversification they experienced during this period. Ireland has historically depended heavily on the oil imports from U.K and Norway, however since 2005 they started importing from other countries, namely: Libya, Algeria, Germany, Denmark and Nigeria (Figure 22). On the other hand, Denmark's oil ESI Price decrease has been similarly driven by an increased supplier diversification. Despite being an oil producing region, Denmark has historically depended greatly on the imports from the U.K. In fact, from 2003 to 2006, the U.K was the only country from which Denmark imported oil from. After 2006, Denmark started importing oil from U.K, Russia and Nigeria which increased its supplier diversity and thus, decreased the oil ESI Price.

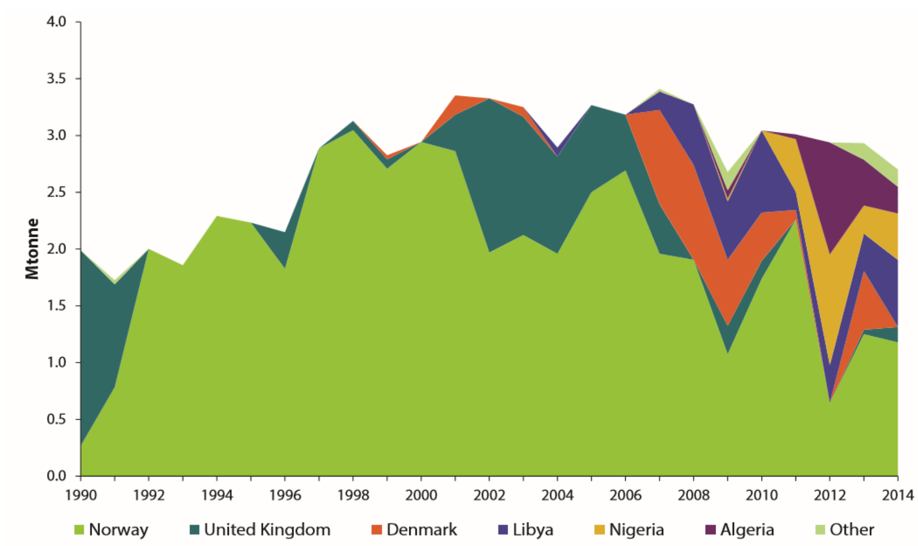

Figure 22: Ireland's oil product imports from 1990-2014. (Sustainable Energy Authority of Ireland, 2016)

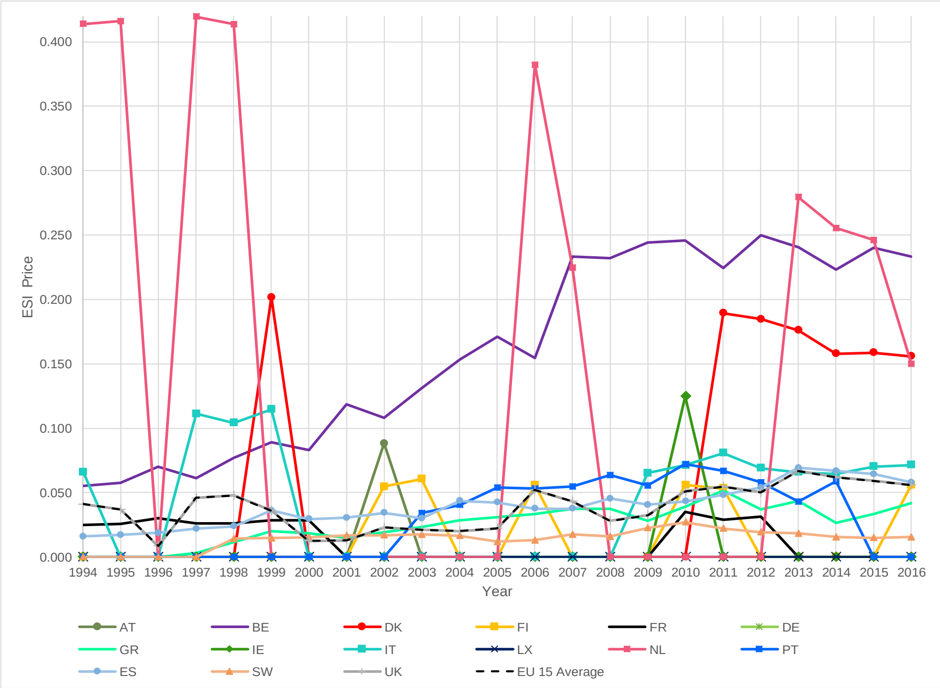

Figure 23a.- Natural gas ESI Price for the EU15 from 1994 to 2016. An overall increase of the ESI Price can be observed which entails a decrease on gas SOS. (World Bank, 2018) (European Commission, 2018) (Eurostat, 2018)

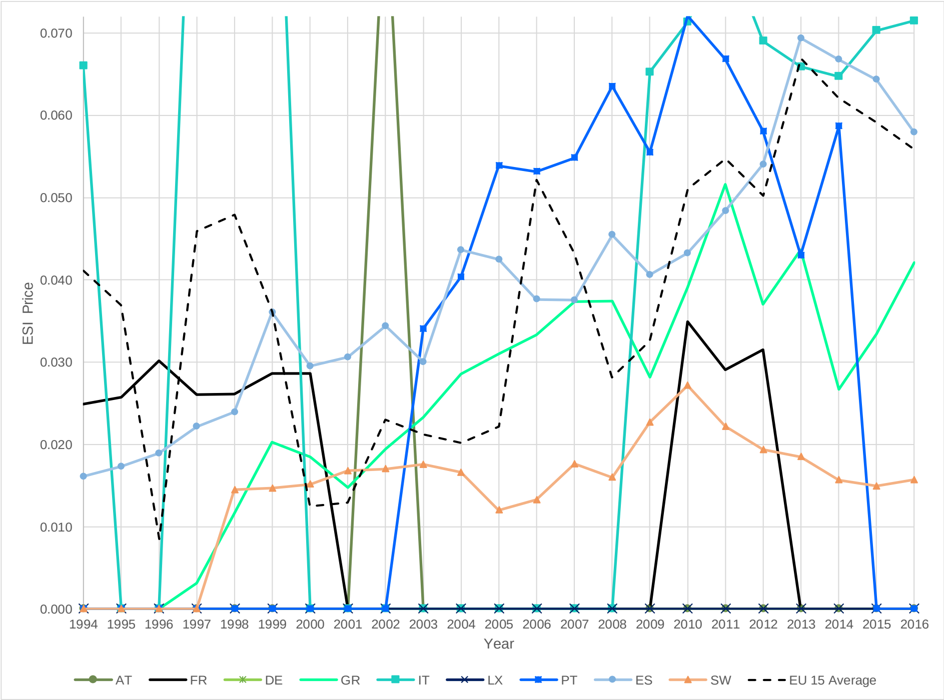

Figure 23b.- Gas ESI Price for the EU15 from 1994 to 2016. Axis adjusted for better data visibility. (World Bank, 2018) (European Commission, 2018) (Eurostat, 2018)

The average ESI Price of gas increased from 1994 to 2016 which means that the overall SOS of gas in the EU15 decreased. As Figure 26 shows, the TPES from natural gas increased during this period illustrates the increasing EU's dependency on natural gas. As long as this tendency continues, the ESI Price will continue to increase since the EIA's indicator relies on the principle that well diversified energy matrix yields lower risks and thus a higher level of SOS. Additionally, the number of countries that supply natural gas to the EU15 Member States has remained relatively static overtime (Figure 24) due to two main factors: (i) Contractual barriers that hinder competition: Importing gas from a given country usually requires the deployment of costly infrastructure. Therefore, both parties involved in the trade of natural gas desire to protect their interests and sign 20-25 year contracts to make their investments pay off. Evidence suggests however, that the length of the natural gas contracts have been steadily declining and have an average length of 8-15 years (Neumann & von Hirschhausen, 2004) (ii) Geopolitical considerations involved: Natural gas is a strategic resource to exporting countries and hence will be resistant to change the conditions that benefit them e.g. 25 percent of Russia's GDP and 40 percent of their budgetary revenues comes from hydrocarbon sales (Percebois, 2008).

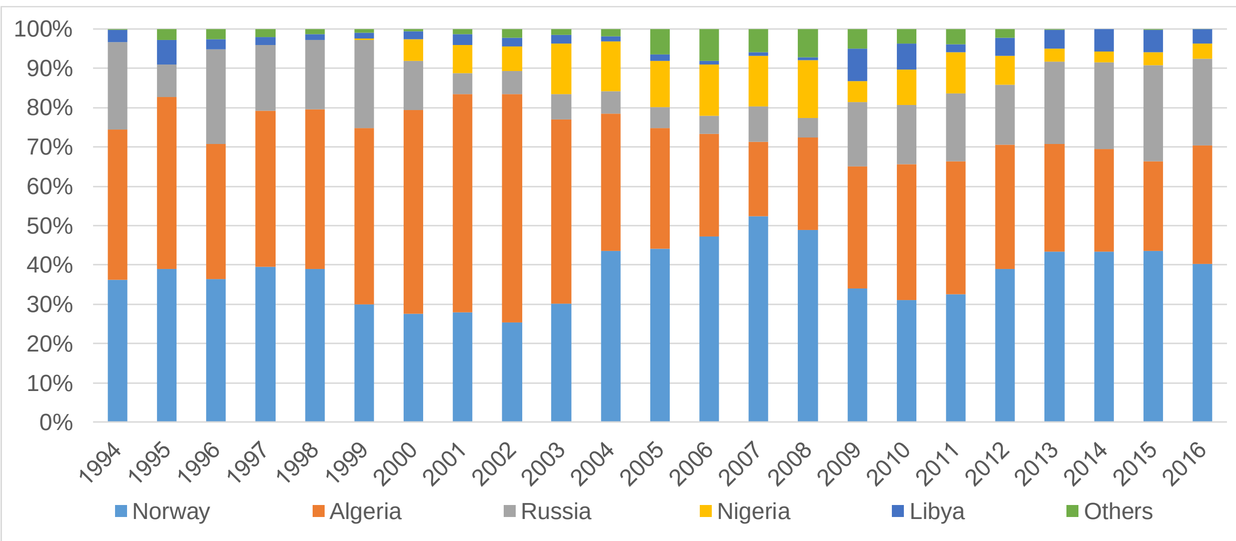

Figure 24: Share of EU15 gas imports per importing country. Trade movements amongst EU15 countries were omitted. (Comext, 2018)

The results also show severe differences among the ESI gas price of Member States. Belgium for example, experienced the highest continuous ESI Price increase from 1994 to 2007 which signify a decrease on gas SOS. As mentioned before, the data used on this analysis was adjusted in order to remove all the inter trade operation amongst the EU15 Member States. Belgium has slowly shifted away from depending on the gas imports of non EU countries and increasing its dependence on Norwegian, English and German gas (Figure 25). Therefore, since the imports from the U.K and Germany were not considered in this analysis, the results point to a market with low supplier diversification (only considering Norway as a natural gas supplier) with a high level of political stability. The Belgian context raises some concerns since several forecasts have predicted an increase on the natural gas demanded in the EU coupled with a decrease of the Norwegian natural gas production of twenty billion cubic meters per year by 2030 (Soderbergh, 2010). As Figure 24 shows, this is a concern not only for Belgium but also the rest of the EU15 Member States who rely heavily not on Norwegian natural gas imports, but also on Russian ones who are also expected to decline.

Another interesting trend of the gas ESI Price is the Netherlands where pronounced peaks can be observed in 1994, 1995, 1997, 1998 and 2016. This peaks correspond to years in which the Netherlands didn't import natural gas from abroad since their own indigenous production allowed them to meet the natural gas demanded. This tendency on the Dutch gas ESI Price will likely not be observed in the future since the Dutch government decided in 2018 to phase out natural gas by 2030 (Reuters, 2018). Unless the Netherlands manages to make some radical changes to its energy mix, their national energy security will be threatened as their dependency on foreign gas increases. Similarly, Denmark gas ESI Price also shows some peaks in 1999 and 2012 onwards. These peaks correspond to years in which Denmark imported gas from Norway.

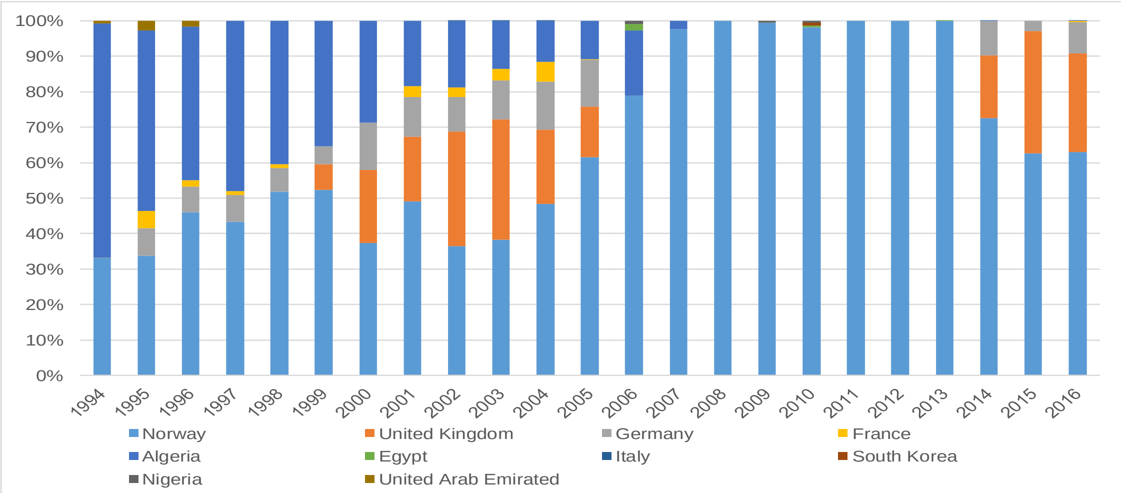

Figure 25: Share of Belgium gas imports per importing country from 1994-2016. (Eurostat, 2018)

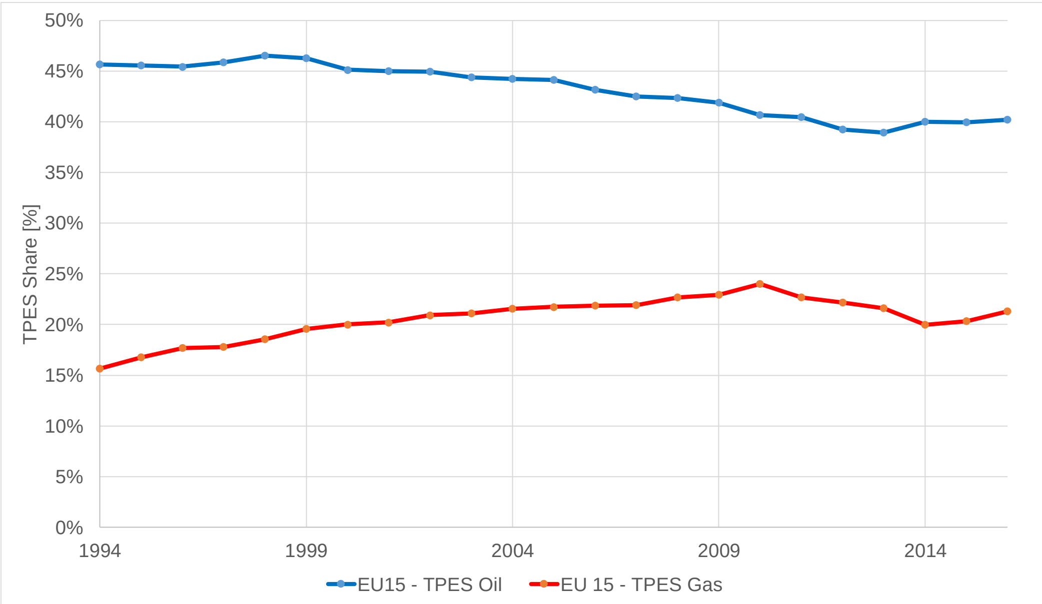

Figure 26: TPES share of oil and gas for the EU15 from 1994 to 2016. (Eurostat, 2018)

c) Limitations of the indicator

The main drawback about this indicator is the difficulty it poses when trying to interpret the results. This potential problem was also discussed by Jansen and Seebregts (2010) who point out that this index cannot be readily interpreted by less informed policy makers and other uses. This complicates the analysis of results unless the use of more simple, less aggregated indicators are used to explained tendencies.

Another drawback is that the indicator does not take into account the weight of the imports of a certain fuel in the total consumption of hat fuel which can lead to wrong conclusions. Denmark for example, shows a gas ESI Price peak in 1999 which could easily be misinterpreted as a year in which Denmark's indigenous production of gas was not enough to meet the internal demand. However, an analysis of the input data shows that Denmark only imported 8 kilograms of gas from Norway in 1999 which is a very insignificant amount when compared to the oi consumption of Denmark during that year which was 4293 ktoe (Eurostat, 2018). Therefore, the indicator should be modified to take into account the weight of the fuel's net import in the total TPES of the fuel as exemplified in Equation X:

Equation 5:

$$ESI_{price} = \sum_{f} \left[\left(\sum_{i} r_i c_i \, S_i^2 \right) \frac{C_f}{TPES} \right]$$

Where:
ESI_{price} = ESI price of country *i* in year *I [1]*
r_i= political risk rating of country *i* in year i
S_i = Share of supplier *i* in total fuel supplied in country *i* in year *i* [%]
$\frac{C_f}{TPES}$ = Share of net imports of fuel *f* in total primary energy consumption [%]

d) Comparison with other SOS studies

The literature review conducted, showed that there are no long term studies of the evolution of the ESI Price of oil and gas in the EU15. Moreover, while several sources mention the indicator devised by the IEA to measure the price of oil and gas (Jansen & Seebregts, 2010; Narula, Reddy, Pachauri, & Dev, 2017) there were no studies found that have used this SOS indicator.

Acceptability

5.1.5.-Share of Zero Carbon Fuels

a) Indicator overview

The APERC uses the share of zero-carbon fuels (Equation 4) to assess fossil fuel acceptability by taking into account the share of renewable and nuclear in the total primary energy supply (Kruyt et al., 2009).

Equation 6:

$$SOZCF = \frac{ZCFP_{Ci}^{Yi}}{TPES_{Ci}^{Yi}}$$

Where:

$ZCFP_{Ci}^{Yi}$ = Zero carbon fuel production of country i in year i [ktoe/year]
$TPES_{Ci}^{Yi}$ = Total primary energy supply of country i in year i [ktoe/year]

For calculating this indicator, the following assumption was made: (i) The non-carbon sources considered were renewable energy and nuclear heat. The renewable energy sources considered were hydro power, wind power, tide wave and ocean, solar thermal, solar PV, solid biomass, charcoal, biogas, municipal wastes (renewable), charcoal, bio gasoline, biodiesel, bio jet kerosene, other liquids biofuels and geothermal energy.

