ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ

UNIVERSITY OF PIRAEUS

Energy and Environmental Policy Laboratory

A Comprehensive Analysis on European Energy Security Fundamentals

---

Alex Skarakis

Working Paper 16

July 2019

ISBN

xxxx

ABSTRACT

It cannot be denied that one of the most important forms of a nation's security is energy security. Sufficient, reliable, affordable, and secure supplies of energy are essential for any economy to smoothly function; to generate electricity, to heat houses, to move cars and buses, to construct buildings and roads, and generally to produce industrial and/or agricultural products. According to the International Energy Agency (I.E.A.), energy security is the adequate, affordable, and reliable access to energy fuels and services. It also includes availability of resources, decreasing dependence on imports, decreasing pressures on the environment, competition and market efficiency, reliance on indigenous resources that are environmentally clean, and energy services that are affordable and equitably shared. However, **(i)** robust growing demand for energy worldwide, **(ii)** high concentration of suppliers of finite energy resources (i.e. gas, oil, coal, and uranium), **(iii)** political unrest in major supplying regions (especially in MENA regions), **(iv)** disputes between demand and supply sides due to geopolitical strategies, **(v)** huge price differentials between energy products and between cross-border trade, as well as **(vi)** the effects of environmental and climate change policies, are major factors that define the future of energy security in a more-than-ever interlinked world/market/society. At first, politicians and scientists believed that energy security was limited to importing countries, but technical change and the robust development of new energy markets and resources have turned energy security into a primary concern of every country, either being a producing, a consuming, or a transit one. The European Commission has already identified energy security as one of its ten major priorities, which aims at providing secure, affordable, and sustainable energy to all its citizens; but as energy security remains context-based, its concept is vague and generalized, thus creating uncertainties for its future. In this paper, I assume that successful energy security in the E.U. is underpinned by five successive pillars: **i)** availability of energy resources **ii)** accessibility to a diverse supply/demand portfolio **iii)** reliability of suppliers/consumers **iv)** economic and environmental sustainability **v)** affordability of consumers. Therefore, the purpose of this paper is to elaborate on the existing literature of energy security, aiming to investigate the five important challenges for each energy security pillar, as well as how these challenges can be measured through use of scientific indexes. Finally, by using both qualitative and quantitative elements, the paper focus is to provide a thorough, yet a summarized, overview of European energy security fundamentals; resulting in a comprehensive analysis, which can be used for further study and narrow investigation.

CONTENTS

1. INTRODUCTION

The robust growing demand for energy worldwide, along with the effects of environmental and climate change policies, cause many concerns about the future of energy security. In fact, energy demand is expected to increase by 45% until 2030, and by more than 300% until the end of the 21st century (Brown & Sovacool, 2011). Additionally, the Russia-Ukraine gas price disputes in 2006 and 2009 revealed the importance of energy security, making it an "insurance policy" for future possible supply disruptions and for an integrated energy market (Ratner, Belkin, Nichol, & Woehrel, 2013). But what is the causality between energy security and integration? Would it be energy security as a prerequisite to achieve integration or vice versa? Unfortunately, causality between energy security and integration has not yet been proved. According to Daniel Yergin's masterpiece "Ensuring Energy Security" (2006), energy security is defined as the reliable and affordable access to energy supplies, diversification, integration into energy markets, and the provision of information. Meaning that integration is necessary to achieve energy security. According to the European Commission (2014), "The E.U. is the only major economic actor producing more than 50% (23% renewable and 28% nuclear) of its electricity without greenhouse gas emissions. This trend must continue. In the long-term, the Union's energy security is inseparable from environmental policies and significantly fostered by its need to move to a competitive, low-carbon economy that reduces the use of imported fossil fuels"[1]. In other words, the European Commission has identified energy security as one of its ten major priorities, which aims at providing secure, affordable and sustainable energy to its citizens[2]. However, between the North-Western and the South-Eastern markets there are visible differences, which prevent complete integration. Without sufficient infrastructure and a competitive integrated market, imports of energy resources from regions with different pricing regimes (i.e. Russia, OPEC), lead to huge price differentials between regional markets, eventually impacting consumers' welfare. Among the different energy resources, natural gas and oil are most prone to be affected by supply disruptions, whose consequences would be severe, if not catastrophic. It is trite to mention that sufficient, reliable, affordable, and secure supplies of energy are essential for any economy to smoothly function; to generate electricity, to heat houses, to move cars and buses, to construct buildings and roads, and generally to produce industrial and/or agricultural products. Even the beneficial impact of technical change on economies, needs energy to take place. It is well-known from the work of Robert Solow (1956), that technical change is the only factor that causes economic growth to continue indefinitely by introducing new goods, new markets, and new production processes (Solow, 1956). Besides, energy and capital stocks are interdependent, because a positive quantity of energy resources is required to produce capital assets. Therefore, the capital stock cannot be increased without depleting the energy stock. In other words, energy is the fuel that drives economic growth and sustainable development. On contrast, many economists support the idea that the absence or the abundance of energy resources in an economy does not play a vital role on the level of economic growth, because there is substitution between energy and physical capital, whereas others support the idea of complementarity between them (Stern,

[1] http://eurlex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0330&from=EN
[2] https://ec.europa.eu/priorities/index_en

2004). In addition, the expansion of international trade has provided countries, which lack energy resources with the opportunity to cover their deficit by trading with resource-abundant countries. The existence of international trade though covers the need for availability of energy resources and the accessibility to foreign energy markets, it does not cover other needs such as reliability, affordability, as well as environmental and economic sustainability.