Table 8: Data requirements and data sources used to calculate the SOZCF

Indicator	**Required information per EU15 country from 1994 to 2016**	**Symbol**	**Database***				
			a	**b**	**c**	**d**	**e**
Non Carbon Share	Total primary energy supply				X		
	Fuel production from zero carbon sources.				X		

** a) British Petroleum Statistical Review of World Energy b) The World Bank c) Eurostat-Energy Balance d) Market Access Data Base e) Comext.

b) Indicator results and discussion

The oil and gas acceptability element was assessed through the only indicator mentioned by Kruyt el al. (2009) to measure acceptability: The share of zero carbon fuels. For this purpose, the total primary energy supply of zero carbon fuels (i.e. nuclear and renewable energy) was divided by the total primary energy supply. The results obtained are shown in Figures 27a and 27b:

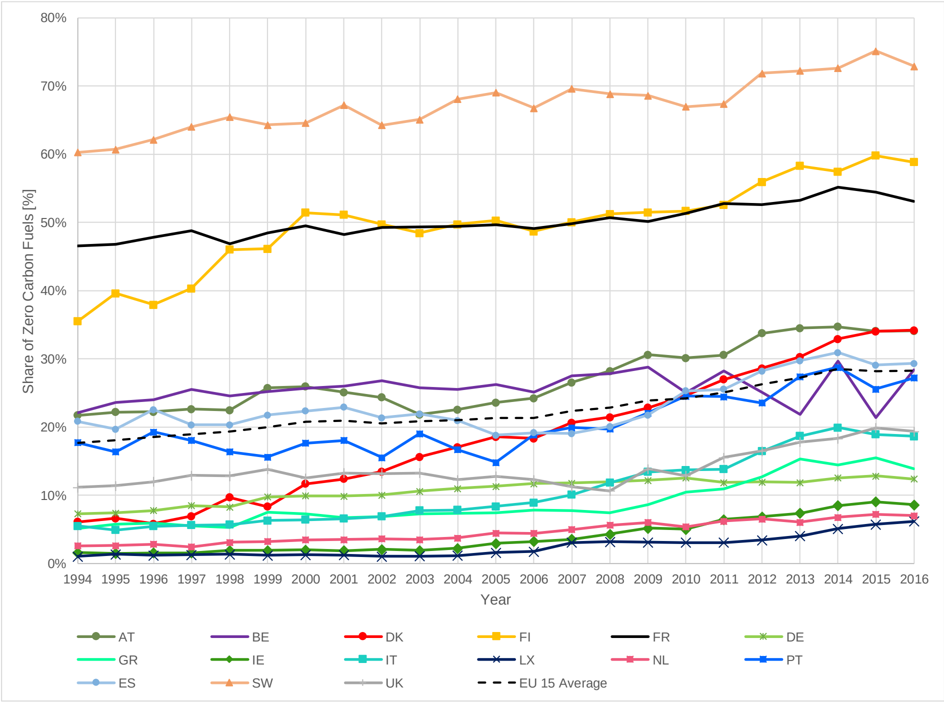

Figure 27a.- Share of Zero Carbon Fuels for the EU15 from 1994 to 2016. An overall increase of the SOZCF can be observed which entails a decrease on oil and gas SOS. (Eurostat, 2018).

The results show that the share of zero carbon fuels has gradually increased over time in the energy mix (from 18% in 1994 to 26% in 2016) of the EU 15 Member States. The main driver behind this tendency appears to be the gradual displacement of solid fuels (from 15% in 1994 to 0.25% in 2016) by renewable energy resources (4% in 1994 to 12.62% in 2016). Nuclear energy did not grow significantly during this period (12.6% in 1994 to 13.3% in 2016) and therefore the growth in the SOZCF is mostly attributable to the penetration renewable energy sources. Based solely on the results of this indicator, the conclusion could be drawn that the acceptability of oil and gas has diminished since SOZCF has increased during the time period analysed. However, an analysis of the TPES of the EU15 (Figure 28) shows (i) that oil has had a relatively stable share without significant variations over time (from 35.5% in 1994 to 34.0% in 2016) and that (ii) natural gas has increasingly gained relevancy in the share of TPES as it increased from 33% in 1994 to 40% in 2016. Therefore, based on the results from EU 15's TPES, an argument could be made that the acceptability of oil has remained relatively stable over time while the acceptability of gas has increased considerably. These misinterpretations of the results highlight the downsides that the SOZCF indicator has to measure acceptability since it the least researched element of SOS.

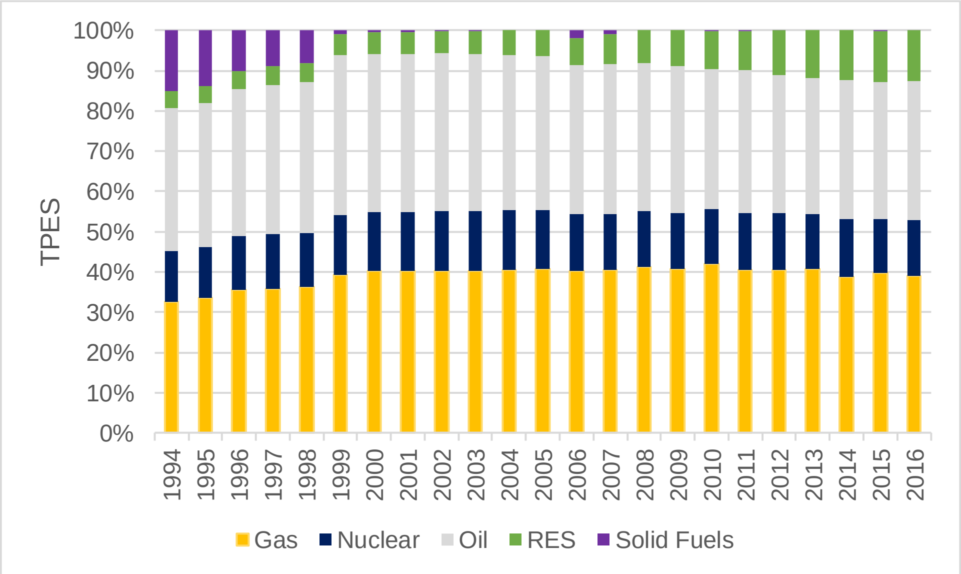

Figure 28: EU 15 TPES by energy source from 1994 to 2016. (Eurostat, 2018)

An analysis of the individual results from each Member State shows that Sweden and France have historically had the highest share of zero carbon fuels and thus the lowest level of oil and gas acceptability. Sweden's has been characterized since 1994 by a strong presence of nuclear (37% in 1994, 32% in 2016) and renewable energy (23% in 1994, 43% in 2016) in its TPES. Factors that have contributed to Sweden's success in reducing their dependence on fossil fuels, were: (i) Sweden's long term strategy to ensure SOS through an increase of domestic and preferably renewable sources of energy established since 1975 (ii) The rapid expansion of nuclear energy that took place between 1973-1985 (iii) The embracement of sustainable development as a government principle in 1991 (iv) The 1990's market liberalisation that took place in Sweden inspired by the reforms in the U.K and Norway as well as the discussions related to Sweden's accession to the EU and (v) Research and development of energy resources, conversion, transmission, distribution and end-use efficiency, as core items in the governmental agenda (Nilsson et al., 2004).

The French case is of particular interest since, despite reaching high levels of SOCZF compared to its counterparts from 1994 to 2016, this might radically change in the future. The SOCZF growth has been mostly driven by the ambitious nuclear program that France started after the first oil shock. However, the fifty-eight reactors built around this time are now reaching the end of their technological lifetime and the extension of these lifetimes will require an investment of 100 billion euros by 2030 which puts French policy makers at a crossroads (Perrier, 2018). Additionally, France has only managed to increase their share of RES in TPES from 7.3% in 1994 to 10.1% in 2016 which proves that the main driver behind the high levels of France's SOCZF has been the proliferation of nuclear energy. The continuance of the French nuclear program will not only guarantee long term security of supply but will also aid in the compliance of emission reduction goal set in the 20-20-20 targets. Moreover, a long term study of a group of 19 countries showed that nuclear energy consumption has a bigger emission potential than renewable energy due to a lack of adequate storage technology to overcome intermittent supply problems. As a result, electricity producers have to rely on emission generating energy sources to meet peak load demand (Apergis et al., 2010).

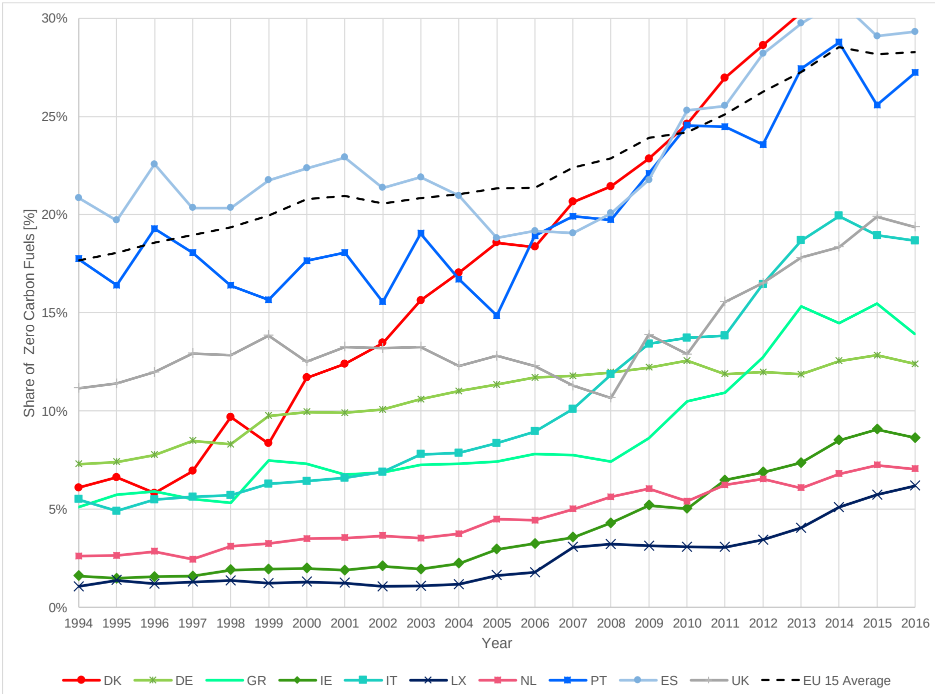

Figure 27b.- Share of Zero Carbon Fuels for the EU15 from 1994 to 2016. Axis adjusted for better data visibility. (Eurostat, 2018).

On the other side, the countries that showed the lowest share of SOZCF were Luxemburg, Ireland and the Netherlands. Luxemburg and Ireland increased their SOZCF from 1.0% in 1994 to 6.2% in 2016 and from 1.6% in 1994 to 8.6% in 2016, respectively. Their growth has been entirely driven by the inclusion of RES in their energy matrix (Luxemburg mainly relies on biomass and biodiesel while Ireland relies on wind power and biomass) since neither one of this Member States have a nuclear energy program. The Netherlands on the other hand, does have a nuclear program that comprises only one nuclear reactor located in Borssele and is expected to stop all operations in 2034 (Euronuclear, 2008). The Dutch increase of SOZCF was driven by the inclusion of RES in the energy matrix, namely solid biomass, renewable municipal waste and wind energy

Analysing the peculiarities of the Dutch, Irish and Luxembourgish energy systems to determine the causalities that led to low levels of SOZCF falls outside the scope of this study. However, a literature review was conducted to determine the causalities that the academia has established as impediments to RES deployment in Europe. A notable study was conducted by Negro et al. (2012) who provided an overview of the main constraints that hinder the deployment of renewable energy in Europe. Among the issues identified, the following ones are worth mentioning (Negro, Alkemade, & Hekkert, 2012):

- <u>Hard institutional problems</u> such as the high volatility in regulations and subsidy schemes or the misalignment between policy levels, different sectors and existing institutions. They cite the Netherlands as the worst example of high volatility in regulations since the subsidies for RES have been stopped and reintroduced in a different form throughout the years (i.e. 1998 start energy tax REB, 2001 stop energy tax, 2002 promised introduction of RES subsidy called MEP, 2003 actual introduction of MEP with lower tariffs and 10 years' durations of 20 years; 2006 unannounced stop of MEP, 2007 start of the SDE+ tax). This volatility generates lack of trust on the government which does not inly influence the current trajectory of RES development but also future ones.

- Soft institutional problems: RES still have to gain legitimacy which is necessary to mobilize resources and acquire political strength to influence institutions.
- Market structures: There is an incompatibility of RES with the paradigm of large-scale centralized generation. This situation has presented itself mostly in the wind energy field, where the first choice is to install large-scale wind turbines. Cases in the Netherlands and in Sweden have proven that the installation of large scale wind turbines led to poor technological designs and reliable technology which hindered the diffusion of technology. Another problem is that in most cases, the government favors the cheapest technology in the short run which reduces the success chances of more radical and long-term options. An example can be observed in the Netherlands, U.K and Sweden were policy has favoured the use of biomass in coal firing plants over solar panels, as it doesn't imply having to make significant alterations to the existing infrastructure.
- Lack of capabilities/capacities and skilled staff: There is a lack of capabilities and skills within the stakeholders such as: (i) Policy makers and engineers may lack technical knowledge (ii) Lack of unity amongst entrepreneurs to formulate a clear and realistic message to lobby the government (iii) lack of capabilities by users to formulate demand.

c) Limitations of the indicator

The limitations of this indicator have already been discussed in this chapter and they mainly concern questions regarding the appropriateness of this indicator as a measure of oil and gas acceptability. An analysis of the EU 15 TPES showed that the increase of the SOZCF has been at the expense of solid fuels (i.e. coal) but the share of oil and gas in the energy mix has been either stable (i.e. oil) or increasing (i.e gas). Therefore, this indicator by itself is a poor measure of oil and gas acceptability unless it is complemented by an analysis of additional indicators. Further research has to be conducted to determine more suitable indicator for acceptability since as mentioned by Kruyt et al. (2009) it is the least explored dimension of SOS.

Since the publication of Kruyt's article other acceptability indicators have emerged that rely on the premise that the acceptability of an energy source is high if there is lower use of resources such as water and land (Narula et al., 2017) and if there is reduced waste generation such as the CO_2 emissions per unit of energy consumed (Chuang & Ma, 2013). However, the applicability of these indicators to the present study is outside the scope of this study since (i) The focus is around the indicators identified by Kruyt et al. (2009) and (ii) There is no historical data base available with an enough level of disaggregation that allowed a breakdown by Member State, year and type of fuel. For example, if the CO_2 emissions per GJ of fuel consumed was to be chosen, we would have to know how that indicator has evolved through time from 1994-2016 in every Member State. Emissions depend not only on the source but also technology, so as the technology in a country evolves so will the total emissions of CO_2.

Comparison with other SOS studies

The literature review conducted, showed that there are no studies that use the SOZCF as a measure of acceptability despite being mentioned in a couple of articles (Martchamadol & Kumar, 2012; Sovacool, Mukherjee, Drupady, & D'Agostino, 2011). However, there have been studies that use the SOZCF indicator to study the evolution of the energy matrix in the EU. An example of this is the study conducted by Capros and Mantzos (2009) who created long term scenarios for the EU and concluded that the SOCZF of the EU will rise to 55.2% in 2030 (Capros P. & Mantzos L.; 2009).

5.1.6.-Supplier Diversity

a) Indicator overview

For every fuel, there is a potential for reducing risk by increasing the diversification among suppliers. The more suppliers (importing countries) a country has available to import energy resources from the more supplier diversity it has. The formula is a modified Shannon index (Appendix A) given by the following formula:

Equation 7:

$$H_j = -\sum_i p_{ij} \ln p_{ij}$$

Where:
H = Shannon index: the higher value of H, the more diverse the system is
p_i= Share of importer country *i* in the energy mix of country *j*

For calculating this indicator, the data was adjusted to remove all the intra EU 15 trade operations.

Table 9: Data requirements and data sources used to calculate the supplier diversity.

Indicator	Required information per EU15 country from 1994 to 2016	Symbol	Database*				
			a	b	c	d	e
Supplier diversity	Share of importer country *i* in the energy mix of country *j*				X		

** a) British Petroleum Statistical Review of World Energy b) The World Bank c) Eurostat-Energy Balance d) Market Access Data Base e) Comext.

A close analysis of the indicator's formula shows that a value of 0 means that the Member State relies solely on the imports from one country outside the EU 15. On the other hand, a higher value is the result of a good supplier diversification with equally distributed shares. For example, a country whose supplier diversity is equal to 2.3, means that the country relies on the imports of 10 countries who all have an equal share of ten percent of the total fuel's imports.

b) Indicator results and discussion

The basic idea behind the supplier diversity index comes from portfolio theory in finance which asserts that the overall risk to energy supply is diminished if there is a diversified portfolio of suppliers (Blyth and LeFevre, 2004). Several indicators have been devised that use this basic principle with certain variations among them such as factoring into account the distance from the importing country to the source , the geopolitical risk or the economic risk associated to a disruption in supply (Le Coq & Paltseva, 2009). However, most studies use a variation of the Herfindhal-Hirschmann or a Shannon index in which high values points to a high supplier diversification and consequently, a higher SOS. Figures 29a, 29b, 31a and 31b show the graphical results obtained for oil and gas respectively.

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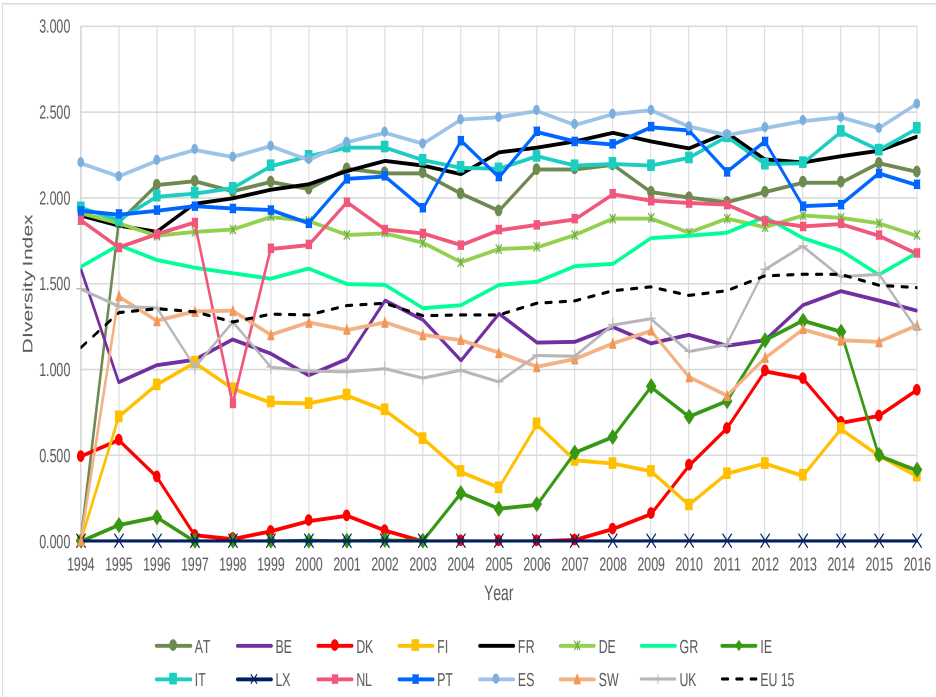

Figure 29a.- Oil Supplier Diversity for the EU15 from 1994 to 2016. An overall increase of the diversity index can be observed which entails a higher degree of SOS. Trade movements amongst EU15 countries were omitted. (Eurostat, 2018)

The results obtained show that the diversity index for the EU15 increased from 1994 to 2016. However, from 1994 to 2005 the supplier diversity index remained stable and only after 2005 it started to show a steady increase. This tendency was mostly driven by a change in the distribution of the shares of the oil supplying countries rather than by the introduction of new oil suppliers which showed no clear tendency over time. While the number of oil supplying countries from outside the EU15 oscillated between a range of (Figure 30) of 20-29 countries, the import share was diversified among oil supplying countries. Figure 21 exemplifies this by analysing how the shares have shifted over time. Russia, Iraq, Kazakhstan, Azerbaijan, Mexico and Angola have gained relevancy as oil importing countries while Norway, Saudi Arabia, Iran and Libya witnessed reductions in their oil exports to the EU15 Member States. The combined effect of both circumstances (Increased number of importing countries and better oil import share allocation) led to an overall increase of the oil diversity index in the time period analysed.