As stated by the International Energy Agency (I.E.A.), energy security is the adequate, affordable, and reliable access to energy fuels and services. It also includes availability of resources, decreasing dependence on imports, decreasing pressures on the environment, competition and market efficiency, reliance on indigenous resources that are environmentally clean, and energy services that are affordable and equitably shared (International Energy Agency, 2006). According to the Asia Pacific Energy Research Centre (A.P.E.R.C.), energy security is the ability of an economy to guarantee the ability 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, spread across the four “As”: availability, accessibility, acceptability, and affordability (Asia Pacific Energy Research Centre, 2007). Additionally, Kleber (2009) introduced the five “Ss”: supply, sufficiency, surety, survivability, and sustainability. Similarly, Hughes (2009) refers to the four “Rs” of energy security: review (understanding the problem), reduce (using less energy), replace (shifting to secure sources), and restrict (limiting new demand to secure sources) (Hughes, 2009). Jonathan Elkind (2010) proposed that energy security should be clustered into four defining elements: availability, reliability, affordability, and sustainability. He also assessed possible threats to each element. For example, a threat to availability is the inefficient depletion of finite reserves, which can otherwise be extracted cost-effectively (Elkind, 2010). Finally, I assume that successful energy security in the E.U. is underpinned by five successive pillars: **i)** availability of energy resources **ii)** accessibility to a diverse supply/demand portfolio **iii)** reliability of suppliers/consumers **iv)** economic and environmental sustainability **v)** affordability of consumers. Yet, energy security remains context-based without a common quantitative framework to measure it.

It is true that energy security, as a concept, is highly vague and generalized. Mainly due to the absence of a common quantitative framework, but also because it is extremely hard to quantify it. Therefore, the purpose of this paper is to elaborate on the current theoretical and quantitative literature of energy security, aiming to investigate the five important challenges each European energy security pillar faces, as well as how these challenges can be measured by using scientific indexes. In section two, I use the current theoretical literature to elaborate on the differences between regional approaches to energy security, as well as to give answers to why energy security has so many diverse definitions. In fact, Benjamin K. Sovacool (2010) found out that there are forty-five different definitions for energy security worldwide; and probably there are a lot more considering that energy security is developed through different country and region-specific factors, which are based on the distinctive characteristics of their political, financial, geological, social, technological and institutional settings, as well as on the magnitude of their energy intensity, and their dependence on energy imports/exports. That is, energy security has multi-dimensional variants, and it often depends on national or regional strategies. Each world leading organization (governmental or not), each research agency (international or domestic), each governmental or department agency gives energy security a different definition. In section three, I present the most common and yet significant challenges of energy security in the EU. Generally, the challenges are linked to the five successive pillars of energy security. Additionally, for every challenge I elaborate on the existing quantitative literature to present proposed indicators (simple and/or aggregate), which are used by research centers and the academia to measure energy security with respect to its different elements. To prevent severe consequences from taking place, policymakers, country leaders, and governmental actors need to consider energy security as a wider concept and pay attention not only to context related material, but also to a variety of aggregate indexes. For example, the idea that the availability of energy resources does not play a vital role on the level of economic growth because of international trade is falsely supported by mainstream economists, because it rules out some fundamentally significant factors such as the reliability of the supplier, the affordability of the consumer, diversity of supplies, sustainability, and the rate of depletion of finite energy resources. The inefficient depletion of exhaustible reserves harms the future availability of energy resources, as well as sustainable development and economic welfare. That is, the planet cannot recover from a deficit of resources. Countries may discover novel reserves of gas that are nominally added up to countries' reserves, but globally the aggregate planet's reserves of are finite, and with every use they are being depleted, leaving lesser quantities to use in the future. Thus, consuming finite energy resources inefficiently now, may challenge the social welfare of future generations. Finally, in section four, I present the conclusions of this research paper.

2. REGION-SPECIFIC APPROACHES TO ENERGY SECURITY

According to I.E.A (2017), in 2015 world total primary energy source supply (T.P.E.S.) of oil, natural gas, and coal was amounted to 31.7%, 21.6%, and 28.1%, respectively. Whereas, their respective T.P.E.S. percentages in 1973, were at 46.2%, 16%, and 24.5%. As it seems, natural gas has already become an increasingly important source of fuel. Its conventional use expands to include new applications in power generation and transportation sectors. Due to the abundance of cheap and strategically diverse global gas reserves, as well as its nature as a more environmentally friendly fuel, natural gas has turned into a vital energy source as the world has been moving on to a "cleaner" and more efficient energy mix. From the early 80s to the early 2000s, European gas demand has expanded robustly due to the continuous increase of oil prices, and high economic and environmental cost of coal plants. None has ever expected that natural gas would have so much success in replacing oil for space heating and power generation, and to become one of the most important fuels in E.U.'s primary energy source balances. The use of coal as a dominant fuel source for power generation in the E.U. has fallen off in recent years, due to environmental and climate policies for lower greenhouse gas emissions. Similarly, Chinese gas demand is increasing due to ongoing efforts of the government to diversify its energy mix away from coal and address local air quality issues driven by the extreme coal consumption in the power generation sector. As it seems, tightening environmental regulations can have a large positive impact on gas usage. Generally, China is expected to emerge as the key destination in Asian markets for liquified natural gas (L.N.G.) trade and it is also expected to be one of the key players that will drive most of natural gas demand growth. Indeed, while global gas demand is forecasted to increase by 340 Bcm annually, China's gas demand is projected to increase by 9% annually from 190 Bcm to 320 Bcm in the period from 2015 to 2021, constituting to more than one-third of the total increase in global consumption (International Energy Agency, 2016). Additionally, per forecasts from C.N.P.C. (China National Petroleum Corporation), the projected Chinese natural gas consumption will reach 400 Bcm per year by 2030[3]. The main factors that will contribute in that increase are: **a)** the relative prices of oil and gas **b)** the large L.N.G. contractual position of both CNOOC and SINOPEC **c)** the diversification of the country's energy mix towards a more efficient and environmentally friendly use of energy.

2.1.THE EUROPEAN UNION

Energy security, especially security of gas supply, is of paramount importance to the EU. Additionally, energy security is one of the five pillars[4] of E.U.'s Energy Union Strategy. The Union's approach to its energy security includes diversification of imports; CO_2 emissions reduction and energy efficiency; integration and increased competitiveness of natural gas; promotion of spot and short-term contracts; and implication of a new pricing mechanism based on hub price indexation. According to the Official Journal of the European Union (2010), E.U.'s energy security strategy aims at integrating the internal energy market by implementing European network codes, and target models for both natural gas and electricity markets. In fact, the regulation 994/2010[5], which repeals the Council Directive 2004/76/EC, introduces measures to safeguard security of gas supply, and to manage supply disruptions and oil stocks by initializing stress tests, as well as schemes for the protection of infrastructure. Due to their high import dependency on Russia, Eastern and South-Eastern Member-States experienced negative effects on their energy security from the Russia-Ukraine gas price disputes in 2006 and 2009 (Dagoumas & Charokopos, 2016). These crises led the European Commission in 2014 to initiate the Energy Security Strategy, which included short-term and long-term measures to protect its energy supply from possible transmission disruptions. Short-term measures were based on energy security stress tests, which simulated two scenarios about possible Russian supply disruptions: a complete halt of Russian gas imports to the E.U., and a disruption of Russian gas imports through the Ukrainian transit route. The results showed that a prolonged supply disruption would have a substantial impact on the E.U., as well as that Eastern E.U. and Energy Community Member-States would be significantly affected[6]. Furthermore, according to O.J.E.U. (2013), the E.U. regulation 347/2013[7] provides guidelines for the trans-European development of energy infrastructure along with the development of PCIs. All in all, the Crimean crisis has prompted E.U. leaders to normalize relations with Iran and to seek international cooperation with other potential gas suppliers to achieve a more diversified network. The European Commission supports that energy security is the uninterrupted physical availability of energy products on the market at an affordable price for

[3] http://eneken.ieej.or.jp/data/3561.pdf

[4] **i)** Energy security, solidarity, and trust **ii)** integration of the internal energy market **iii)** energy efficiency and moderation of demand **iv)** decarbonization of the economy **v)** research, innovation, and competitiveness.

[5] Official Journal of the European Union, 12th November 2010. *Regulation (EU) No 994/2010 of October 2010*.

[6] https://ec.europa.eu/energy/en/topics/energy-strategy/energy-security-strategy

[7] Official Journal of the European Union, 25th April 2013. *Regulation (EU) No 347/2013*.

all consumers (Olz, Sims, & Kirchner, 2007). Affordability is a significant element of energy security strictly related to consumers' welfare, especially for major importing countries such as the E.U., Japan, India, and China. Due to its import dependency and its limited availability of energy resources, the E.U. act as price taker agent in the global market, thus being:

- Dependent on long-term gas contracts, which are linked to oil prices and bonded to rigid clauses (take-or-pay).
- Dependent on the fluctuations of global oil and gas prices, caused by changes in export and production strategies of major suppliers of natural gas and oil such as Russia and O.P.E.C.
- Dependent on the fluctuations of global coal prices, which are still very low, impacting gas demand of their power generation sectors in a negative way, leading to increased energy intensity.
- Dependent on short-term power and carbon price movements, which cause changes both in the "spark spread"[8] and "dark spread"[9].
- Their fuel imports are dependent on a concentrated number of countries, which are political unstable[10].

These factors influence greatly the affordability and economic welfare of its citizens, as well as its energy security. According to the World Bank, energy security is underpinned by four key factors: **a)** access to secure supplies of fuel **b)** a competitive market that distributes those fuels **c)** stability of resource flows and transit points **d)** and efficiency of end use (Sovacool, 2010). Integration is a well-regarded measure to promote sustainable competition across E.U.'s internal energy market. In fact, it will narrow the existing price differentials between national markets, facilitating international trade, as well as it will promote international cooperation, solidarity, and trust, facilitating technical change and investments in PCIs. Technical change will provide better solutions to bottlenecks and congestion management, securing stability of resource flows. Additionally, investments in PCIs will accelerate the development of critical infrastructure (capability of bidirectional flows, and increased compressor stations) to safeguard energy flows of isolated regions such as the Baltic and South-Eastern Member-States. Eventually, technical change will increase economic growth by lowering energy intensity, as well as it will help in the direction of sustainable development by creating more efficient end-use technologies, which will help balancing production between exhaustible energy resources and renewable energy resources. To gain the afore-mentioned benefits of an integrated market underpinned by technical change, the E.U. reform agenda[11] (including a numerous set of changes) have been initiated to improve its energy security and integrate its internal energy market. For integration purposes the E.U. aims to adopt a more liberalized

[8] Spark spread is determined as the difference between the selling price and the cost of electricity, when it is generated by natural gas.

[9] Dark spread is determined as the difference between the selling price and the cost of electricity, when it is generated by coal.

[10] The "Arab Spring" curtailed gas exports from Libya for most of 2011.