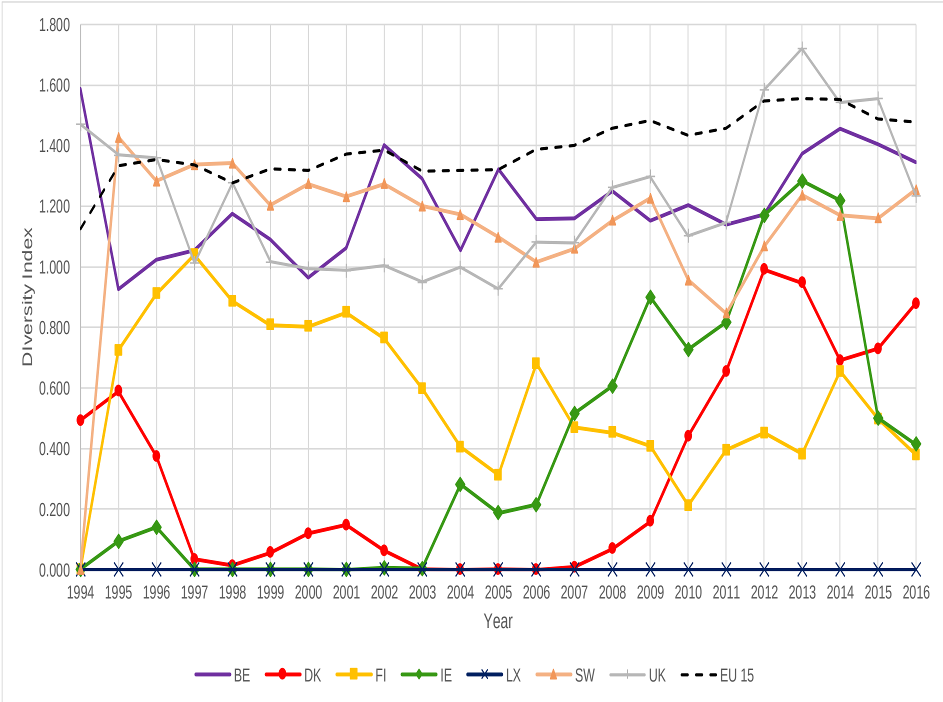

Figure 29b.- Oil Supplier Diversity for the EU15 from 1994 to 2016. Axis adjusted for better data visibility. Trade movements amongst EU15 countries were omitted. (Eurostat, 2018)

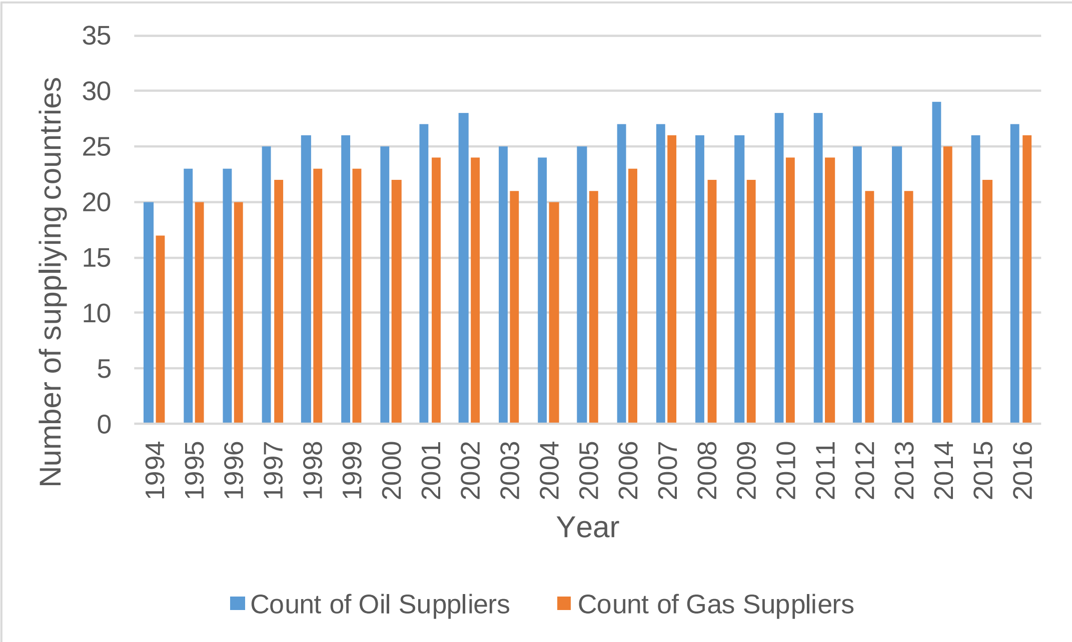

Figure 30: Count of EU15's oil and gas supplying countries from 1994-2016. Trade movements amongst EU15 countries were omitted. (Eurostat, 2018)

An analysis by Member State indicated that Spain has the highest degree of oil supplier diversification as they imported from 31 different countries from which, Iran, Libya, Mexico, Nigeria, Russia and Saudi Arabia have historically had the highest import shares. However, jumping to the conclusion that the oil SOS in Spain increased overtime on the sole basis of the results from this indicator is deceiving since the countries from which they imported from do not display the same geopolitical stability (Figure 20) as other countries (e.g. Norway). This particular case demonstrates the main drawback of this indicator, since it fails to account for certain risks that could potentially cause market disruptions. For example, Libya used to be a strategic oil supplier to the EU15 Member States until there was a civil war that started in 2011 that made their share go from 11% in 1996 to 3% in 2016 (Figure 21).

On the other side of the spectrum, the Member State with the lowest degree of supplier diversification was Luxemburg who has historically been dependent on oil imports from EU15 Member States, namely France and Germany. Finland's results also showed a decreasing oil supplier diversity after 1997 when they started to gradually increase the import share of Russian oil (from 39% in 1997 to 78% in 2007) at the expense of the Norwegian and Kazakhstani oil exports. Finally, Ireland's and Denmark's supplier diversity increased during this time period which is consistent with the results obtained an analysed for the oil ESI Price indicator.

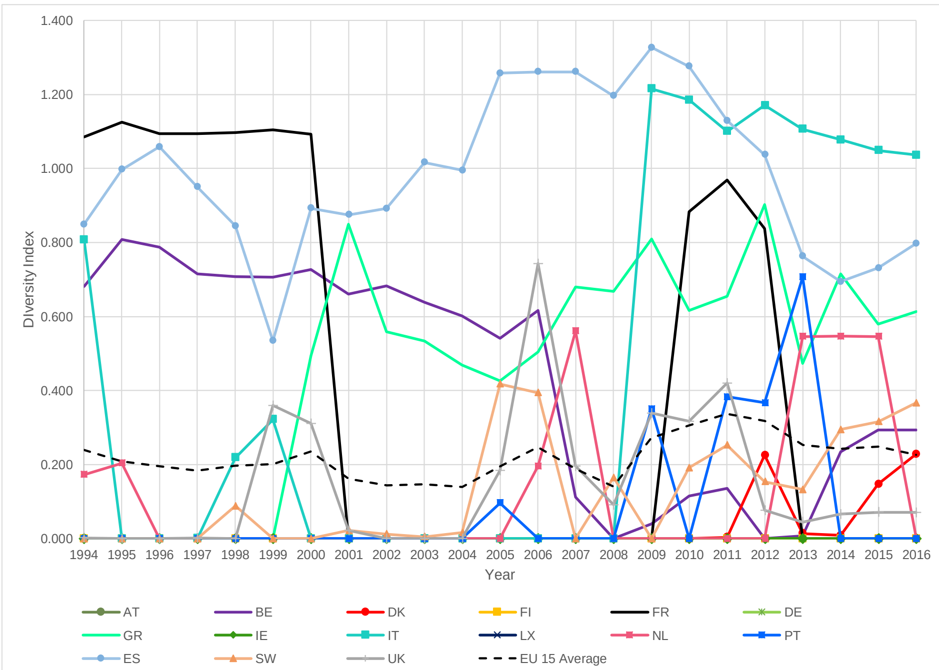

Figure 31a.- Gas Supplier Diversity for the EU15 from 1994 to 2016. Trade movements amongst EU15 countries were omitted. (Eurostat, 2018)

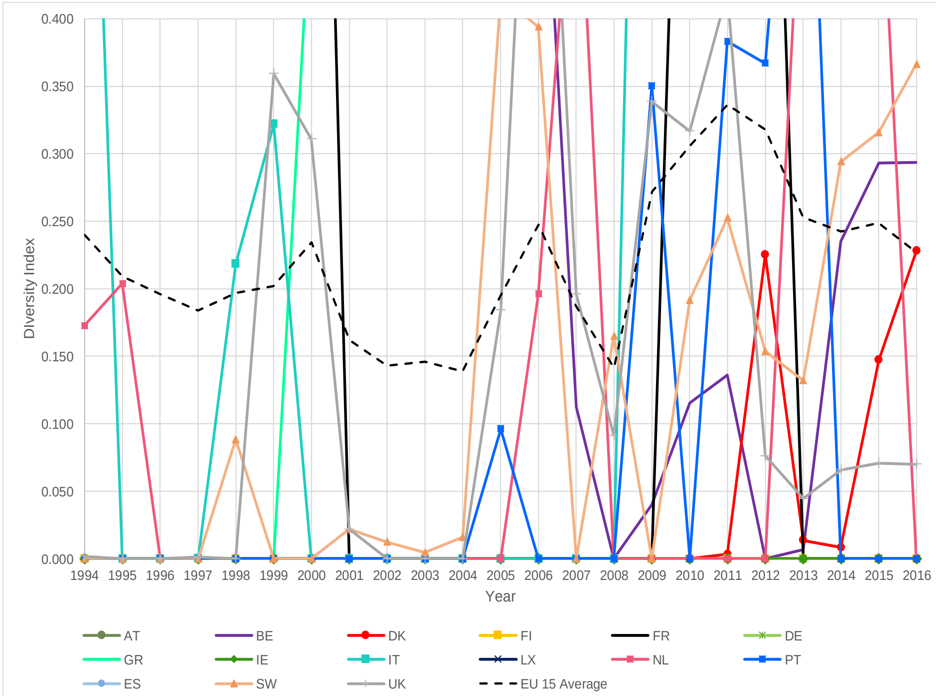

Figure 31b.- Gas Supplier Diversity for the EU15 from 1994 to 2016. Trade movements amongst EU15 countries were omitted. Axis adjusted for better data visibility. (Eurostat, 2018)

The results (Figures 31b and 31b) show that the supplier diversity of the EU15 gas has increased from 1994 to 2016, meaning that overall, Member States have increased the number of supplier countries that they obtain their gas from, however the gas market has less supplier diversity than the oil market. This is expected since the EU15's oil demand is more dependent on oil imports from countries outside the EU15 and thus, require the oil input from more countries to meet their demand (Figure 32).

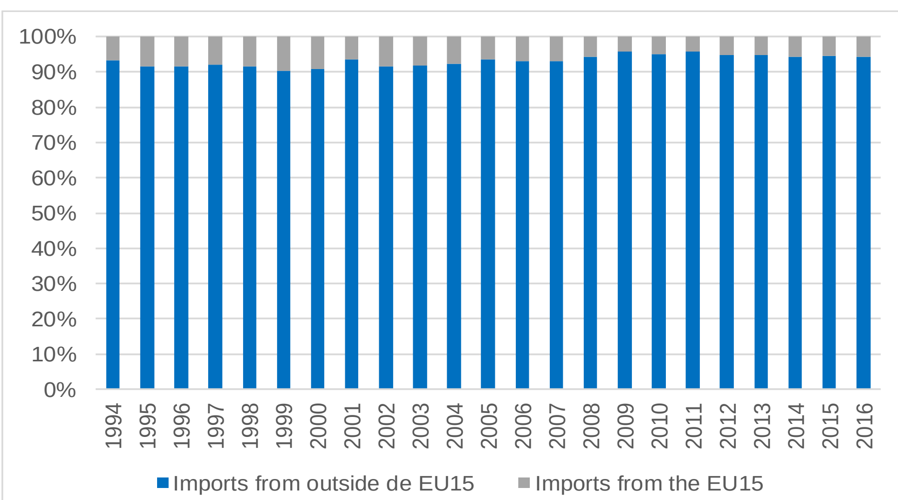

Figure 32: Origin of the EU15 oil imports from 1994 to 2016. (Eurostat, 2018)

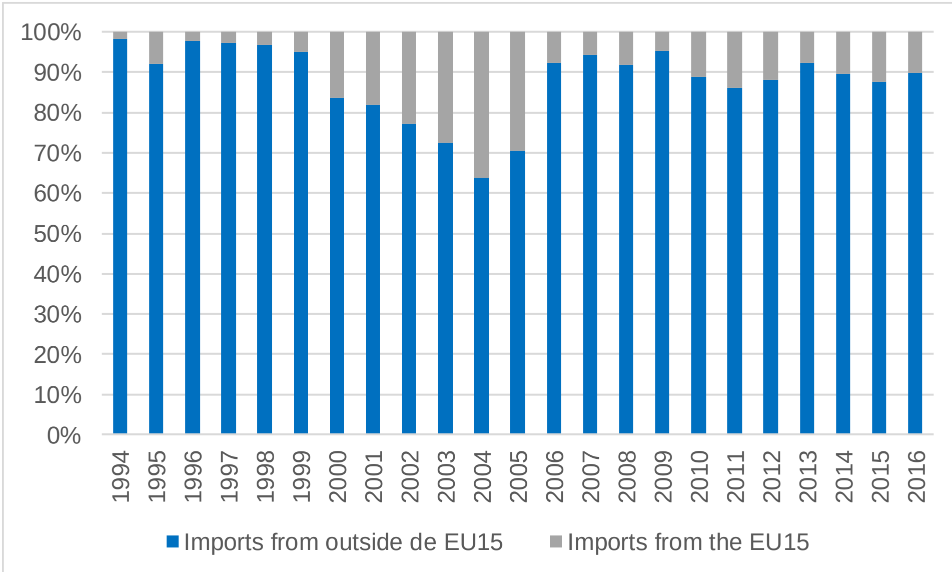

Figure 33: Origin of the EU15 gas imports from 1994 to 2016. (Eurostat, 2018)

An analysis of the results by Member State shows that in 2008 the supplier diversity from the EU15 declined sharply due to a reduction in the supplier diversification of Belgium, Netherlands, and the U.K. Belgium depended greatly on the gas imports of Algeria from 1994 to 2006, however after the Distrigaz Belgium contract expired (Aissaoui, 2016), the Algerian import share decreased from 66% in 1994 to 0% in 2008. Since then, most of the Belgian imports of gas have come from Norway who has seen an increased share of their Belgian gas exports from 33% in 1994 to 100% in 2015. The last three years of Belgian imports have witnessed the inclusion of Germany and the United Kingdom as natural gas suppliers. The Netherlands supplier diversity evolution has been erratic since as a gas producing Member State, there are some years in which their natural gas imports from countries outside the EU15 were inexistent. This tendency changed as of 2018, when the Netherlands became a net importer of natural gas (ICIS, 2018). Lastly, the U.K is highly dependent on imports from Norway to the extent that from 2010 to 2016 the average share of gas imported from Norway was 97%. Figure 21, shows that the EU15 Member States rely heavily on the oil and gas imports from Norway whose production is expected to decline on the next few years. Several Member States have taken measures towards ensuring continuous oil and gas SOS by increasing the supplier diversity through the addition of new LNG infrastructure (Reuters, 2018). Additionally, the EC sees the import of LNG as essential in achieving its objective of diversifying sources of energy supply to its member states. (Rogers, Nelson, & Howell, 2018)

While the diversification of oil suppliers has always been one of the cornerstones of EU's policy, there are several limitations that have hindered the diversification of oil and gas suppliers (Vivoda, 2009):

(i) Geography: Transport distance and freight costs affect the success of diversification policies.
(ii) Political relationships: If there is an alignment between an importing country and a supplying country's policies, the likelihood of them entering a contractual agreement for the supply of oil or gas is higher. The U.S.A for example, halted all of their oil imports from Iran since 1979 after both countries ended their diplomatic relations.

(iii) Oil and gas availability and transport infrastructure: oil and gas from alternative supplying countries might not always be available due to previous trade commitments with other nations, lack of proper infrastructure to retrieve the resources from the ground or inadequate transportation infrastructure. China for example, has had constraints for importing oil from Russia due to the absence of a pipeline that links both countries and from Venezuela due to an inadequate tanker fleet.

(iv) Refining Capacity: Refineries are configured to process a specific type of crude (i.e high or low on Sulphur) which limits the choice of crude that a interested party can acquire in the international market (Canadian Fuels Association, 2013). Furthermore, despite the recent tendency of decommissioning refinery plants in Europe, the crude oil destined for the refinery process in the EU15 still accounts for 60% of the total crude input (Eurostat, 2016).

(v) Resources: Oil importers often commit resources to assist supplying countries to, for example: secure transportation routes, provide military assistance and international political support, finance infrastructure projects and give incentives to oil exporters. A notable recent example of resource allocation can be observed in the Nord Stream II natural gas pipeline project that links Russia with Germany. For the development of this project, several European companies partnered up with Gazprom for the project's development (Wintershall, Engie, Unipiper and Gasunie) and collectively were granted financial resources by EU15 institutions such as the German United Loan Guarantee Program and the Italian Export Credit Agency (Gazprom, 2013). The main concerns about this project is that the pipeline will not only increase the political influence that Russia currently exerts over Western Europe but might also affect Europe's SOS of natural gas (Goldthau & Sitter, 2014).

c) Limitations of the indicator

Although an increased supplier diversification a desirable state for oil and gas SOS, there are other factors that affect the accessibility to these fuels that are not captured by this indicator such as: geopolitical risk of the supplying countries or the reliability of the transportation infrastructure. Additionally, there are some price benefits that come with limiting the number of suppliers. For example, if the EU 15 was to allocate a higher oil import share to a certain country, they could receive a better oil price or commercial agreements. This example proves that there is an optimal number of oil and gas suppliers that can guarantee imports from geopolitical stable countries at good prices however further financial research needs to be performed to determine such number.

d) Comparison with other SOS studies

A literature review showed that there have been no long term studies that use the same formula to calculate the oil and gas supplier diversity of the EU 15 Member States. Therefore, for comparison purposes, the oil supplier diversity of the U.S.A was calculated and compared to the oil supplier diversity of all of the EU 15. The results are shown in Figure 34.