[11] Official Journal of the European Union (2009), "Directive 2009/73/EC of the European Parliament and of the Council", L211/94, 14 August.

market within its vicinity. It is true that the transition to a more spot based pricing with short-term contracts and gas-on-gas pricing mechanisms requires first the deregulation of the domestic markets. Since the 90s, domestic markets have started liberalizing by separating the management of upstream, midstream and downstream activities of state-owned physical monopolies, which controlled the largest share of the energy market. That means exploration and production, transportation and distribution, wholesale and retail marketing of natural gas and electricity would behave as three different markets, exposed to greater competition. To achieve a successful transition from a regulated to a liberalized energy market, the E.C. created directives that forced national governments to implement policies such as unbundling of vertically integrated companies, workable third-party access in infrastructure investment (PCIs), as well as providing consumers' with the freedom to choose between existing and new providers of gas and electricity, thus enabling healthy competition and decreasing the market power of existing harmful monopolies. These steps have gradually led to a progressive connection between national markets, lowering price differentials, enabling better congestion management, and increasing consumers' welfare. According to the European Council Conclusions on the 4th of February 2011, the E.U. needs a fully functioning, interconnected and integrated internal energy market. Thus, legislation on the internal energy market must be speedily and fully implemented by the Member-States in full respect of the agreed deadlines[12].

Still, there is no complete integration and the internal market should have been completed by 2014, to allow natural gas and electricity to flow freely. A factor preventing complete market integration is that Member-States do not speak with one voice yet, due to substantial differences in their institutional settings and energy policies. For example, lower coal consumption or the so-called decarbonization is not unanimously supported by E.U.'s Member-States. In fact, while western Member-States (mainly U.K.) propose that E.U. should accelerate its decarbonization strategy, eastern Member-States (mainly Poland) support that this would be unaffordable for their economies, as well as a destabilizing factor of E.U.'s electricity grid (Haase, 2008). In the U.K., energy security tends to be market oriented; it aims at promoting liberalized energy markets through regulatory frameworks, and at fostering investments to prompt technical change and deliver diverse and reliable energy. It also aims at minimizing CO_2 emissions to improve environmental sustainability; at enhancing competitiveness and productivity of the economy by lowering energy costs and energy intensity, that otherwise would cause investments and economic growth to drop; and at providing fair access to energy supplies by increasing social equity and by minimizing fuel poverty (U.K. Department of Trade and Industry, 2006). According to I.E.A. (2016), because coal is more competitive than gas in terms of prices, the U.K. government has imposed a "floor" price in coal that would prevent coal's price from dropping even further, thus making natural gas to be occasionally competitive again. Additionally, the European Commission in its Energy Security Strategy (2014) proposes that technical change in production from indigenous renewable energy sources would reduce CO_2 emissions and accelerate decarbonization of the economy, mitigating import dependency on Russia for fossil fuels. There is also evidence that domestic renewable resources can reduce the dependence from imported entities, thus assuring

[12] https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/119175.pdf

sustainability and stability (Faulin, Lera-Lopez, Arizkun, & Pintor, 2009). On the contrary, someone would argue that energy independence from Russia could risk the process of decarbonization, because most of natural gas imports into Eastern E.U. depend on Russia (Buchan, 2014). In addition, coal has been the solid foundation of energy security for many eastern Member-States, and especially for Poland, where its industrial sector depends on coal consumption. The E.U. can never be completely independent from Russian fuel imports. Still, it is possible to differentiate its trading routes and sources. A recent report showed that E.U. could diversify its energy supply to improve its energy security (Leal-Arcas & Rios, 2015). Building new infrastructure and investing in new PCIs between Member-States is a significant component part of the E.U.'s energy security approach[13]. The E.U. is committed to build missing energy infrastructure links and ensure that isolated Member-States have access to at least three different sources of gas. Indeed, the European Council has called for priority to reaffirm the objectives of completing the internal energy market by 2014 and developing interconnections, to end any isolation of the Member-States from the European gas and electricity networks by 2015[14]. Such priority is to integrate the Baltic Sea[15] region with the rest of continental Europe. In October 2016, there was the agreement of a new P.C.I. between Finland and Estonia called the Baltic Connector pipeline, which alongside with the G.I.P.L. (Gas Interconnector Poland-Lithuania) will allow the Baltic States to integrate with the rest of the system. The project is realized under the Baltic Energy Market Interconnection Plan (B.E.M.I.P.)[16], which is funded by the European Economic Recovery Plan (E.E.R.P.)[17], and aims to further integrate the Baltic States' energy markets by building new infrastructure: **i)** new interconnections such as the Baltic Connector pipeline **ii)** implementations of reverse flows such as the proposed Amber PolLit pipeline (Poland and Lithuania) **iii)** L.N.G. facilities in Estonia and Latvia **iv)** gas storage facilities in Latvia. According to Taavi Roivas Prime Minister of Estonia, the Baltic Connector signifies a key development for Nordic-Baltic energy market integration, for region's security and diversity of supply and for consumers' benefit[18]. Therefore, there is no deny that technical change and investment in PCIs significantly contribute to augment energy security and increase consumers' welfare. Looking at the broader picture, by building more interconnectors and agreeing on a pan-European target model, bottlenecks and congestions can be easily removed from energy markets, allowing gas and electricity to flow where it is most needed. And it is the markets of South-Eastern E.U. that are most vulnerable to supply disruptions and least attractive for suppliers (European Commission, 2014). Accordingly, the Council of European Energy Regulators (C.E.E.R.) acknowledged the need of a pan-European target model for gas and electricity markets on December 2011. Initially, the Regulators have seen a competitive European gas market as a combination of

[13] http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe101aa75ed71a1.0001.03/DOC_1&format=PDF

[14] https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/137197.pdf

[15] Finland and the other three Baltic States (i.e. Estonia, Latvia and Lithuania) are heavily dependent on gas imports from a single unreliable supplier (Russia).