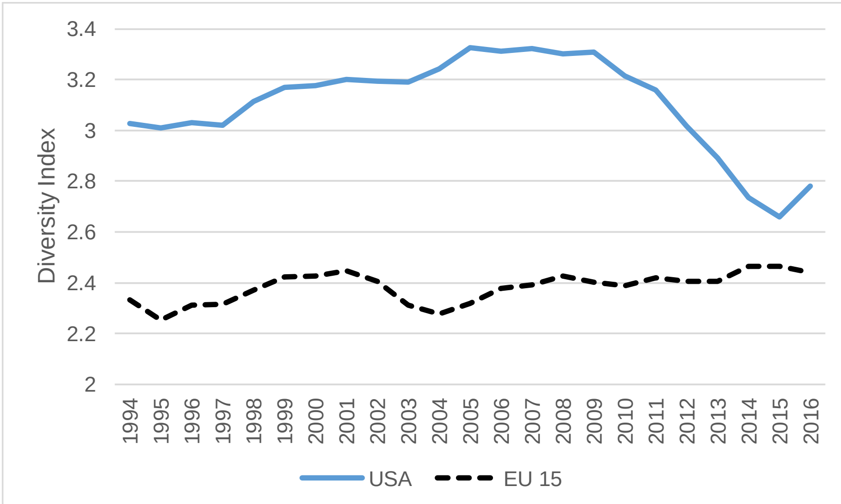

Figure 34: Oil supplier diversity of the U.S.A and of the EU 15. *(Eurostat, 2018). (EIA, 2018)*

The results show that the oil supplier diversity of the U.S.A was higher than the EU 15 from 1994 to 2016. However, from 2010 to 2015 there has been a decreasing tendency on the oil supplier diversity of oil of the U.S.A. The reason behind this decrease was the relevancy that Canada gained as an oil supplier once the Keystone pipeline project extension was completed in 2010. Canada went from supplying 21% of the oil imported by the U.S.A to 40% in 2015.

This tendency will probably continue on the future once the future extension projects of the pipeline become operational provided that they don't get cancelled due to increasing environmental concerns.

5.2.- Overview of SOS results

The results from the previous section are summarized in Table 10 which show that in a year to year comparison analysis (1994 vs 2016) the SOS of oil and gas in the EU 15 Member States has decreased. The results for Market Liquidity of Oil and Gas, the Oil Vulnerability Index, the IEA's ESI Price for Gas, the SOZCF, and the Supplier Diversity of Gas point out to an overall decrease of oil and gas SOS from 1994 to 2016. The only indicators that display favourable results for oil and gas SOS are IEA's ESI Price for Oil and the Supplier Diversity for Oil.

Table 10: Summarized results per indicator in a year to year (1994 vs 2016) comparison analysis.

SOS Element	Indicator	Unit	1994	2016	% Change	Impact on SOS
Availability	Market Liquidity Oil	1	1.01	1.01	-0.4%	Decrease
	Market Liquidity Gas	1	1.01	1.00	-0.2%	Decrease
Affordability	Oil Vulnerability Index	%	0.516	1.032	50.0%	Decrease
	IEA's ESI Price - Oil	1	0.09	0.08	-11.8%	Increase
	IEA's ESI Price - Gas	1	0.04	0.06	26.4%	Decrease
Acceptability	SOZCF	%	17.67	28.29	37.5%	Decrease
Accessibility	Supplier Diversity - Oil	1	1.13	1.48	23.8%	Increase
	Supplier Diversity - Gas	1	0.24	0.23	-5.7%	Decrease

The following general remarks were drawn based on the results: (i) The ML of the oil and gas markets remained, for the most part unaltered. However, the slight decreased of this indicator (-0.4% in the oil market and -0.2% in the gas market) is attributed to an increase of the worldwide supply of oil and gas coupled with a decrease on the demand of these fuels in the EU 15 Member States (ii) The OVI index was the indicator that showed the biggest increase (50%) which means that the EU15 Member States increasingly allocate a bigger portion of their GDP to acquire oil in the international markets. This indicator results also shows that the EU 15 Member States are highly exposed to the volatility of international oil prices. (iii) The IEA ESI Price of Oil decreased 11.8% as a result of an increased reduction on the oil demand of the EU 15 Member States, diversification in oil suppliers and geopolitical stability in the supplying countries (iv) The gas ESI Price increased 26.4% due to poor gas supplier diversification that has been hindered by geopolitics and the contractual conditions inherent to the gas market. (v) The SOZCF has increased significantly overtime due to increased inclusion of RES in the energy matrix. However, based on these results we cannot conclude that the acceptability of oil and gas has declined over time (vi) The supplier diversity of oil has increased over time due to the inclusion of more oil suppliers but also due to a better distribution of the import shares among the supplying countries (vii) The gas supplier diversification has decreased 5.7% in the time period analysed due to the preference of EU 15 Member States to rely on gas imports from Norway, Netherlands and UK whom they perceive as reliable partners.

Nevertheless, it is important to mention that from an individual level, Member States displayed different levels of performance in each of the SOS indicators as a result of the national policies they implemented during the time period analysed. Therefore, the following map (Figure 35) shows the overall individual levels of oil and gas SOS performance from 1994 to 2016 based on the results per individual indicator. Appendix D, contains an explanation on how the indicator data was analysed to elaborate Figure 35. Below an explanation of the colour coding is provided:

- Green: Assigned to the Member States that's displayed the most favourable results for oil and gas SOS according to the results of individual indicators.
- Yellow: The yellow colour was assigned to the five Member States that displayed medium levels of oil and gas SOS performance according to the results of individual indicators
- Red: The red colour was assigned to the five Member States that displayed the least favourable results for SOS according to the results on indicator i.

Figure 35: Individual performance of oil and gas SOS per indicator from 1994 to 2016.

The individual analysis by Member States showed that Spain, France, Germany, Italy and the United Kingdom showed the most favorable indicator results for SOS. The Member States that displayed medium performance results for oil and gas SOS were Austria, Greece, the Netherlands and Luxemburg. Finally, the Member States which displayed the least favorable results of oil and gas SOS were Portugal, Belgium, Ireland, Denmark, Sweden and Finland. The reasons that explain the individual performances of each Member State differ greatly but ultimately stem from the unique characteristics of their energy systems.

Lastly, these findings are similar to the study conducted by Christie who conducted a study of the EU 15 of oil and gas SOS in order to determine which Member States and industries within the EU 15 are the most vulnerable to possible oil and gas disruptions. The methodology consisted on a calculation of different indicators that cover the total economy and industry-level energy intensities, import dependence, import diversification and electricity generation. The study found that: (i) Russia is the most important source of crude oil, followed by Norway, Saudi Arabia and Libya and (ii) Most EU 15 countries are strongly import dependent for both oil and gas and more importantly, that: (iii) the EU-15 as a block is in a less vulnerable position than the average of its constituent parts (Christie, 2014).

VI.- Energy Policy Effectiveness Assessment

As mentioned in Chapter 2.3, it is imperative from a governance theory perspective that the study draws conclusions not only on the impact of the policies (indicator results) but also consider the output (stringency of the policies) and the outcome (policy level of compliance and uptake) as proposed by Easton (1965). This chapter contains a high level analysis of these two elements which were assessed through the use of certain indicators, namely: (i) the output, whose stringency was assessed through the level of detail provided in the policy, the existence of quantifiable targets, the ambition of the policy, the inclusion of targets to measure performance and the existence of a requirement to develop management plans and (ii) the outcome, which was evaluated through the level of compliance and policy uptake. These indicators were taken from the work of Kalfagianni and Pattberg (2013) and were chosen based on the availability of the required data. Additionally, a literature review was conducted to identify previous studies that have assessed the effectiveness of the policy instrument in question.

It is important to mention that the high level analysis (Chapter 6.1) only centers around three of the policies discussed in Chapter 2.2: The Energy Charter Treaty (Chapter 6.1.1), the Gas Directive (Chapter 6.1.2) and Regulation 994 (Chapter 6.1.3). The other policies were left out of this analysis since they only lay out proposals for legislative changes that may or may not materialize into a proper legally binding policy (Borchardt, 2016). The Treaty of Lisbon was also excluded since it provides a broad mandate for energy policy making instead of providing a set of specific articles and implementation procedures related to energy (Biesenbender, 2015). Lastly, the discussion of results is provided in Chapter 6.2.

6.1 Energy Policy Effectiveness

6.1.1 Energy Charter Treaty

Policy overview and relation to SOS: Through the issuance of fifty articles, the ECT lays out basic rules for cooperation among countries and investors to foster the development of energy infrastructure. For this purpose, its establishes procedures and rules that signing countries and energy infrastructure investors have to agree upon to conduct all activities related to the energy asset's construction, management and other related issues (i.e. trade, transit and energy efficiency). This treaty was originally designed by the western European countries (through the EC) who on one hand, wanted to increase their oil and gas SOS by accessing the fossil fuel resources of Russia but on the other hand, needed a governance framework to protect their interests (e.g. compensation for the investor in case the government expropriates energy assets). Overtime the ECT has been adapted and now also foresees all types of energy infrastructure, and more countries outside the original policy's scope have agree to sign the ECT (which is why the ECT is sometimes referred to as the International Energy Charter Treaty).

A) Output

- Policy's level of detail: The wording is very vague and the it does not provide a detailed description on how activities are to be conducted.
- Quantifiable targets: The policy does not establish quantifiable targets. For example, article nineteen states that every contracting party shall strive to minimize harmful

environmental impacts however there was no limit set on the environmental impact allowed.

- Ambitiousness: According to Kalfagianni & Pattberg (2013), a policy is ambitious if it goes beyond existing regulation. Therefore, under this premise the ECT is a highly ambitious policy as there is no other legal instrument that aims to protect energy investments in a global scale (Westphal, 2006).
- Performance: This indicator relates to the degree in which a policy includes targets to measure the actual performance of the countries. Article twenty-three of the policy appoints sub-national authorities and contracting parties as the actors for the observance of all the provisions in the Treaty yet it fails to include targets to measure the performance of the countries.
- Management: the ECT doesn't mention anything related to the development of a management plan to oversee the implementation of the provisions entailed on the ECT.

Based on this high level assessment of the ECT's provisions, the stringency of the ECT was categorized as low.

B) Outcome

- Level of uptake: The level of uptake related to the degree in which the intended group, decide to embrace the policy. In total fifty-six countries have signed the ECT including all of the EU 28 countries, the U.S.A, Russia, Australia, Albania, Armenia, Azerbaijan, Belorussia Canada, Estonia, Georgia, Japan, Kazakhstan, Kyrgyzstan, Latvia, Norway, Romania, Switzerland, Tadjikistan, Turkey, Turkmenistan, Ukraine and Yugoslavia.

- Level of compliance: Difficult to assess as there is limited information on this matter. However, the ECT does contain multiple dispute resolution mechanisms that depend on the type of grievance such as: (i) Article 26: In the event of an alleged non-compliance event, the contracting parties have three months to solve the dispute in amicable terms. If at the end of this period the dispute is not settled, then Article 26 allows investors to pledge their case to the courts or administrative tribunals. (ii) Article 29 and Appendix D: Contain a mechanism that settles trade disputes among countries. (iii) Article 27: Includes an arbitration procedure for disputes regarding the interpretation or application of the ECT (Dowling, 2018). Despite the multiple tailor-made mechanisms to ensure the ECT's compliance, there have been cases that have been to be solved through the intervention of courts or administrative procedures. The Energy Charter's portal currently lists one hundred and twenty-one investment dispute settlement cases, which means that there is some degree of non-compliance (Energy Charter Treaty, 2019). Therefore, the level of compliance of the ECT is medium.

C) Literature Comparison

There are opposing views when it comes to assessing the effectiveness of the ECT. While some scholars argue that this treaty has failed to address the main issues hindering the improvement of global energy security, other authors mention that it has proven effective. Selivanova (Selivanova, 2012) for example, argues that trade activities are conducted under the WTO guidelines which have been mostly designed to remove import barriers which in the energy sector are not as common as the export ones. Similarly, Klyomin (Klyomin, 2008) states that the ECT has failed to address its main political objective which originally was to lay down the fundamental rules of “joint” possessing and managing of the Russian gas. Other authors argue that despite its shortcomings, the ECT has a unique role as the only energy specific multilateral agreement that covers all major aspects if international energy turnover (i.e. trade, transit, investment and energy efficiency) that collectively tackle the main issues related to ensuring security of supply (Peters, 2018).

6.1.2 Gas Directive

Policy overview and relation to SOS: There have been several versions of the Gas Directives issued by the Commission (1996, 2003 and 2009) which have been increasingly improving and lay down the fundamentals to create and liberalise an internal EU market for natural gas. Arguably, one of the main important strategies that the EC has devised to increase oil and gas SOS has been the creation and strengthening of the Single European Energy Market.

A) Output

- Policy’s level of detail: The wording is very vague and the it does not provide a detailed description on how activities are to be conducted. For example, Article 5 states that: ‘…Member States shall ensure the monitoring of security of supply issues…Such monitoring shall, in particular, cover the balance of supply and demand on the national market, the level of expected future demand and available supplies, envisaged additional capacity being planned under construction, and the quality and level of maintenance of the network, as well as measures to cover peak demand and to deal with shortfalls of one or more suppliers…”.
- Quantifiable targets: The policy does not establish quantifiable targets.
- Ambitiousness: high, as there is no other instruments that aims to improve the gas market conditions at the EU level.
- Performance: The continuous monitoring of the actual performance of each Member State is responsibility of the EC as mentioned in Article 52. Every year they have to monitor and review the application of the Gas Directive in the Member States and submit an overall progress report to the EU Parliament which shall cover some elements (e.g. lessons learned and progress made in creating a fully operational internal market in natural gas Examination of issues relating to security of supply of natural gas, etc.) however, the scope of this performance monitoring is very broad and fails to establish targets.
- Management: The Gas Directive mentions the requirement to develop management plans. For example, Article 35 states that management rules should be implemented in infrastructure projects to manage congestion however, it doesn’t detail the specifics of this management plans.

Based on this high level assessment of the Gas Directive provisions, the stringency of this policy instrument was categorized as low.

B) Outcome

- Uptake level: High since all of EU 28 Member States agreed upon and signed the Gas Directive.

- Level of compliance: the EC has faculties to establish mechanisms to ensure Member State compliance with the law through a process called "infringement procedure" which consists of the following steps:

1. Formal Notice: The EC sends a letter to the Member State asking for additional information regarding the suspected violation of EU law.
2. Reasoned Opinion: If the EC determines that the Member State is failing to fulfill its obligations, it may send a formal request to comply with the law.
3. Referral to the CJ: If the Member State does not comply, the EC may decide to refer the matter to the Court of Justice. The EC may ask the court to impose penalties, which are calculated taking into account the importance of the rules breached, the period in which the Member State was non-compliant and the country's ability to pay. If the International Court of Justice determines that the Member State has breached the law, the national authorities must to take action to comply with the court's ruling.

The only study that was found in literature that addresses the level of compliance of the Gas Directive was published by Pointvogl (2009) who conducted an analysis of a sample of Member States to determine the infringement proceedings to due to non-compliance of the Gas Directive. The results (Table 11), highlights the importance of the EC not only as a law enacting entity but also as a supervisor of law implementation and compliance.

Table 11: Infringement proceedings due to non-compliance of the Gas Directive. Adapted from: (Pointvogl, 2009)

	Infringement proceedings due to the Gas Directive 2003/55/EC		
Country	Formal Notice	Reasoned Opinion	Referral to ICJ
Austria			
Belgium			
Denmark			
Finland			
France			
Germany			
Ireland			
Italy			
Luxemburg			
Netherlands			
Spain			
Sweden			
United Kingdom			

Additionally, with aims of increasing transparency and accountability, the EC issues periodically compliance reports related to on-going infringement procedures against Member States (European Commission, 2018). Therefore, based on these findings we can say that the level of compliance is medium since six of the EU 15 Member States were referred to the ICJ as of 2009. There were no studies found that contain updated figures regarding the directive's compliance.

C) Literature comparison

Arentsen (2004), argues that that the Gas Directive only provides the basics of gas market liberalization but it is, a first step in the process of the establishment of a single European gas market. Furthermore, he also mentions that its effectiveness has been limited due to the plethora or problems that arise during its implementation such as technical, economical and institutional barriers that stem from the unique characteristics of the national and regional gas markets that comprise the European gas market. This opinion is also shared by Hancher (2003) and Radetzki (1999) who recognize the Directive as a weak compromise filled of unsolved issues which will be solved by national actors even if the problem requires a European wide solution. Based on the results of this literature review, we can determine that most scholars see the Directive as a first step towards gas market liberalization but several challenges need to be solved before its considered an effective policy instrument.

6.1.3 Regulation no.994/2010 Measures to safeguard security of gas supply

Overview and relation to SOS: This regulation was proposed by the EC after the gas disruptions that occurred due to the Russia-Ukraine dispute and replaced the Directive 2004/67/EC of April 26, 2004, related to measures to safeguard the SOS of gas. It requires that all of the EU 28 Member States: (i) Mutually provide gas in the case were gas imports from abroad fall by 10 percent or more and (ii) that they secure gas storage to cover 60 severe winter days of supply.

A) Output

- Policy's level of detail: The wording contains more detail that the other policy instruments analysed. For example, Appendix I provides a methodology to be used to calculate a parameter referred to as N-1 which describes the ability of the technical capacity of the gas infrastructure to satisfy total gas peak demand.
- Quantifiable targets: The policy establishes several deadlines in which certain activities need to be implemented, for example Article five provision 5 mentions that every Member State has to prepare a preventive action plan and an emergency plan in case of a gas disruption that had to be issued no later than December 3rd, 2012. Furthermore, out of the policies analysed, it is the only one that sets a quantifiable target (other than deadlines related to administrative procedures) on the value of the N-1 parameter.
- Ambitiousness: high, as there is no other instruments that aims to implement measures to safeguard the security of gas supply at a EU level.
- Performance: The continuous monitoring of the actual yearly performance of each Member State is responsibility of the EC as mentioned in Article fourteen. Even though, the scope of this performance monitoring is very broad and fails to establish targets, the process envisioned to conduct this monitoring activities is more stringent than those found in the other policies analyzed.
- Management: The third article present on this regulation mentions that the party responsible for carrying out the measures provided in the regulation is the competent authority that each Member State designates. Even though the policy doesn't establish targets, it does provide more detail on how the policy management is to be conducted.

B) Outcome

- Uptake level: High since all of EU 28 Member States agreed upon and signed the Gas Directive.
- Level of compliance: Unknown. There was no information available regarding the level of compliance of this regulation.

C) Literature comparison

There were no studies found that study or assess the effectiveness of this instrument.

6.2 Discussion

The results of the effectiveness analysis of the ECT, the Gas Directive and the Regulation 994 are summarized in Table 12.

Table 12: Output and outcome results of the effectiveness analysis of the ECT, the Gas Directive and Regulation 994

Year	Regulation	Output					Outcome	
		Stringency						
		Level of detail	Quantifiable targets	Ambitiousness	Performance	Management	Uptake level	Level of compliance
1994	Energy Charter Treaty	Low	Low	High	Low	Low	High	High
2009	Gas Directive	Low	Low	High	Medium/Low	Low	High	High
2010	Regulation 994	Medium/Low	Medium/Low	High	Medium/Low	Medium/Low	High	High

The results show that all of the policies analysed lack a sufficient level of detail, fail to establish quantifiable targets, and do not set sufficient performance or monitoring targets. Additionally, all of them have a high degree of ambitiousness since they are the first and only regulations of their kind and scope which is the criterion established by Kalfagianni and Pattberg (2013) to determine whether or not a policy is ambitious. Based on these results, the conclusion is drawn that the stringency of the ECT and the Gas Directive is low whilst Regulation 994 has Medium/Low degree of stringency. There appears to be a continuous improvement in the stringency of the policies, however more research needs to be conducted before reaching this conclusion.

The outcome element of policy effectiveness analysis was assessed through the level of compliance of the laws as well as the level of uptake. The level of compliance was an indicator difficult to assess because there is not much information available however there were some general findings: (i) all of the policies analysed have provisions to establish penalties for countries that fail to comply with the regulation and (ii) the EC monitors the reports issued by the competent authority regarding the level of compliance. These two instruments collectively ensure that the non-compliant Member States eventually observe all of the provisions that they are subject to. Therefore, the level of compliance of the policies is high.

More importantly, the last finding relates to (i) the uptake level of the policies which is really high as all of the EU 15 Member States signed them and (ii) the stringency of the rules. This is a finding that is consistent with governance theory, which states that low stringency levels lead to higher uptake levels since the rules that actors have to observe if they decide to adopt the regulation, are amenable. If the EC had issued more draconian policies and thus with a higher degree of stringency, Member States would be more hesitant to adopt them since they may entail a radical change in their energy production systems. Moreover, due to the strategical role that energy plays in the economy of any country, the EC established energy sovereignty as an inalienable right of every Member State. Thus, the implementation of highly stringent SOS policies might contravene one of the principles of the by which the EU was founded.

This analysis also showed that it is really difficult to determine the extent to which the results from the indicators discussed in the previous sections, are influenced by the SOS policies issued by the EC. The analysis of the content of the policies conducted, showed that out of all the SOS policies issued by the EC, only three of them have legally binding consequences as the rest of them are just policy propositions. Moreover, Regulation 994 is the only policy instrument that deals with gas SOS while the other two determine that an increase in oil and gas SOS will be the result of either (i) Increased investment on energy infrastructure (ECT) or (ii) The deployment and strengthening of the internal gas market (Gas Directive). Since Regulation 994 was issued until 2010, then the effects would only be noticeable in the last six years of the period analysed (i.e. 2010-2016), however the indicator results show that no significant increase happened after the regulation's introduction. This is a consequence of the low stringency level of the rules set upon Regulation 994 that are a consequence of the intrinsic nature of the energy sovereignty principle by which policy is enacted in the EU.

Based on these results, this chapter answers the main research questions by concluding that EC's policy to increase of oil and gas SOS has proven ineffective. While the indicator assessment helped identify a decreasing trend in the oil and gas SOS of the EU15, this complementary qualitative output/outcome analysis helped identified some of the underlying reasons which are explained below:

- **There are not enough legally binding policies that directly address oil and gas SOS:** Despite SOS being one of the EU policy cornerstones, out of all the policies issued by the EC during 1994-2016 that are catalogued in literature as SOS related policies, only three of them have translated into legislative instruments with legally binding consequences (i.e. ECT, the Gas Directive and Regulation 994/2010). Out of these regulations, only one of them (i.e. Regulation 994/2010) is dedicated exclusively to implement measures to counteract gas SOS and its impact may be difficult to detect in the SOS indicator results as it is relatively recent. The other two regulations mostly focus on the establishment and strengthening of the internal energy market and not so much on oil and gas SOS. However, they are usually catalogued as SOS policies since the EC considers that a strong, liquid, functional internal energy market will counteract risks associated to disruptions in oil and gas supply.

- **The low stringency level of the policies led to limited outcomes:** The indicator results show that in general, the oil and gas SOS of the EU 15 decreased between 1994 and 2016 which means that policy enacted to enhance SOS has not been efficient. The underlying reasons behind this inefficiency is that there are not enough legally binding policies directly related to SOS, and the few that exist, lack stringency. However, before issuing any policy, the EC has to reconcile the diverse interests among EU Member States which means that the rules that everyone agrees upon, are the result of compromises and negotiations. Since energy is a matter of national security and sovereignty, Member States are not willing to compromise significantly, which ultimately results in low levels of stringency. This characteristic leads to what Scharpf (1988) called a joint-decision trap that leads to suboptimal policy outputs, with limited outcomes.

However, while this characteristic of the European Union helps understand the difficulties involved in drafting common energy policy, it does not explain the progress that has already taken place. Examples of this progress are (i) The EU competition rules – which prohibit companies to abuse their dominant position. The EC has broken up monopolies in the past (e.g. Norwegian gas exporter GFU) as well vetted and cleared a number of mergers and acquisitions. (ii) Article 11 of the 2009 Gas Directive (also known as the Gazprom clause): Security of supply risks need to be accounted for when Member States revise third-country firm acquisitions, ownership and operation of gas transportation networks (Goldthau & Sitter, 2014).

Pollack & Slominski (2011) also defend the role of the EC as an international energy governance body and its intervention on SOS by arguing that the driving force behind the progress witnessed across the EU, has been a result of the EC efforts and exploit of formal and informal instruments at its disposal granted by the EU's regulatory framework. First, the EC relies heavily on the powers that were granted on the fields of competition and supremacy of EC law. This allowed them to deal with energy companies directly, bypassing the involvement of individual Member States. Secondly, thanks to the EC's activities, the EU has adopted several forms of directives (e.g the gas and electricity directives) which have been steadily improving. The EC has also established informal bodies and a regulatory network of regulators where public and private stakeholder discuss regulatory issues, identify implementation problems and discuss future plans for regulation. However, despite all these achievements, questions still remain among governance scholars regarding who is the optimal actor to promote SOS in the region. On one hand, some scholars argue that the problem requires a European wide solution and that the EC is the actor that is best suited to come up with solutions, while others argue for a subsidiarity approach in which Member States are better off promoting national solutions (Hadfield, 2011).

Going forward, the EC should continue its long term strategy to mitigate oil and gas SOS risks through strengthening the internal energy market by addressing the current market failures. Moreover, while this study focused on the SOS of oil and gas specifically, the deployment of renewable energy capacity is a better long term strategy to mitigate SOS risks, since: (i) Contrary to oil and gas, the production of renewable energy is indigenous (ii) The supply of renewable energy is independent from international markets and political situations and (iii) The production cost of renewable energy is generally a fixed cost. In the short-term given the fixed production technology, the price fluctuation is rather modest and independent from international energy prices (Chuang & Ma, 2013). Fortunately, the EC acknowledges the deployment of renewable energy as a key strategy to tackle not only risks associated to oil and gas disruptions but also climate change. For this purpose, the EC has enacted several policy instruments with binding consequences such as the (i) Directive 2009/29/EC which relates to the green house emission allowance trading scheme of the EC (ii) Directive 2009/28/EC that promotes the use of renewable sources and (iii) Regulation 443/2009 which sets emission performance standards for new passenger cars (Vis & Delbeke, 2016). Additionally, other less stringent more well-known policy instruments have been issued to promote renewable energy such as the Climate Package or the Low Carbon Roadmap.

VII.- Limitations of the study

Evidently, there are some limitations to the present study which are briefly discussed in this chapter.

1. Even though the data sources used were made by reputable institutions such as the World Bank or the EC, there is a certain degree of uncertainty which is difficult to quantify. The available resources issued by these institutions only provide a high level explanation of how the statistics are collected and transformed into output data which hinders the identification of possible sources of error or data incompatibility.
2. The indicators that were assessed through the USAID framework, were limited to the indicators mentioned by Kruyt et. al (2009). SOS has gained relevance among researchers, and thus more SOS indicators have been devised since 2009 which factor in different variables that contribute to SOS. By limiting the indicator analysis to those mentioned by Kruyt et. al (2009), there may have been some more suitable indicators that were left outside the present study.
3. The chosen indicators to assess oil and gas SOS have a few limitations which were discussed with detail on Chapter 5.1. The main ones were: (i) The ML indicator makes the assumption that all of the oil and gas produced in the world in a yearly basis is available to the EU 15 market. (ii) The OVI indicator is an oversimplification of factors that affect a country's vulnerability to oil disruptions (iii) The ESI Price indicator devised by the IEA doesn't account for the weight of the fuel's net import in the total TPES of the fuel, which leads to erroneous interpretations of the results. (iv) The SOZCF indicator was not considered to be an appropriate measure of the acceptability of oil and gas and (v) The supplier diversity indicator doesn't account for the geopolitical risk of the countries that export oil and gas to the EU 15 Member States.
4. This study only focused on the SOS of oil and gas however a decrease on the SOS of these fuels doesn't necessarily entail a decrease of the SOS of the energy system. A more complete SOS study would consider all the energy sources that constitute the energy mix, however there is a significant lack of studies that devise indicators for this purpose.
5. The discussion of results centred mostly on the indicator results of EU 15 arithmetic average. This approach may lead to wrong generalisations as individual Member State's performance may have been significantly different that the average EU15 performance.
6. Table 11 contains the equation and R^2 value of the trend line that was obtained for the average indicator value of the EU 15 data. These values alongside the obtained equation were used as a supporting tool to identify the trends observed in each of the chosen indicators however since most indicators showed a tendency, they had limited applicability. The highest R^2 values were obtained for the following indicators: Market Liquidity of Oil (0.96) and the SOZCF (0.94). This means that if the behavior of these two indicators was to be predicted for the following years, the equation obtained could be a good model to forecast data points. The rest of the indicators display medium or low level of R^2 which makes the obtained equations unfit to predict future behaviors since the data points obtained for previous years display a high level of variability.
7. The output and outcome assessments that were conducted to complement the indicator analysis, were of a qualitative nature which entail a certain degree of subjectivity. To counteract the subjectivity of this qualitative analysis, a literature review was performed to compare the findings of the present study and the findings of other authors. In most cases, the results of this study were consistent to those found in literature.

Table 11: Result overview per indicator and their respective impact on oil and gas SOS

SOS Element	Indicator	Equation	R^2	Indicator Tendency	Effect on SOS
Availability	Market Liquidity Oil	$y = -0.0002x + 1.4347$	0.9648	↓	↓
	Market Liquidity Gas	$y = -0.0002x + 1.3712$	0.6675	↓	↓
Affordability	Oil Vulnerability Index	$y = 0.0005x - 1.0179$	0.6177	↑	↓
	IEA's ESI Price - Oil	$y = -0.0025x + 5.1486$	0.622	↓	↑
	IEA's ESI Price - Gas	$y = 0.0015x - 2.9826$	0.3518	↑	↓
Acceptability	SOZCF	$y = 0.0049x - 9.536$	0.9413	↑	↓
Accessibility	Supplier Diversity - Oil	$y = 0.013x - 24.656$	0.7376	↑	↑
	Supplier Diversity - Gas	$y = 0.0038x - 7.438$	0.2135	↑	↑

VIII.-Conclusion

The purpose of this research was to analyse the evolution of oil and gas SOS in the EU 15 from 1994 to 2016 and determine to what extent the findings could be attributed to the policies drafted by the EC to counteract energy supply insecurity. For this purpose, twenty-seven SOS indicators identified by Kruyt et al. (2009) were evaluated through the USAID framework to determine their suitability, applicability and coverage of all aspects entailed in the chosen definition of SOS. As a result from this evaluation, the following six indicators were chosen to conduct the quantitative study of the evolution of the four main elements of SOS: (i) Oil and gas Market Liquidities which measured the availability of oil and gas (ii) Oil Vulnerability Index and IEA's ESI Price which measured the affordability of oil and gas (iii) Share of zero carbon fuels in the energy mix as a measure of acceptability and (iv) Supplier Diversity to measure the accessibility to oil and gas resources. Additionally, other indicators were used as support material to explain some of the tendencies observed such as TPES by source, oil and gas trade, oil price, etc.

The results show that on a year to year basis (2016 vs 1994), the SOS in the EU15 has diminished over time, meaning that Member States have increased their risk exposure to oil and gas disruptions. Although generalizations are hard to make due to the specific characteristics of each Member State, the following key points provide an explanation to the overall trends observed: (i) There is a decrease in the consumption of oil and gas in the region driven mostly by a decrease in energy intensities and a higher penetration of renewable energy in the total primary energy supply. (ii) Member States have increased their import dependency over time. While some Member States have managed to successfully diversify their portfolio of oil and gas suppliers (i.e Spain, X and X), others still depend highly on oil and gas imports from fellow Member States whose oil and gas production is expected to decline in the near future (i.e. U.K and the Netherlands) (iii) Member States are still highly exposed to the price volatility of oil (and gas) which means that increasingly a higher portion of their GDP needs to be allocated towards oil imports.

Additionally, an individual analysis by Member State of the evolution of oil and gas was also conducted. This assessment was performed by identifying the five Member States who displayed the best, medium and bad results for every indicator during the period analysed. The results show that the Member States who displayed the most favorable oil and gas SOS results in the EU 15 were Germany, France, Spain, Italy and the United Kingdom. The Member States that displayed medium performance results for oil and gas SOS were Austria, Greece, the Netherlands and Luxemburg. Finally, the Member States which displayed the least favorable results of oil and gas SOS were Portugal, Belgium, Ireland, Denmark, Sweden and Finland. The reasons that explain the individual performances of each Member State differ greatly but ultimately stem from the unique characteristics of their energy systems.

To complement the analysis of the effectiveness of the energy policies related to oil and gas SOS, a governance framework was adapted to also include the outcome and the output of the policies. For this purpose, a literature search was conducted to first identify all of the policies related to oil and gas SOS. The result of this analysis showed that even though several policy instruments have been devised by the EC to enhance the SOS in the EU, only three of them have materialized into legislative acts with binding consequences, namely the Energy Charter Treaty, the Gas Directive of 2009 and Regulation 994/2010. The content of these policies was analysed to determine their stringency, the level of compliance and the level of uptake by the EU 15 Member States. The results show that: (i) The stringency of the rules is low since they lack enough level of detail and do not set quantifiable targets for performance and management and (ii) The level of uptake of the policies is high since countries inside and outside the EU 15 have willingly embraced the policies. The high level of policy uptake witnessed across the EU 15, is a consequence of low stringency levels embedded in the policies in question.

Based on these results, the energy policy drafted by the EC to counteract oil and gas supply disruptions was proven to be inefficient which is finding that is consistent not only with the results from the indicators, but also with similar comparable studies. This is largely explained by the diverse energy interests among EU Member States, which in turn reflect the intra-EU variety of energy mixes and different degrees of import dependencies that hinder the EC's objective to issue common energy policy. Moreover, there seems to be no correlation between the policies issued by the EC and the SOS indicator performance which means that (i) the differences in national energy policies have a higher impact on oil SOS than EU common energy law and (ii) That there are other factors in the global market development that have a bigger impact on the indicator results. However, despite the unfavorable results the role of the EC should not be undermined since the main strategies the EC has against oil and gas disruptions are to: (i) Strengthen the oil and gas Single Market of the EU 15, a clear objective of the Gas Directive and (ii) Foster international cooperation which is the main objective of the Energy Charter Treaty. Both of these strategies are well embedded in the objectives in the policy instruments in question however the outcomes have been limited because the rules are not stringent enough. Moreover, there have been a few positive outcomes that have been a result of the EC's legislative effort, namely the dissolution of energy conglomerates (Norwegian gas exporter GFU) and the introduction of the so called Gazprom clause which makes it mandatory for Member States to weigh in SOS risks when revising third-country firm acquisitions.

Furthermore, this analysis also showed that it is really difficult to determine the extent to which the results from the indicators used to study the evolution of SOS in the EU 15, are influenced by the policies issued by the EC. The analysis of the content of the policies provided some insight into the reason why, despite all the policies that have been issued by the EC to counteract oil and gas SOS risks, there appears to be no impact on the indicators: only Regulation 994 has binding consequences to all EU 15 Member States and directly deals with gas SOS. This regulation was issued in 2010 and thus, it might be either too early to impact the indicator results, or the policy has proven ineffective since the internal EU 15 oil and gas market is not resilient enough to counteract the external factors of the international oil and gas markets.

Further research should focus on analysing the individual national policies that led to different SOS results as well as: (i) Conducting a long term study of the SOS evolution of the EU 15 Members taking into account all the energy sources (ii) Developing indicators specialized in renewable energy sources (iii) A revision and update of indicators identified by Kruyt et al. (2009) and (iv) Develop additional indicators to measure the acceptability element of SOS.

Going forward, the EC should continue its long term strategy to mitigate oil and gas SOS risks through strengthening the internal energy market by addressing the current market failures in revised versions of current energy policy. Moreover, while this study focused on the SOS of oil and gas specifically, the deployment of renewable energy capacity is a better long term strategy to mitigate SOS risks. Fortunately, the EC has already acknowledged the importance of this strategy to not only increase SOS but also to combat climate change and has issued for this purpose, several policies. Arguably the EC is the most suitable institution in the world to lead the regulatory energy landscape due to its vast experience in related matters. Therefore, energy authorities across the globe will be closely watching any regulatory developments issued by the

EC as their hits and misses provides useful energy governance insights not only into SOS but also into the complex issues that constitute the energy landscape.

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X.-Appendixes

Appendix A.- Indicator Overview

(i) Reserves Estimates

This indicator expresses the quantity and likelihood of occurrence of oil and gas resources. There are several methods and considerations to estimate the oil and gas reserves of a particular field and therefore it is advised to only use the data from one single data source as the numbers can differ depending on the preferred estimation method. An example is shown on Figure 1 where the authors compared the global estimates of technical recovered shale gas reported by different academics and institutions (McGlade et. al, 2013).

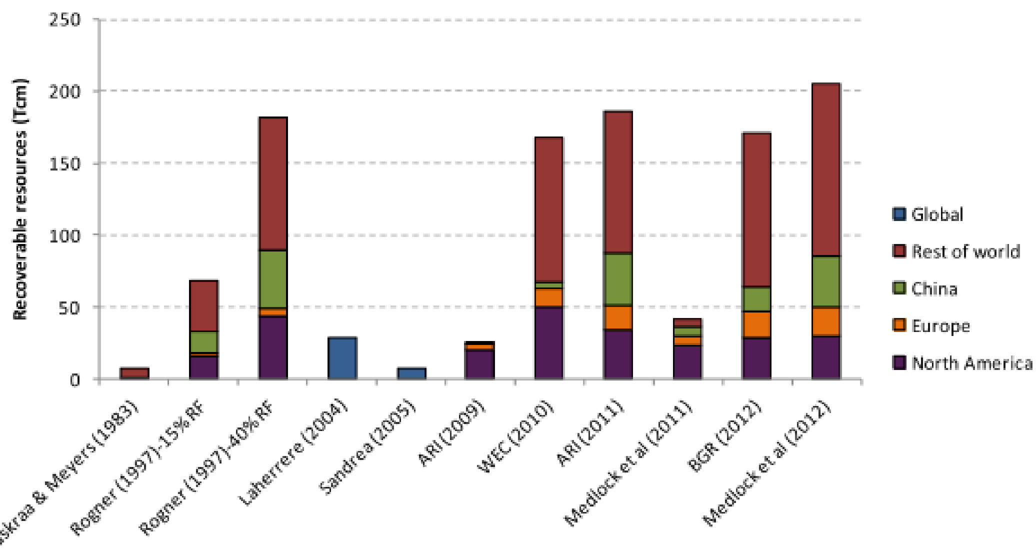


Figure 1: Global estimates of shale gas resources. Note: Different studies cover different countries and regions and none provide a truly global estimate.