[16] https://ec.europa.eu/energy/sites/ener/files/documents/BEMIP_Action_Plan_2015.pdf

[17] http://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:52008DC0800&from=EN

[18] http://europa.eu/rapid/press-release_IP-16-3470_en.htm

entry-exit zones with "virtual" trading hubs. Their vision[19] of the gas target model suggests that: **a)** the development of competition should be based on the development of liquid trading hubs across E.U. **b)** market integration should be served by efficient use of infrastructure, allowing market players to freely ship natural gas between market areas **c)** the target model must allow for sufficient and efficient levels of infrastructure investment, where physical congestions hinder market integration. Finally, according to the Agency for the Cooperation of Energy Regulators (A.C.E.R.), the launch of an effective Gas Target Model[20] should include the following five key objectives: **i)** establishment of liquid, competitive and integrated wholesale energy market **ii)** enhancement of Europe's energy security and channeling of the external element of the internal energy market **iii)** movement to a low carbon society with increased penetration of renewable energy sources, as well as a smart, flexible, and responsive energy supply **iv)** development of a functioning retail market that benefits end-users **v)** building of an effective stakeholder dialogue, along with cooperation and new governance arrangements.

2.2.ASIA

As mentioned before, energy security has a social value and is linked with environmental and climate change policies. Indeed, the World Resources Institute (2007) refers to energy security as sufficiency of supply, reliability, affordability, environmental sustainability, as well as it gives a more geostrategic and social meaning with references to geopolitical stability and social acceptability (Logan & Venezia, 2007). China's approach to energy security aims to social acceptability and geopolitical stability. Faced with extreme pollution challenges and public health issues, China decided an urgent reform of its energy policy and turned to consumption of natural gas for power generation, which is obviously less pollutant and more environmentally friendly in terms of greenhouse gas emissions. The efforts of the Chinese government to increase the relative share of natural gas in the energy mix can be reflected on the robust increase of gas-fired generators, despite the stagnant growth in electricity generation. Moreover, this environmental policy transition can be viewed in its 12th Five Year Plan (2011 to 2015), which states that 18% of the Chinese population will have access to a domestic gas supply. Moreover, while increasing its L.N.G. import capacity by 1 Bcm, it displaces 2 Mt of coal, thus reducing by 40% to 45% the CO_2 emissions below 2005 levels by 2020. In addition, C.N.P.C. has promoted the use of L.N.G. in 200,000 vehicles until the end of 2015 by creating additional capacity in L.N.G. import terminals and thus encouraging the government decisions of cleaner energy use[21]. Such policy transitions and ample import capacity facilitate coal-to-gas substitution, reducing energy and carbon intensity and leading to the development of new gas markets for power generation and residential sectors. China's dependence on global oil and gas markets grows stronger (due to robust increase in demand), leading the government to follow a more geostrategic, rather than

[19] http://www.ceer.eu/portal/page/portal/EER_HOME/EER_CONSULT/CLOSED%20PUBLIC%20CONSULTATIONS/GAS/Gas_Target_Model/CD/C11-GWG-82-03_GTM%20vision_Final.pdf
[20] http://www.acer.europa.eu/Events/Presentation-of-ACER-Gas-Target-Model/Documents/Launch%20of%20ACER%20updated%20Gas%20Target%20Model%20Presentations.pdf
[21] http://af.reuters.com/article/idAFL3E8HC22320120612

economic, approach to energy security. Its geopolitical stability approach can be achieved by buying rights to explore foreign oil and gas fields, as well as by militarily protecting vulnerable shipping lanes on its exclusive economic zone (Cheng, 2008). Another report also acknowledges the significant effect that China's decision to energy security would have on the future of energy markets and resources. Particularly, if China is to adopt a more strategic, rather than economic, approach towards energy security, that would increase the likelihood of future conflict over energy resources (Manning, 2000). Moreover, the link between China's energy security and rapid economic growth has deepened since the mid-1990s[22] (Li, 2006). For example, a disruption of China's supply of oil could lead to twin forces of mass discontent: a stagnating economy and inflation caused by spikes in domestic energy prices. Examining Chinese oil consumption over the last two decades makes this clear. From 1993 to 2010, oil consumption increased from about 140 Mt (Million tons) to about 440 Mt (British Petroleum, 2011). Japan and Korea that lack sufficient reserves of oil and natural gas to cover their demand, aim at diversifying their supply sources and routes through trading with multiple agents. Energy security is defined as the reliable and affordable access to energy supplies, diversification, integration into energy markets, and the provision of information (Yergin, 2006). Thus, diversification cannot be excluded from the broad concept energy security. Both Japan and Korea are major L.N.G. importers, accounted for around 50% of global L.N.G. imports. They have also accounted for 45% of total global L.N.G. regasification capacity expansions from 2010 to 2016. However, their imports are estimated to stagnate until 2021, because they depend heavily on the rate of the nuclear plants comeback in Japan (International Energy Agency, 2016). To rebalance the stagnation, Japan and Korea invest in Projects of Common Interest (PCIs) with neighboring Asian countries to jointly develop energy resources (Atsumi, 2007). Developing countries such as Jordan and Pakistan invest in floating small regasification units (F.S.R.U.) and small-scale L.N.G. projects, because lower up-front capital costs and shorter deployments times tend to be more attractive, as well as because these new technologies present an easy and profitable process in the long-term. The reason is that major suppliers such as Russia, Qatar, Nigeria, and Australia will start searching for smaller buyers to sell their cargoes, due to lower gas prices and slower demand growth in major importers such as the E.U. and China.