(i) R/P ratio

The existence of energy sources is crucial for ensuring SOS and thus it is often used as an indicator such as the oil and gas reserve estimates or the R/P ratio (Equation 1). The latter provides a more comprehensive assessment of resource availability since it indicates how many years of oil or gas a country still has at its current production levels.

Eqn. 1

$$\frac{R}{P} = \frac{FFR_{Ci}^{Yi}}{FFP_{Ci}^{Yi}}$$

Where:

FFR_{Ci}^{Yi} Oil and gas reserves of country i in year I [mtoe]
FFP_{Ci}^{Yi} Oil and gas production of country i in year I [mtoe]

The R/P ratio is a dynamic quantity since the amount of oil and gas reserves a specific region changes continuously as new oil and gas deposits are discovered, new technologies emerge which allow the extraction of previously unrecoverable oil or the production of a country varies.

(ii) Investments

It has been argued that underinvestment in long-term SOS leads to increased risk of supply disruptions (International Energy Agency (IEA), 2007). Therefore, a continuous monitoring of the investments can provide not only an overview trend in the energy sphere but also SOS vulnerabilities due to underinvestment.

(iii) Market liquidity

This indicator measures the capacity of markets to cope with fluctuations in supply and demand (i.e market's ability to purchase or sell an asset without affecting the price).For this purpose different actors have developed their own methodology to measure market liquidity. The IEA, for example, has created a market liquidity measure where they define an exponential function of the ratio of a country's consumption over the total of the fuel available on the market (Lefèvre, 2007). Islam et al. define market liquidity as the oil availability in the world market against the portion of oil demanding the domestic market that cannot be supplied by the local oil production. Thus, high market liquidity expresses the necessity for extra oil supply from another country. A close relation exists between market liquidity and SOS in balancing the fluctuation of demand and supply of fuels in the market (Islam et al., 2014).When dealing with stock markets, a coefficient of elasticity trading has been suggested as a potential indicator of market liquidity (Datar, 2000)called coefficient of elasticity trading which is defined as:

$$CET = \frac{\%\ Change\ in\ trading\ volume}{\%\ Change\ in\ price}$$

Values below the unit indicate an inelastic market while values above unity indicate elastic markets.

(iv) IEA's ESI Price

The IEA devised an indicator of the price component of energy security which measures the market concentration in each international fossil fuel market (ESCM). For countries in particular, it weights the relative importance of ECSM based on the exposer of the country to each fuel (IEA, 2007). It also accounts for the political risk rating which refers to the risk faced by several actors (e.g investors, governments, corporations) that political decisions or certain events, could affect the profitability of a certain project. The rationale behind this indicator (Equation 2) lies on the following premise: the more a country is exposed to high concentration markets, the lower energy security. Additionally, price developments (e.g historical price trends) for fossil fuels will be included to facilitate the analysis of results and discussion.

Eqn. 2

$$ESI_{price} = \sum_{f}\left[\left(\sum_{i} r_i\, S_{if}^2\right)\frac{C_f}{TPES}\right]$$

Where:
r_i = political risk rating of country *i*
S_{if} = Share of supplier *i* in (fuel) market *f* [%]
$C_f/TPES$ = Share of fuel *f* in total primary energy consumption [%]

One of the major limitations of this indicator is that it was designed to evaluate the international fuel market and consequently, other sources of energy were neglected. Furthermore, since this index stems from the Herfindhal-Hirschmaan index it offers some difficulties to policy makers and other users when it comes interpreting the results (Jansen, Arkel, & Boots, 2004).

(v) Oil price

The price of oil has been frequently used as a direct measure of the affordability of this energy source. Several sources report the historic price of several oils that are used as a benchmark o reference price for buyers and sellers of crude oil such as ones the West Texas Intermediate (WTI), Brent blend and Dubai Crude.

Historically, the price of natural gas has been closely related to the price of oil until recently, where several scholars have noticed a decoupling in the price of these two energy sources due to increased shale gas production (Erdos, 2012). Therefore, if this indicator is chosen, the price of natural gas will also be included.

It is important to mention that oil and gas prices will be adjusted by inflation to reflect prices from 2016 using the following formula (Thompson, 2009):

Eqn. 3

$$Year\ y\ value * \left(\frac{index\ number\ for\ yearx}{index\ number\ for\ year\ y}\right) = year\ y\ value\ in\ year\ x\ prices$$

(vi) Mean Variance Portfolio (MVP)

This variable is more an optimisation method than an indicator (Kruyt, et al, 2009) as it provides a limit in the cost-risk domain beyond energy investment portfolios. It is useful for the analysis of energy portfolios by interpreting expected returns as the reciprocal of unit generating cost. For a simple two stock or technology portfolio, the return is given by:

Eqn. 4

$$E(r_p) = x_i E(r_1) + x_1 E(r_1)$$

Where:

$E(r_p)$ = Expected portfolio return

x_i = The share of asset i in the portfolio

$E(r_1)$ = Expected return for asset *i*

(vii) Non-carbon share

The APERC uses the share of zero-carbon fuels (Equation 5) to assess acceptability by taking into account the share of renewable and nuclear in the total primary energy supply (Kruyt, et al., 2009).

Eqn. 5

$$SOZCF = \frac{ZCFP_{Ci}^{Yi}}{TPES_{Ci}^{Yi}}$$

Where:
$ZCFP_{Ci}^{Yi}$ Zero carbon fuel production of country i in year i [mtoe]
$TPES_{Ci}^{Yi}$ Total primary energy supply of country i in year i [mtoe]

(viii) Bollen's indicator

Bollen & van der Zwaan constructed a "willingness to pay" function for implementation in a model. It aims to represent what percentage of GDP a country is willing to spend to mitigate or lower the SOS risks (Bollen, Hers, & van der Zwaan, 2010). The function is on the form of:

Eqn. 6

$$IMP_{t,r} = Ai_{t,r}^{\propto} C_{t,r}^{\beta} E_{t,r}^{\gamma}$$

Where:

$IMP_{t,r}$ Willingness to pay to avoid a lack in SOS [% of GDP]
i Import ratio of the fuel
c Share of the fuel in total primary energy supply
E Energy intensity
A region specific calibration constant relating to the SOS at *t=0*
α, β, γ exponents with a value of 1.1, 1.2 and 1.3 respectively

(ix) Market concentration

This indicator deals with price risk stemming from supply market concentration. To measure this indicator a Herfindhal-Hirschman Index is frequently used. Note that if each importing country is considered a supplier, then the market concentration is given by the following formula:

Eqn. 7

$$D = \sum_i p_i^2$$

Where:
p_i Market share of supplier country i

(x) Oil Vulnerability Index (OVI)

This composite indicator was developed by Gupta to assess the oil vulnerability of 26 net oil importing countries based on various parameters (Gupta, 2008): (1) the ratio of value of oil imports to GDP (2) oil consumption per unit of GDP (3) GDP per capita (4) oil share in total energy supply (5) ratio of domestic reserves to oil consumption (6) exposure to geopolitical oil supply concentration (7) market liquidity. These combined yield an overall index where the weighting is based on a statistical method called principal component analysis which transforms a number of correlated variables into a smaller number of uncorrelated variables called principle components. The formula is given by:

Eqn. 8

$$OVI = 0.26OI_k + 0.297\frac{VOM}{GDP}k + 0.216GDPpercapita_k + 0.08OS_k + 0.22GOMCR_k + 0.11ML + 0.07\frac{DR}{DC}k$$

Where:
OI_k Ratio of oil consumed in an economy to its GDP [toe/GDP]
VOM/GDP Ratio of value of net imports to GDP measured at the market exchange rate [%]
OS_k Ratio of oil consumption in total primary energy consumption [%]
$GOMCR$ Geopolitical oil market risk
ML Market liquidity
DR/DC Domestic oil reserves to total oil consumption

The main drawback about this particular indicator is that it requires a principal component analysis to express the results in a manageable scale from 0 to 1. Since this method requires a highly statistical and numerical analysis that is resource intensive, it was considered to be outside the scope of this analysis. However other formulas that are more simple exist to calculate an economy's exposure and thus vulnerability to oil disruptions such as the one proposed by the Energy Sector Management Assistance Program (2005) which consists of:

Eqn. 9:

$$V = \frac{NIV\$}{GDPC\$} = (P\$) * \left(\frac{NI}{OC}\right) * \left(\frac{OC}{EC}\right) * \left(\frac{EC}{GDPRL}\right) * \left(\frac{GDPRL}{GDPCL}\right) * (\frac{GDPLC}{GDPC\$})$$

Where:
$NIV\$$ Net import value in dollars, that is volume of net imports of oil and oil products per year in barrels' time annual crude price in current U.S dollars [USD]
$GDPC\$$ Value of GDP in current U.S dollars [USD]
$P\$$ Price of oil in current U.S dollars [USD]
NI Volume of net oil and oil product imports in barrels per year [boe/year]
OC Volume of consumption of oil products in barrels per year [boe/year]
EC Total primary energy consumption [Y BTU/ year]
$GDPRL$ Value of GDP in constant local currency
$GDPCL$ Value of GDP in current local currency

(xi) Supplier diversity

For every fuel, there is a potential for reducing risk by increasing the diversification among suppliers. The more suppliers (importing countries) a country has available to import energy resources from the more supplier diversity it has. The formula is a modified Shannon index (See the section on Fuel diversity) given by the following formula:

Eqn. 9

$$H_j = -\sum_i p_{ij} \ln p_{ij}$$

Where:
H = Shannon index: the higher value of H, the more diverse the system is
p_i = Share of importer country *i* in the energy mix of country *j*

(xii) Trade

This indicator is a simple measure of how much of the energy demand of a given country is met by international trade. This indicator differs from imports as it subtracts the total value of the energy exports that were made in a specific year:

Eqn. 10

$$NE_i = I_i - E_i$$

Where:
NE_i Net imports of energy source i, in country *i*, in year *i*. [mtoe]
I_i Imports of energy source i, in country *i*, in year *i*. [mtoe]
E_i Exports of energy source i, in country *i*, in year *i*. [mtoe]

(xiii) Net energy import dependency (NEID)

Shannon index for import dependency: The accessibility element of SOS for fossil fuels is often assessed by looking at import dependency. However, a more refined indicator devised by the APERC captures two elements of SOS namely import dependency and diversification, by adapting the Shannon index to measure an economy's import dependency weighted with its fuel diversity.

Eqn. 11

$$\textbf{(xiv)} \quad NEID = \frac{\sum_i mi*pi*lnpi}{\sum_i pi*lnpi}$$

Where:
mi = share in net imports of energy carrier *i*, in country *i*, in year *i*. [mtoe]
pi = the share of energy carrier *i*, in total primary energy supply of country *i* in year i [%]

(xv) Imports

The imports as a share of total energy consumption is often taken as an indicator of SOS. A rise in this parameter implies a lower degree of SOS since it leaves a country dependent on oil and gas imports vulnerable to supply disruptions or energy price increases (Cohen, Joutz, & Loungani, 2011).

(xvi) Political stability

This indicator is defined as the absence of civil wars, successful or attempted coups, frequently major constitutional changes, terrorism, corruption and expropriation (Posner, 1997). This factor influences the investment inflows in a country and therefore affects the access to resources such as oil and gas (Busse & Hefeker, 2007).

(xvii) Jansen et. al indicator

The authors of this study argue that little research has been done to construct long term indicators of SOS (Jansen et al., 2004). After an extensive literature research they determine that the best simple indicator for diversity is the Shannon index which was originally used as a quantitative measure of the richness component of diversity in species (Nagendra, 2002). This index was adapted in order to develop indicators that capture the following aspects of SOS: (i) Diversification of energy sources in energy supply (I_1) (ii) Diversification of imports with respect to imported energy sources (I_2) (iii) Long-term political stability in regions of origin (I_3) (iv) The resource base in regions of origin, including home/region itself (I_4).

Eqn. 12

$$I_1 = -\sum_i c_i{}^1 p_i \ln p_i$$

Where:

I_1 Energy supply indicator no. 1
p_i Share of primary energy source i in total primary energy supply

i 1…….M: Primary energy source index (M sources are distinguished
${c_i}^1$ correction factor to p_i for indicator I_1. All these corrections factors are equal to unity in case of the first indicator.
Eqn. 13

$$I_2 = -\sum_i {c_i}^2 p_i \ln p_i$$

Subject to:

Eqn. 14

$$ {c_i}^2 = 1 - m_i(1 - S_i^m / S_i^{m,max}) $$

Where:

I_2 Energy supply indicator no. 2
${c_i}^2$ Correction factor to p_i for indicator I_2
m_i Share of net import in primary energy supply of source *i*
S_i^m Shannon index of import flows of resource *i*

Eqn. 15

$$S_i^m = -\sum_j (m_{ij} \ln m_{ij})$$

m_{ij} Share of imports of energy resource I from region j in total import of source I
j 1…….N: index for (foreign) region of origin. A total number of N regions of origin are distinguished
$S_i^{m,max}$ Maximum value of Shannon index of import flows of resource i (equal to 2.77 for 16 regions of origin, excluding the home region)

Eqn. 16

$$I_3 = -\sum_i {c_i}^3 p_i \ln p_i$$

Eqn. 17

$$ {c_i}^3 = 1 - m_i(1 - S_i^{m*} / S_i^{m*,max}) $$

Eqn. 18

$$S_i^{m*} = -\sum_j (h_j m_{ij} \ln m_{ij})$$

I_3 Energy supply indicator no. 3 accounting for energy imports and the extent of long-term socio-political stability in regions of origin
h_j Extent of political stability in region j, ranging from 0 (extremely unstable) to 1 (extremely stable).
S_i^{m*} Shannon index of import flows of resource I, adjusted for political stability in the regions of origin
$S_i^{m*,max}$ Maximum value of aforementioned Shannon index (equal to value 2.77 for 16 foreign regions of origin)

Eqn. 19

$$I_4 = -\sum_i {c_i}^4 p_i \ln p_i$$

Where:

Eqn. 20

$$r_{ij} = Min\left\{\left[\frac{(R/P)_{ij}}{50}\right]^a ; 1\right\} (a \geq 1)$$

Eqn. 21

$${c_i}^4 = \{1 - (1 - r_{ik})(1 - m_i)\} * \{1 - m_i(1 - S_i^{m**}/S_i^{m**,max}\}$$

Eqn. 22

$$S_i^{m**} = -\sum_j (r_{ij} h_j m_{ij} \ln m_{ij})$$

I_4 Energy supply indicator 4, accounting for energy imports, political stability in producing regions and for the proven regional reserves with respect to annual production in the region concerned

r_{ij} Depletion index for resource i in import region j
r_{ik} Depletion index for resource i in home region k, for which indicators are determined (that is, OECD Europe)
$(R/P)_{ij}$ Proven reserve-production ratio for resource i in region of origin j

(xviii) S/D index

This index was designed for evaluating the long-term performance of SOS. It covers all relevant aspects such as demand, supply, conversion and transport of energy in the medium to long term

(Scheepers et al; 2006). For the calculation of this index a computer model has to be set up that represents the energy demand and supply structure of an EU Member State *(Figure IV*).

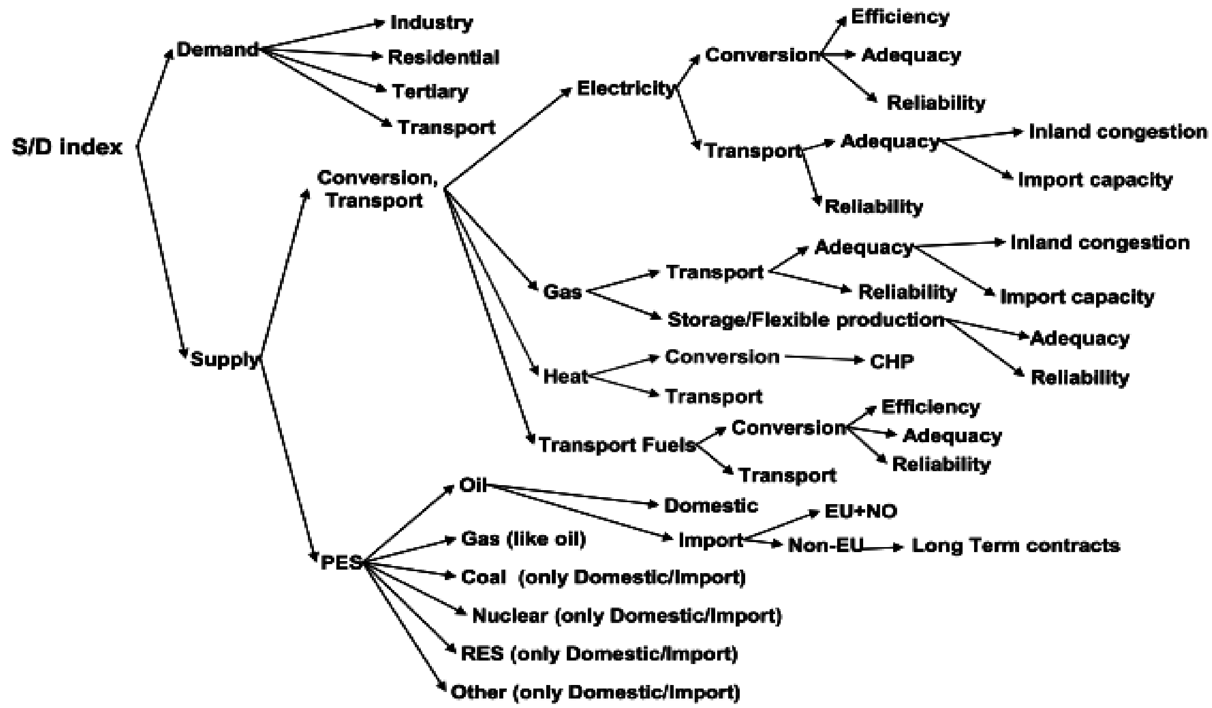


Figure 2.- S/D Model as devised by Scheepers et al., 2006

(xix) Fuel diversity

A quantitative measure can serve as a SOS indicator because diversity in energy type is thought to be an important means to hedge against supply risks. An index of diversity should have the following three key elements: (i) Variety (ii) Balance and (iii) Disparity. A good example is the Shannon-Wiener index which has been adapted by several authors to quantify the diversity in several fields. Neff for example used a variation of it to measure fuel diversity with the following formula (Neff, 1997):

Eqn. 23

$$H = \sum_i x_i^2$$

Where:
H = Shannon index: the higher value of H, the more diverse the system is
x_i = Fraction of total supply from source *i*

Appendix B: Rationale behind every indicator.