2.3.RUSSIA

Regarding exporting countries, they have their own energy security strategies, which differ significantly from these of the above-mentioned importing countries. For example, Russia aims at safeguarding its state power over its vast oil and gas reserves by blocking foreign investment decisions in production, and at increasing its share on the European and Asian markets through new infrastructure agreements that will transfer Russian fuel to these markets and will eventually increase Russia's fiscal revenues (Sevastyanov, 2008). Qatar's energy security should be to safeguard their sales and exports worldwide by maintaining high demand in the E.U. and Asia (Yergin, 2006). Russia is one of the world's most resource-rich countries. In 2012, the value of the country's natural resources was at 75.7 trillion dollars, of which natural gas reserves (1,680 Tcf) were at 19 trillion dollars representing 26% of its total natural

[22] It was not until the mid-1990s that mass, large-scale industrialization took place.

resources value[23]. Its total proven reserves of natural gas in the end of 2015 were at 1,139.6 Tcf (British Petroleum, 2016). Russia is the second largest producer of natural gas worldwide and its natural gas rents as a percentage of G.D.P. reach 0.52%, which is quite low than that of 2012 (2%) and backwards, whereas oil rents were at 12.7% of G.D.P.; 2% lower than that of 2012 (14.86%)[24]. Russia opts to diversify its economy dependence on natural resources, because its economy is highly dependent on oil and gas revenues. Being dependent close to 43% on oil and gas revenues, Russia's federal budget is reeling from the impact of low oil prices and sanctions, also affecting future infrastructure agreements. Indeed, in 2014, crude oil prices decreased from 115$ per barrel to below 70$ per barrel, due to higher production output and weaker demand[25]. The falling of oil prices has its fiscal revenues. More specifically, in November 2015, the total impact of lower oil prices and economic sanctions was estimated by Russia's Finance Minister Anton Siluanov at 130 to 140 billion dollars per year (around 7% of G.D.P.): 90 to 100 billion dollars from reduced oil revenues (based on oil prices of 80$ per barrel) and 40 billion dollars from sanctions[26]. The first economic sanctions against Russia were introduced in March 2014 after its annexation of the Crimea and were gradually stepped up over the year. Participants include the E.U. and E.F.T.A. countries, the U.S., Canada, Australia, New Zealand and Japan. Restrictive measures include: **a)** freezing assets of persons and companies close to the Russian leadership **b)** severely limiting access by the main Russian banks and companies in the energy and defense sectors to the E.U. and U.S. financial markets **c)** banning exports of technology and equipment useful to the defense and energy sectors. Generally, dependency on high oil pricing to cover expenditures brings high risks of economic failure, when the pricing environment is unstable[27]. Additionally, in 2015, Russia's revenues from natural gas exports accounted for about 13% of its total export revenues and more than 75% of Russia's natural gas exports went to Europe[28]. Russia continues being a major supplier of the E.U. despite the gas price disputes with Ukraine. Particularly, Gazprom has expanded its market to more countries in the western regions by investing in pipeline and storage facilities. However, E.U.-Russia energy relations remain purely transactional, conducted mostly by companies. While Russia has a big interest in maintaining its energy export in Europe, the anticipated rising demand of natural gas in China has already led to more infrastructure developments, differentiating Russia's export portfolios and decreasing its relative dependency on European gas demand, which growth is slower than that of China's. More specifically, Russia aims at increasing its market share in the Far East by expanding pipelines to China and South Korea from producing wells in East Siberia, and to Japan and South Korea from the Shakalin Islands (Troner, 2000). Russia keeps its eyes fixed on the emerging Asian gas markets and it is very decisive to aggressively hold a dominant position there, by exploiting its huge reserves and investing in new infrastructure. Additionally, higher and stable oil prices would help Russia to exploit its output ratio to its maximum and expand

[23] http://247wallst.com/special-report/2012/04/18/the-worlds-most-resourcerich-countries/
[24] http://data.worldbank.org/indicator/NY.GDP.NGAS.RT.ZS?locations=RU
[25] http://www.economist.com/blogs/economist-explains/2014/12/economist-explains-4
[26] http://www.reuters.com/article/us-russia-siluanovidUSKCN0J80GC20141124
[27] http://www.bloomberg.com/news/articles/2016-10-26/oil-near-three-week-lowafter-inconsistent-u-s-supply-decline
[28] http://www.eia.gov/beta/international/analysis.cfm?iso=RUS

its supply network without fearing a collapse in its federal budget. On the other hand, its ability to influence the global natural gas markets will be decreasing in the long-term, due to competition from alternative emerging suppliers (i.e. North America, Australia). After the Ukrainian gas crisis, Russia's approach to energy security is to diversify its exports and to strengthen its geopolitical role in the growing Asian gas markets. Asian gas demand offers a major growth opportunity for its export capacity compare to a more stable and slow-paced growth in European markets, in which U.S. L.N.G. imports will be extremely competitive. Russia's RPR indicates that its proven reserves can support more than 50 years of total global demand. In fact, U.S.G.S. (United States Geological Survey, 2012) reported a mean estimate of undiscovered, technically recoverable natural gas resources of 1,623 Tcf and a mean estimate of 31,786 million barrels of natural gas liquids. That means, the fast-growing Asian gas demand is likely to cause additional exports from Russia, considering the vast spare capacity of its reserves. Therefore, Russia's main approach to energy security is to exploit its vast capacities of oil and gas and use its geographical and geological advantages to ensure its dominant position in the Asian and European markets.