B.1 Reserves Estimates

Criteria	Grading	Rationale
Direct	3	The reserve estimates have been used in numerous occasions to assess the availability of fossil fuels in a given region (Martchamadol & Kumar, 2012). It measures directly the quantity and likelihood of occurrence of oil and gas resources, however it doesn't account for the production profile or gross inland consumption in the region being analyzed and therefore doesn't truly capture the physical availability of the resource as the production profiles aren't considered.
Objective	5	There is general consensus on how this indicator has to be interpreted.
Adequate	2	Since this indicator doesn't account for the consumption profile in the region being analyzed, it doesn't measure adequately the availability of oil and gas. Moreover, the region subject of this study is a net import region meaning that the existence of resources is limited and it is unlikely that the EC enacts a law that increases the amount of reserves in a region.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	3	This indicator is disaggregated as it doesn't include any operations or require any other input other than the amount of oil and gas reserves. Nevertheless, the data base that would be used, contains aggregated data on the amount of reserves of several of the EU15 Member countries which is not ideal.
Practical	5	The information is free to the public and available for the time period analyzed.
Reliable	3	Stakeholders that report oil and gas reserve estimates have different quantitative methodologies for determining this parameter that lead to polarized views on the status of these resources (Owen, Inderwildi, & King, 2010). However, the data source that would be used for calculating this indicator if selected, would be the BP Statistical Review of World Energy. This report is made in collaboration with the Society of Petroleum Engineers who set industry guidelines to avoid data misreporting (Society of Petroleum Engineers, 2017) and thus increases data reliability. The drawback about this indicator is that the data sources that would be used, only discloses disaggregated data for the four main gas producers in Europe and aggregates the production of all the other remaining

		countries. This reduces the transparency of the information and brings incoherence to the methodology od the present study.

B.2 R/P Ratios

Criteria	Grading	Rationale
Direct	3	Contrary to the reserves estimates, this indicator accounts for the production profile of the region at hand, as it shows the number of years that current oil and gas reserves would last at steady constant production rates. This indicator has been criticized in the past since it assumes a constant production rate which is an unrealistic assumption since it has been proven that the energy consumption growth is tied to economic growth (Belke et al, 2011). Arguably, since this study focus on historical data the real production rates figures could be used and this significant indicator drawback would be avoided. However, Kruyt et al. (2009) argue that the indicator might be way too simplistic in case of changing demand and/or highly uncertain reserve estimates.
Objective	5	There is general consensus on how this indicator has to be interpreted.
Adequate	2	By using real historic figures of the production patterns the adequateness of this indicator on assessing the availability increases significantly. However, it still has the potential drawback that it doesn't measure appropriately the availability of the resource as it doesn't account for consumption patterns or international trade. Moreover, the region subject of this study is a net import region meaning that the existence of resources is limited and it is unlikely that the EC enacts a law that increases the amount of reserves in a region.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	3	This indicator is disaggregated as it doesn't include any operations or require any other input other than the amount of oil and gas reserves. Nevertheless, the data base that would be used, contains aggregated data on the amount of reserves of several of the EU15 Member countries which is not ideal.
Practical	5	The information is free to the public and available for the time period analyzed.

Reliable	3	For the information listed in the analysis provided for the Reserves Estimate indicator, the R/P ratio is reliable since it's based on reports issued by BP in collaboration with the Society of Petroleum Engineers. However, for the reasons mentioned during the evaluation of the oil and gas Reserves of a country as an indicator the reliability decreases.

B.3 Investments

Since an adequate data base wasn't found for this indicator, it was inefficient to provide an assessment of this indicator for each of the two SOS elements this indicator is devises for. The following table assess the suitability of the indicator as whole**.**

Criteria	Grading	Rationale
Direct	3	Analysing the historic investment data of a region provides an overview of the overall trends in investment, from the financing for energy projects in different sectors to how oil and gas companies are responding to oil and gas price fluctuations. However, since most investments made in the energy sector come from the private sector, the investments tend to be profit-driven which means that companies will opt for the cheapest options but not necessarily the most secure ones (Keppler, 2007). Therefore, this parameter doesn't offer an ideal direct measure of SOS.
Objective	3	Although there is a general consensus on how this indicator should be interpreted, some authors argue that the interpretation of this indicator should be interpreted with certain precautions as increased investment isn't necessarily linked to increased SOS (Cherp & Jewell, 2014)
Adequate	3	The grade was given due to the reasons explained in the assessment of the directness of this indicator.
Quantitative	5	The input and output data is quantitative in nature
Disaggregated	2	The data source that was found for this indicator doesn't offer the required level of desegregation mainly because it doesn't show the investment made specifically in oil and gas.

Practical	1	The main drawback about this indicator is the lack of information available for the time period analysed. The World Bank created a database (World Bank, 2018) that contains the private energy investments per country however there are two main drawbacks associated to using this data base: (i) Government energy investments are not included (ii) The level of data desegregation isn't ideal (issue previously discussed).
Reliable	2	The IEA recently started issuing a report (WEI, 2018) that contains the worldwide investments made in each of the energy sectors. In their report they briefly mention the difficulties encountered while collecting the required information due to differences in the methodology used to measure investments mainly due to differences in data availability and nature of spending which collectively reduces data reliability.

B.4 Market Liquidity- Availability

Criteria	Grading	Rationale
Direct	5	With the purpose of assessing the availability of oil and gas, the IEA has devised an indicator that consists on an exponential function of the ratio of a country's consumption over the total fuel available on the market. Contrary to the R/P ratio, this indicator uses the consumption data of a country instead of the amount of reserves to determine the availability of oil and gas in a region which provides an extended and direct overview of the market.
Objective	3	No studies where found that use this indicator to assess the SOS of a particular region or country. This reduces the amount of available information on the interpretation of results in order to determine whether or not there is general consensus on its interpretation. However, the IEA is a respected institute in the energy sphere and often set the industry standards to conduct research, therefore a 3 will be given in this criteria.
Adequate	5	This indicator uses as input data variables that directly and adequately reflect the availability of energy sources in a country.
Quantitative	5	The input and output data is quantitative in nature.

Disaggregated	3	Since the indicator is an exponential function, it offers a lesser degree of desegregation. Moreover, its interpretation is not as obvious as the R/P ratio or other indicators made to assess the availability of energy sources.
Practical	5	The required information can be calculated from data that can be easily obtained using the free data bases made available to the public by Eurostat.
Reliable	4	The indicator accounts for the main variables that affect the availability of the source in a country. However, a lot of the required data requires additional calculations that require a lot of time to compute.

B.5 Market Liquidity - Affordability

Criteria	Grading	Rationale
Direct	2	When it comes to stock markets, the market liquidity indicator can determine their elasticity which indicates how sensitive is the stock price to a change on its supply or demand. In the oil context, the International Petroleum Exchange (now ICE) was created to exchange futures and options related to a specific type of crude produced on the North Sea called Brent. Later, more commodities were added such as gas, electricity, and coal contracts. This market is complicated to understand as it doesn't obey the standard economic principle where the price is determined by supply and demand of the physical good but by the oil futures market were several speculations based transactions determine the price (Carollo, 2012). Therefore, this indicator doesn't provide the desire degree of directness.
Objective	2	Even though the coefficient of elasticity is an indicator commonly used in econometrics, there is no general consensus on how this indicator should be interpreted within an energy context where the future market influences the price of the commodity more than availability of the commodity in question.
Adequate	2	Since the prices of this market are based on speculation more than in the supply and demand of the physical good, it is a poor indicator of the physical availability of oil.

Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	3	Due to the reasons mentioned above there isn't a sufficient degree if disaggregation due to the complexity of the market in question.
Practical	1	The information required to calculate this indicator isn't available for the time period analysed.
Reliable	3	The information is reliable however the indicator isn't for the reasons given above.

B.6 IEA's ESI Price

Criteria	Grading	Rationale
Direct	3	This indicator doesn't directly assess the affordability of oil and gas sources since a close analysis of the variables involved point to another element of SOS: availability. The rationale behind this argument is that the indicator relies on the premise that the more a country is exposed to high concentration and risky markets, the higher the chance of a disruption in supply and thus less availability and accessibility.
Objective	3	Only the IEA uses this index as a measure of affordability. There is no general consensus on how this indicator should be interpreted because it hasn't been used by other scholars. Furthermore, since this index stems from the Herfindhal-Hirschmaan index it offers some difficulties to policy makers and other users when it comes interpreting the results (Jansen, Arkel, & Boots, 2004).
Adequate	2	This indicator doesn't assess the affordability of oil and gas resources due to the reasons mentioned above.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	1	This indicator is categorized as an aggregated indicator.

Practical	3	The information can easily be obtained from the Eurostat Energy Balance, the World Bank and the Market Access Data Base issued by the European Commission. The only resource intensive data requirement would be the data base crossover to determine the risk associated to importing oil and gas from countries that have different levels of geopolitical stability.
Reliable	4	Since the index was devised by an international authority within the energy sphere, the indicator provides certain degree of reliability since it was constructed by experts in the field. The databases that would be used to construct this indicator also come from reliable sources.

B.7 Mean Variance Portfolio Theory

Criteria	Grading	Rationale
Direct	2	This indicator is used by firms to decide which investments they should pursue based on how much risk they are willing to take in exchange of different levels of return. Since Bar-Lev and Katz used for the first time the Mean Variance Portfolio Theory to assess fossil fuel procurement in the U.S electricity industry , the applications in the energy field have increased. Nowadays it is used mostly to forecast and model future possible scenarios in order to determine the best outcome, instead of doing a time series back casting analysis like the one intended in the present master thesis (Roques et al, 2008). Moreover, there were no studies found that use MVPT to assess the SOS of a region or country and therefore evidence suggests that this indicator is used for other purposes in which companies or firms are the interested party.
Objective	2	Since the indicator hasn't been used to assess the SOS of a country or region, there is no general consensus on how the results should be interpreted.
Adequate	2	This indicator is used for forecasting purposes instead of a time series analysis.
Quantitative	5	The input and output data is quantitative in nature.

Disaggregated	2	This indicator is categorized as an aggregated indicator and therefore provides an insufficient level of disaggregation that could lead to missed opportunities to identify trends and insights.
Practical	1	In order to calculate this indicator, the associated risk to every energy producing asset is needed (i.e. the risk of source of energy involved in the total primary energy supply of a country) for every country in the EU15 from 1994-2016. This data is unavailable and therefore the selection of this indicator is unviable.
Reliable	2	The unreliability of this indicator relates to all the assumptions behind conducting a risk assessment of the total primary energy supply of a country.

B.8 Share of Zero Carbon Fuels

Since Kruyt et. Al only identified only one indicator to assess Acceptability and the purpose of this study was to evaluate SOS from the four elements, this indicator was chosen as it its the only option. Nevertheless, the table was made to provide consistency.

Should I consider another indicator to measure acceptability in the context of climate change? Maybe CO2 emission per unit of energy consumed is a good one. (See the Taiwan article).

Criteria	Grading	Rationale
Direct	3	The SOS element “Acceptability” only has one indicator identified by Kruyt et al. that is used continuously by the APERC, however the analysis of results should be carefully conducted since there are several interpretations and explanations on the overall increase or decrease of the share of non-carbon sources in the energy mix.
Objective	3	There is general consensus on how the results should be interpreted, however authors argue that in the context of climate change there are other Acceptability indicators that are more suitable for SOS studies such as the CO2 Emissions per unit of energy consumed (Chih Chuan M. & Wen Ma H., 2013)

Adequate	3	The validity of this indicator relies on the assumption that the more accepted a certain energy source is, the larger the share of this source on the country's energy mix will be. This isn't necessarily true as governments might have chosen in the past to prioritize the economy over the environment, giving then a higher share to fossil fuels than to renewable sources.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	5	Since the indicator is a simple division of two concepts that are really common and easy to understand, the indicator provides sufficient desegregation level that doesn't leave a lot of room for interpretation.
Practical	5	The required data can be acquired easily from the Eurostat Energy Balance.
Reliable	4	The databases that would be used to construct this indicator also come from reliable sources however there aren't a lot of studies that use this indicator as a measure of acceptability other than those conducted by the APERC.

B.9 Bollen's Indicator

This indicator requires a MERGE (Model for evaluating regional and global effects of GHG reduction policies) model which consists of the three different modules that are linked that represent the major processes of interest: (i) the cost of reducing the emissions of radioactively important gases (ii) natural system disposition and reactions to the emissions of these gases and (iii) the reaction of human and natural systems to changes on the atmospheric/climate system .Through this model, the Bollen's indicator can be calculated by implementing a willingness to pay function which represents what percentage of GDP a country is willing to spend in order to lower SOS risks. Since setting up a MERGE model is outside the scope of this study as building it is very resource intensive, this indicator will not be considered.

B. 10 Market concentration

Criteria	Grading	Rationale
Direct	3	The Market Concentration index is usually used to measure the combined market shared of the most important companies in a given industry (usually the top 5). If these firms hold a large portion of the market share, the industry in question is highly concentrated and therefore tends to be oligopolistic. This index can also be used to measure concentration across several

		industries such as the energy field, where a variation of the Herfindhal-Hirschman Index is frequently used. In this particular study, this indicator could be used to assess the concentration of the energy imports of a given country and determine whether or not the country in question has increased their risk exposure by increasing their dependence on the energy imports of a given country and limiting their suppliers. However, there are other indicators in this study that weigh in the geopolitical risk of the importing country and thus, much be a better suitor to directly assess the SOS.
Objective	4	In competition law and antitrust, there is a general consensus that a lower value of market concentration generally indicates a loss of pricing power and an increase in competition.
Adequate	3	This indicator by itself isn't ideal since relying only on its results might lead to mistaken conclusions. Imports are not the only mechanism to gain access to energy sources and it is only appropriate for those countries who are net importers of energy. Jumping to these mistaken conclusions could be avoided by relying on other indicators to appropriately interpret the results.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	3	The index is an aggregated index.
Practical	3	The information can easily be obtained from the Eurostat Energy Balance and the Market Access Data Base issued by the European Commission. The only resource intensive data requirement would be the data base crossover to determine the origin of the imports from every country.
Reliable	4	The method used to measure market concentration and the data are reliable as they have been used numerous times across several fields.

B.11 Oil Vulnerability Index

Criteria	Grading	Rationale

Direct	5	This indicator captures the relative sensitive if various economies towards developments of the international oil market, with a higher index indicating higher vulnerability (Gupta E., 2008). This indicator assesses the macroeconomic effects due to erratic price fluctuations in the market and thus makes it a direct measure of the affordability element of SOS.
Objective	5	There is general consensus on how the results should be interpreted.
Adequate	4	This indicator is adequate when assessing oil importing countries, which fortunately applies to the EU15, however it wasn't built to assess the SOS of natural gas.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	1	The indicator is highly aggregated.
Practical	1	This indicator requires a lot of data compilation which can be resource consuming.
Reliable	3	The authors used a method called principal component analysis that consists on a multivariate statistical approach to determine the weights of each SOS component. Even though the paper contains a detailed description on the methodology that was used to determine these weightings, there is still a high degree of uncertainty related to the assumptions that are not listed.

B.12 Supplier diversity

Criteria	Grading	Rationale
Direct	3	This indicator measures the supplier diversification of oil and gas importing countries to determine their exposure to supply disruptions. However, as it has been discussed before, importing countries can reduce their exposure by entering in trade agreements with countries that have low geopolitical risk.
Objective	3	This indicator doesn't objectively assess the accessibility to energy sources as it fails to capture the risk associated to the dominant positions that exporting countries hold among countries who depend on energy imports.

Adequate	3	The indicator doesn't properly measure what it is intended to assess due to the reasons provided above.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	3	It is an aggregated index.
Practical	3	The information can easily be obtained from the Eurostat Energy Balance and the Market Access Data Base issued by the European Commission. The only resource intensive data requirement would be the data base crossover to determine the origin of the imports from every country.
Reliable	4	The information to be used comes from a reliable source however there are some doubts regarding the reliability of this indicator.

B.13 Trade

Criteria	Grading	Rationale
Direct	4	This indicator was categorized under the accessibility element of SOS. It is a good initial indicator to determine whether a country is a net importer or a net exporter of energy carriers. Since a lot of indicators were devised for energy importing countries (e.g. Oil Vulnerability Indicator, Net energy import dependency, ESI Price) it is useful to use this indicator to determine the suitability of this indicator to the trade profile of every country. However, this indicator by itself doesn't adequately assess the availability of energy sources and should be complemented by additional indicators that collectively provide an integrated overview of the trade profile of a country.
Objective	5	There is general consensus about how this indicator should be measured and interpreted.
Adequate	4	This indicator needs to be adjusted in order to adequately assess the availability of energy sources. Since the research subject of the master thesis is the EU15, then adjustments to the data need to be done to correct the import and export data within Member States of the EU15.

Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	5	The indicator has a sufficient level of disaggregation since there is a general consensus on what the minus or plus sign mean.
Practical	3	The information can easily be obtained from the Eurostat Energy Balance and the Market Access Data Base issued by the European Commission. The only resource intensive data requirement would be the data base crossover to determine the origin of the imports from every country.
Reliable	5	This indicator is used in several analysis across several industries due to its reliability and practicality.

B.14 Net Energy Import Dependency (NEID)

Criteria	Grading	Rationale
Direct	4	This indicator accounts not only for the import dependency of a specific energy carrier of the country but also its weight in the overall total primary energy supply making it a more suitable indicator than those which only reflect import dependency.
Objective	4	There is a general consensus on how the results should be interpreted, however only a limited amount of sources has used this indicator to assess SOS and therefore there are not many sources to conduct a comparison analysis on the interpretation of results (APERC, 2007).
Adequate	2	Contrary to other indicators, doesn't account for the risk associated to the country where the energy source is imported from. Moreover, a disaggregation between oil and gas is preferred if the indicator allows it. However, if the indicator is to be disaggregated, then terms of equation would cancel out and as a result, the indicator would only reflect the net imports from outside the EU15 divided by the net imports from energy sources. The last variable cannot be adjusted to exclude intra EU15 trade movements (See the practicality grading in this table).
Quantitative	5	The input and output data is quantitative in nature.

Disaggregated	2	The indicator is aggregated.
Practical	1	The calculation requires to know the share in net imports of energy carrier i, in country i in year i. This would have to be calculated by dividing the total net imports from countries outside the EU 15 of energy carrier *i*, in country *i*, in year *i* by the total net imports of energy from all sources. The last variable can't be adjusted to remove the trade amongst EU 15 Member States since there isn't a data base available that discloses the amount of renewable and nuclear energy traded by source of origin from 1994 to 2016 (e.g. According to Eurostat, Austria imported in 1994, 127 ktoe of renewable energy, however there is no data base that discloses the origin from this energy and thus a data correction could not be made). This limitation about the international statistics on climate relevant trade has been previously identified by the OECD who points out that the trade classification system poses several challenges for energy systems researchers (OECD, 2009).
Reliable	4	The information to be used comes from a reliable source.