2.4.QATAR

Russia may be first in pipeline exports internationally, but Qatar has been a "traditional" and a globally dominant supplier of LNG since 2006[29]. Qatar started exporting L.N.G. in 1996, and now is the fourth-largest natural gas producer and the largest L.N.G. exporter. In 2012, natural gas and crude oil exports accounted for 57.8% of its G.D.P. (National Statistic Authorities , 2013). In 2015, global gas imported capacity was at 236.9 million tons, of which Qatar represented 33% (78.17 mt) of global gas supplies, followed by Malaysia at 11% (26.05 mt), and Australia at 10% (23.69 mt) (International Group of Liquified Natural Gas Importers, 2016). In the end of 2015, its reserves of natural gas represented 13.1% of global proven reserves amounting at 866.2 Tcf. That percentage is the third globally behind Iran (18.2%) and Russia (17.3%) (British Petroleum, 2016). Additionally, Qatar's RPR shows that its reserves may well hold for at least the next 150 years. Qatar has a highly developed system of liquefaction infrastructure that underpins its large exporting L.N.G. capacity. Its large N.O.C. (National Oil Company) Qatar Petroleum, which is responsible for the development of its oil and gas sector, has two sector subsidiaries companies Qatargas and RasGas. These two companies have been developing five L.N.G. trains from 1996 to 2000. Until 2010, they have had fourteen L.N.G. export trains, which brought total liquefaction capacity at around 105 Bcm. These trains have taken FIDs in the past, when unit and average costs for L.N.G. plants were lower in comparison to other L.N.G. projects at the same period, giving a comparative advantage in cost-benefit analysis against other exporters such as Australia. Indeed, Qatar remains one of the largest and simultaneously lowest cost producers, even in a scenario of low oil and gas prices. According to Bank Audi (2010), the estimated break-even prices of its L.N.G. infrastructure were at 12.8$ per Bbl of oil and at 1.6$ per MMBtu of gas, shielding RasGas revenues from potentially severe downturns in global commodity markets[30]. Additionally, Fitch Ratings (2015) stated that Qatar's L.N.G. projects can withstand oil prices

[29] http://www.gulfbase.com/ScheduleReports/01827aac_Qatar-EconomicInsight2013.pdf

[30] http://www.bankaudigroup.com/GroupWebsite/openAudiFile.aspx?id=831

of 30$ per Bbl or below, due to their high financial flexibility[31]. It has also estimated a break-even oil price from 2016 to 2018 at 27$ per Bbl, which is equivalent to an L.N.G. price of 2.7$ per MMBtu[32]. Moreover, Qatar's petrochemical sector is one of the largest globally due to the size and nature of its gas reserves. In fact, the major deposit North Field, which has been discovered by Shell in 1971 is the largest non-associated gas field[33] internationally. Its development has boosted the production of condensates and non-gas liquids (NGLs) to 900,000 barrels per day in 2012, exceeding its crude oil production. It seems that with low-cost energy structure and stable regulatory and business environment, the country has managed to create a strong competitive advantage over that of its neighboring countries, as well as against global competitors. Indeed, Qatar produced 2.2 Mt and 4.2 Mt of basic petrochemicals (i.e. ethylene, propylene, methane, benzene, toluene, xylene, butadiene, butylene) in 2008 and 2012 respectively, and has been the second largest producer in the Gulf Cooperation Council (G.C.C.)[34] after Saudi Arabia. The establishment of new producers and capacity expansions by the already existing producers has led to an average increase in capacity by 17.5% annually. Furthermore, Qatar has increased its share in the total G.C.C. petrochemical capacity expansion from 12.3% in 2008 to 15.3% in 2012, and its own petrochemical capacity grew by 18.4%, which was well above the G.C.C.'s compound annual growth rate (C.A.G.R.) of 12.2%[35]. The growth rate in that period was impressive and the driving factor for that increase has been the country's competitive gas feedstock low-cost of 0.75 to 1.00 $ per MMBtu. In terms of G.D.P., Qatar is the world's fastest growing economy since its real G.D.P. have grown by 12% between 2008 and 2012. Additionally, its petrochemical sector represented 9.9% of the country's nominal G.D.P. in 2012 and was estimated at the value of 6.7 billion dollars. It is worth mentioning that its petrochemical industry is of major significance for its diversification policy. According to Qatar's national development strategy from 2011 to 2016, Qatar will leverage its cheap domestic feedstock and energy to the expansion of its productive base and long-run diversification[36]. In other words, its petrochemical sector is a driving factor for a sustainable and stable economic growth, job creation, and for the protection of the country's economy from the extreme volatility of commodity prices. However, Qatar's energy security strategy is challenged by new emerged suppliers such as the U.S. and Australia.

2.5. THE UNITED STATES OF AMERICA

Qatar's L.N.G. exports may not be in the first place for long. To put it more plainly, the United States has shown great financial resilience, despite the devastating low-price environment. Firstly, the two-year period of 2014 and 2015 is dominated by U.S. FIDs. In fact, 2015 was the starting point for the first two trains of Corpus Christi LNG, which is a greenfield

[31] https://www.fitchratings.com/site/pr/996545

[32] These price levels represent a conservative estimate of break-even resiliency, reflecting conservative assumptions for L.N.G. prices and stresses to operating costs, output levels, and stable tax and royalty calculations.