B. 15 Imports

Criteria	Grading	Rationale
Direct	2	This indicator fails to capture several elements of SOS since it provides a very simplistic approach to assess the accessibility of the energy source.
Objective	3	Even though there is general consensus on how this indicator should be interpreted, by itself it doesn't provide useful insights.
Adequate	2	This is not an adequate indicator as it doesn't account for a lot of variables that significantly affect the accessibility to energy sources.
Quantitative	5	The input and output data is quantitative in nature.
Disaggregated	5	The indicator is highly aggregated.

Practical	5	The information can be easily obtained from the Eurostat Energy Balance and no additional calculations or adjustments need to be done.
Reliable	1	The information to be used comes from a reliable source however as discussed before, is not a reliable indicator.

Appendix C: Line regression equations and R2 graphs obtained for the EU15

Availability

A) Market Liquidity

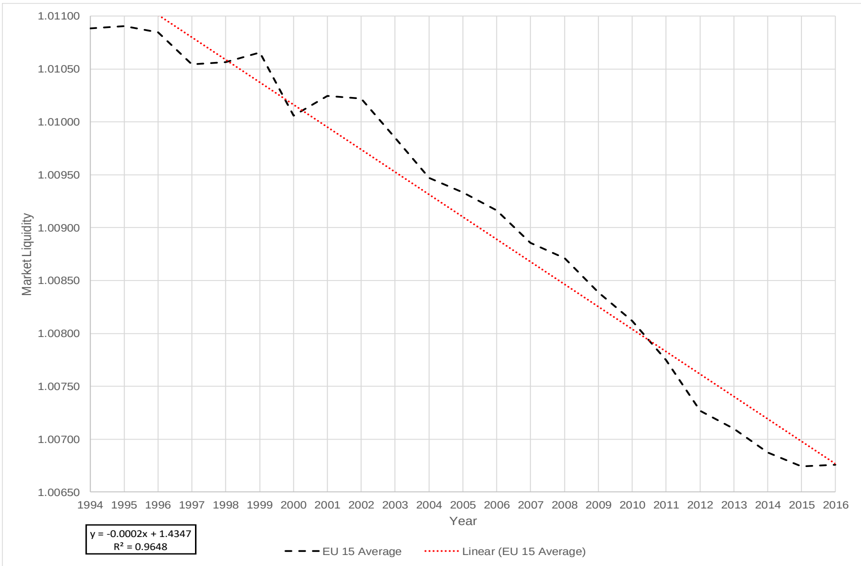


Figure 1: EU15 Market Liquidity for Oil from 1994 to 2016.

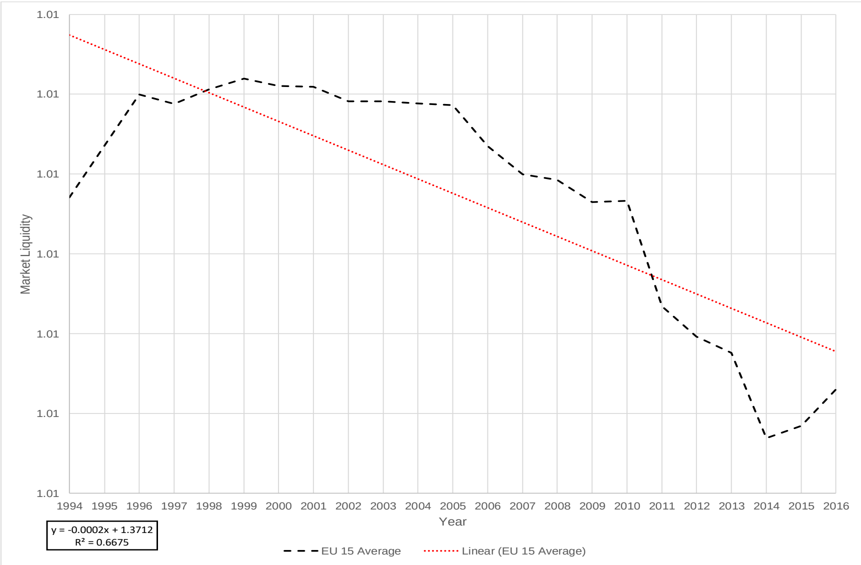


Figure 2: EU15 Market Liquidity for Gas from 1994 to 2016

Affordability

A) Oil Vulnerability Index

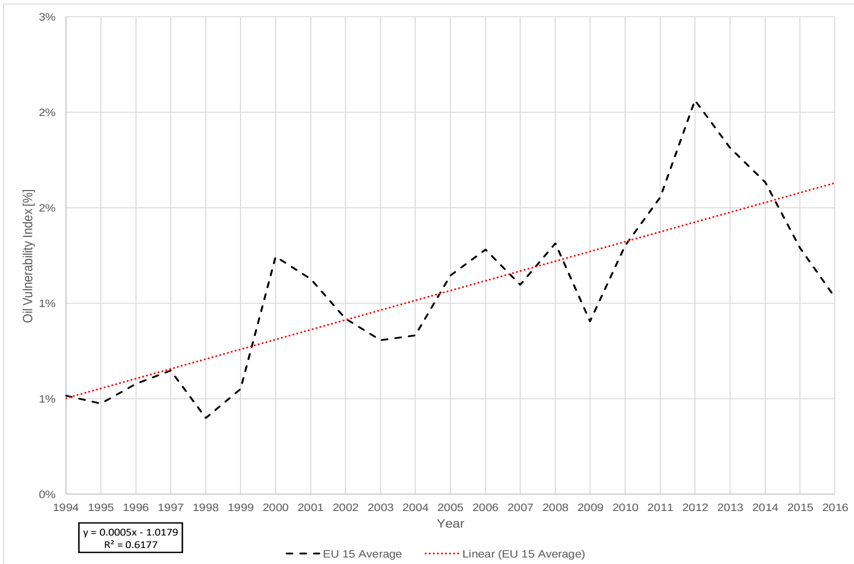


Figure 3: EU15 Oil Vulnerability Index for Oil from 1994 to 2016

b) IEA's ESI Price

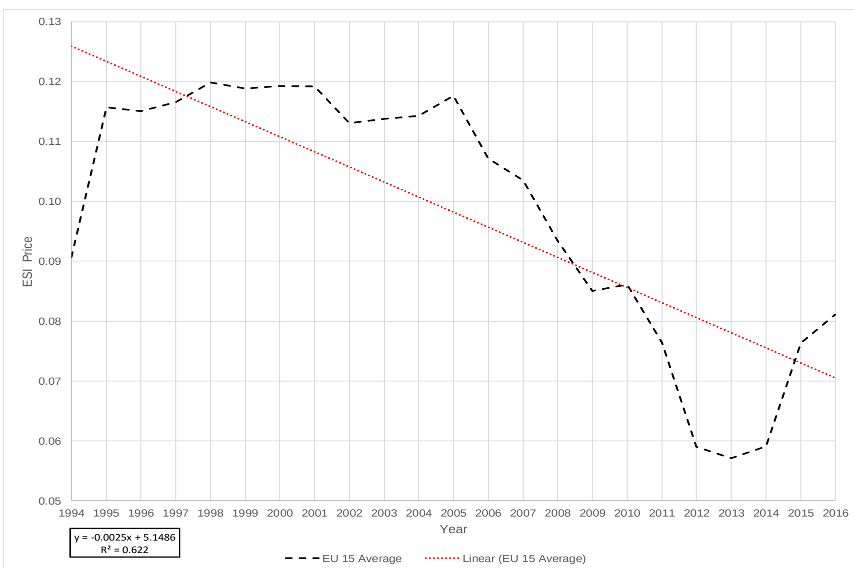


Figure 4: EU15 Oil IEA's ESI Price from 1994 to 2016

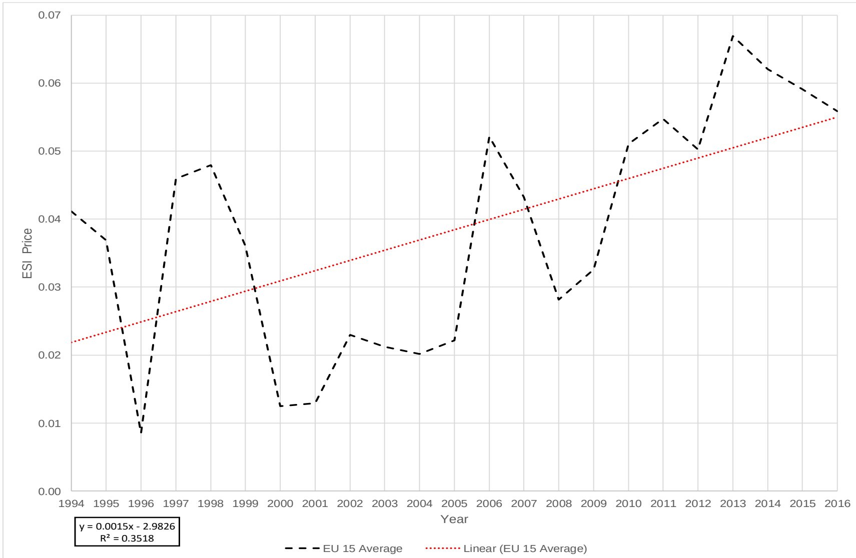


Figure 5: EU15 Gas IEA’s ESI Price from 1994 to 2016

Acceptability:

A) Non Carbon Share

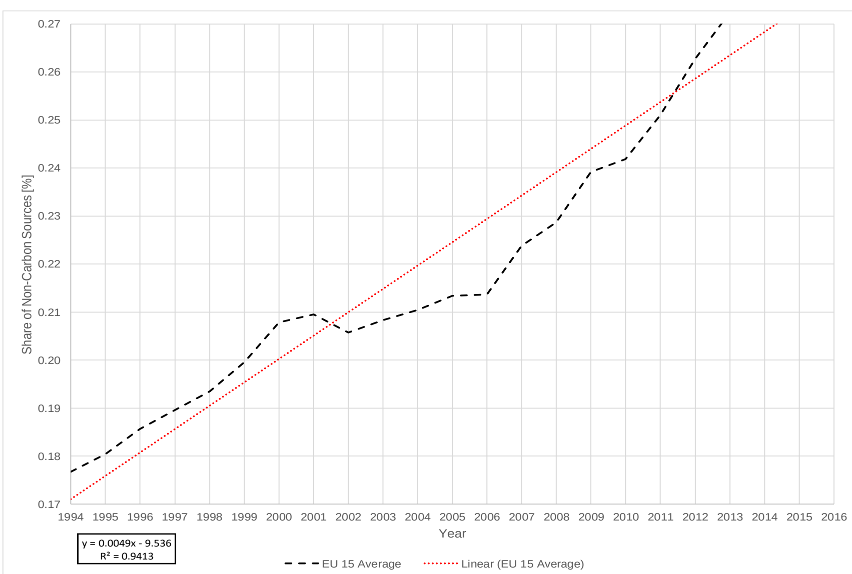


Figure 6: EU15 Non Carbon Share from 1994 to 2016

Accessibility:

A) Supplier Diversity

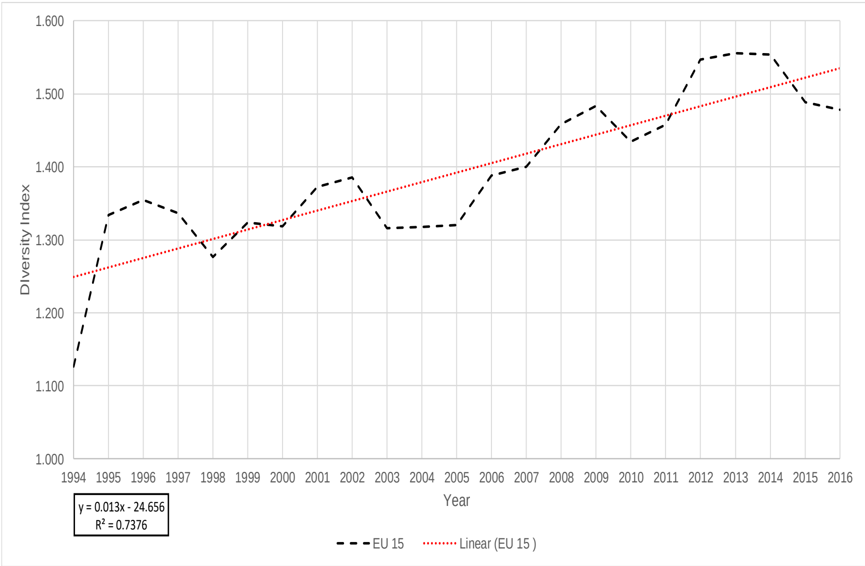


Figure 7: EU15 Oil Supplier Diversity from 1994 to 2016

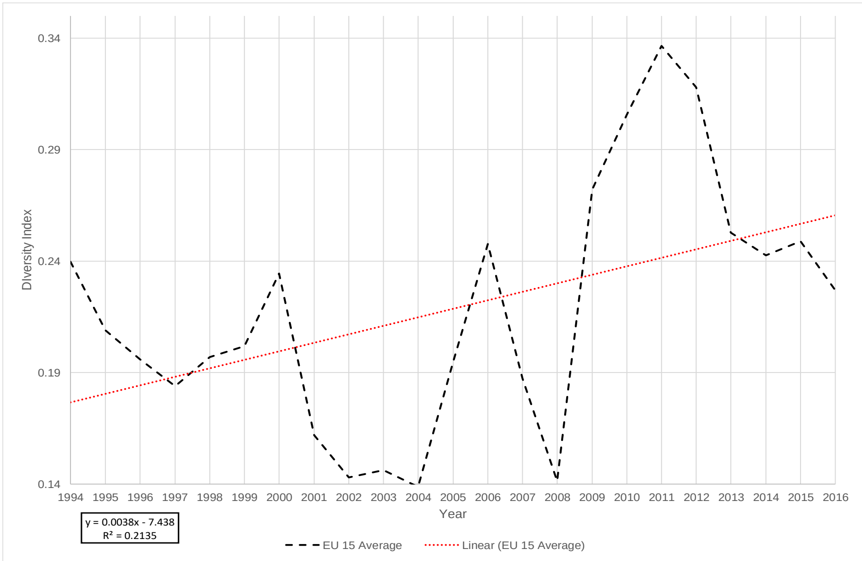


Figure 8: EU15 Gas Supplier Diversity from 1994 to 2016

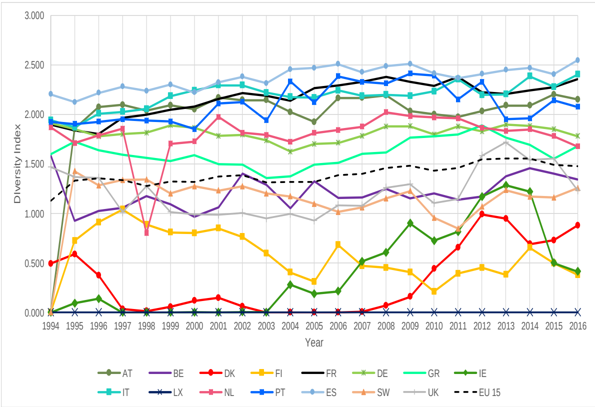
Appendix D: TPES of oil and Gas by EU15 Member State

Country	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
AT	43	42	43	43	44	42	42	42	43	43	43	42	41	41	39	39	37	36	36	36	36	36	36
BE	43	42	43	43	42	42	41	41	40	41	41	42	40	39	42	41	40	40	40	40	43	45	41
DK	43	45	43	45	46	46	46	45	44	40	41	41	39	40	40	38	38	38	39	37	38	38	39
FI	32	29	31	31	32	31	29	27	29	28	29	30	28	28	29	29	27	28	27	25	28	27	28
FR	36	36	36	36	36	36	35	36	35	34	34	34	34	34	33	33	31	31	31	30	31	31	30
DE	40	40	39	40	40	39	38	38	37	37	36	36	35	33	35	35	33	34	34	34	35	34	34
GR	59	59	61	60	58	58	57	57	58	58	57	58	58	55	56	55	52	49	48	46	49	51	53
IE	51	51	51	53	55	59	56	57	56	56	58	56	56	55	53	53	52	50	48	49	49	50	50
IT	59	58	57	57	55	53	51	51	51	48	46	44	44	43	41	41	39	39	36	36	37	37	36
LX	52	54	55	58	62	63	63	64	62	64	65	66	63	63	63	63	62	64	63	64	63	63	63
NL	38	38	37	38	38	40	39	39	40	41	41	42	42	43	41	40	39	40	40	40	42	41	41
PT	64	66	64	65	67	64	61	62	62	59	58	59	55	54	53	50	51	48	46	46	46	45	46
ES	53	54	53	53	54	53	52	52	51	51	50	49	49	48	48	48	46	45	41	42	42	43	44
SW	32	33	32	32	32	32	31	29	31	30	28	28	27	26	28	27	28	29	26	25	25	23	24
UK	39	38	36	36	36	36	35	34	35	35	36	36	36	36	35	35	34	35	34	34	36	37	38
EU15	46	46	45	46	47	46	45	45	45	44	44	44	43	42	42	42	41	40	39	39	40	40	40

Appendix E – Explanation of individual Member State oil and gas SOS analysis

To conduct this analysis, the following procedure was performed:

(i) The graph per every individual indicator was analyzed to determine which Member States displayed the most, medium and least favorable results for SOS (e.g those Member States whose data points where closer to the ideal indicator value that would entail higher oil and gas SOS). An example for this qualitative analysis is provided below using the graphical data obtained for oil diversity:



Spain, Italy, France, Portugal and Austria were the five countries that had higher values of oil supplier. Consequently, these countries were assigned the colour green in Table 1.

(ii) Based on the results from the previous step, the following table was constructed using the same colour coding system explained in Chapter 5.2. The last three columns of the table count the number of times that a country was assigned each of the three different colours (G: Green, Y: Yellow and R: Red).

(iii) A weighted average was calculated (Equation 1), were a value of 3 was assigned to green, 2 to yellow and 1 to red. The summation of these results were used to build the figure shown on Chapter 5.2.

Eqn. 1

$$SOS\ performance = GI * 3 + YI * 2 + RI * 1$$

Where:
GI = Number of indicators that were assigned the green colour
YI= Number of indicators that were assigned the yellow colour
RI= Number of indicators that were assigned the red colour

Table 1: Results of the individual results analysis of oil and gas SOS.

	Availability		Affordability			Acceptability	Accessibility		Results		
Member State	ML-Oil	ML-Gas	OVI	ESI Price - Oil	ESI Price - Gas	SOZCF	SD - Oil	SD-Gas	G	Y	R
AT									3	3	2
BE									1	4	3
DK									1	2	5
FI									0	2	6
FR									5	1	3
DE									3	4	1
GR									3	3	2
IE									2	2	4
IT									4	2	2
LX									4	0	4
NL									3	3	2
PT									1	3	4
ES									5	2	1
SW									1	4	3
UK									3	4	1

Member State	G	Y	R	SOS performance
AT	3	3	2	17
BE	1	4	3	14
DK	1	2	5	12
FI	0	2	6	10
FR	5	1	3	20
DE	3	4	1	18
GR	3	3	2	17
IE	2	2	4	14
IT	4	2	2	18
LX	4	0	4	16
NL	3	3	2	17
PT	1	3	4	13
ES	5	2	1	20
SW	1	4	3	14
UK	3	4	1	18