[33] North Field is a "wet" gas field, which means it contains significant amounts of natural gas liquids and condensates such as ethane, propane, butane, and higher alkanes.

[34] The Member-States of the G.C.C. are: U.A.E., Qatar, Oman, Kuwait, Saudi Arabia, and Bahrain.

[35] http://www.gpca.org.ae/adminpanel/pdf/ff12e.pdf

[36] http://www.mdps.gov.qa/en/knowledge/HomePagePublications/Qatar_NDS_reprint_complete_lowres_16May.pdf

project with a total capacity of 12.2 Bcm per year operated by Cheniere Energy. Secondly, Cheniere got the green light for the fifth train of Sabine Pass L.N.G., adding 6.1 Bcm per year. Thirdly, there was the development of the third train of Freeport L.N.G. with 6 Bcm per year. From 2015 to 2018, there has been a robust increase of 202.3 Bcm in global L.N.G. capacity, of which 86.2 Bcm (42.6%) have been concentrated in the U.S.A. and 80.2 Bcm (39.64%) in Australia. That is, there has been a high concentration of 82.25% (166.4 Bcm) of total liquefaction project developments in the U.S. and Australia (International Energy Agency, 2016). In fact, new liquefaction project from Asia-Pacific and the U.S. have come online between 2015 and 2016, delivering their first cargoes. More specifically, eight L.N.G. liquefaction projects located in Asia-Pacific (i.e. Australia, Indonesia, Malaysia) with total capacity of 55.9 Bcm per year and the first two trains of Sabine Pass L.N.G. in the U.S.A. with total capacity of 12.2 Bcm per year. Half of the Asian-Pacific projects were Australian and accounted for 78.6% (44 Bcm) of the upsurge in the region. Similarly, between 2017 and 2018, twelve newly constructed L.N.G. liquefaction projects have contributed to an increase of L.N.G. supply to an international total of 134.2 Bcm per year. Precisely, four in Australia at 36.2 Bcm per year, six in the U.S.A at 74 Bcm per year, one floating L.N.G. in Cameroon at 1.6 Bcm per year, and the first three trains of Yamal L.N.G. in Russia at 22.4 Bcm per year total. Still, these regions have great differences in pricing LNG. Until now, Australian and Indonesian L.N.G. has been drawn from costly deep-water fields, while North American from low-cost shale gas reserves. On the other hand, the U.S. and Cameroon faces relatively higher shipping costs for exports than that of Australia, and Russia which are closer to Asian key markets. These price differentials play an important role in the share of future Australian exports in the global market, due to more competitive pipeline (Russia) and L.N.G. (the U.S.) exporters by 2020s. Nevertheless, Australia has the potential for lower-cost unconventional gas in the future (Aling, 2014). A significant amount of capital has been allocated for these projects, many of which are backed up by long-term contracts, making them more profitable and competitive than other projects. Yet, L.N.G. projects in the U.S. and Australia must compete against other natural gas supply projects aimed at similar markets, such as pipeline projects from Russia into Asia, as well as projects to develop shale gas in Europe. Nonetheless, the driving factors of the high concertation in the U.S. and Australia were the following:

- Cost-competitiveness of liquefaction projects in the U.S. compared to those in other locations.
- Large disparity in natural gas prices between U.S. and other major exporting regions of the world such as Russia and Qatar.
- Lower regulatory and other risks in comparison to other countries' proposed liquefaction projects (i.e. Iran, Venezuela, and Nigeria).
- Greater diversity of energy supply that North American liquefaction projects provide, particularly for the E.U. and China.
- Increasing L.N.G. import capacity in China.
- Stabilization of demand and diversification of imports in Europe.
- China's gas demand will keep growing rapidly over the next years.
- Abundant resources of low-cost shale gas in the U.S.A., creating opportunities for arbitrage in foreign markets.

- Proximity to China's coasts, causing transportation tariffs to be lower.

The most striking feature is that energy security in the U.S. is defined differently even between governmental agencies and departments of the same government. In fact, the U.S. Department of Defense (2009) refers to energy security as the "Capacity to avoid adverse impact of energy disruptions caused either by natural, accidental, or intentional events affecting energy and utility supply and distribution systems" (Kleber, 2009). Whereas, the U.S. Congress focuses on a future where abundant, reliable, and affordable energy is produced with minor impact on the environment and no dependence on the goodwill of hostile nations (Kessels, Bakker, & Wetzelaer, 2008). For instance, the minor environmental impact of U.S.'s energy security is mainly expressed through the reduction of the highly carbon-intensive coal use in its energy mix. U.S. government's first step into a cleaner energy mix was the "Clean Air Act" law amendments in 1990 requiring the substitution of renewable fuels such as ethanol for gasoline[37]. This substitution in the fuel mix served the Congress's environmental goal to reduce the emissions that contributed to photochemical smog[38]. In fact, the rules impose a fixed volume of renewable fuel use: thirty-six billion gallons or 2.35 million barrels per day by 2022[39]. Furthermore, the U.S. Agency for International Development (2008) defines energy security as the availability of usable energy supplies, at the point of final consumption, in sufficient quantity and timeliness so that, the economic and social development of the country is not materially constrained (United States Agency for International Development, 2008). On the other hand, the World Economic Forum (2009) when describing energy security prefers the term autonomy rather than availability (World Economic Forum, 2009). Autonomy is a more strategic term emphasizing the enhancement of national control mechanisms over energy supplies that block disruptions caused by external agents, while availability is a more market-oriented term that refers to the ability of consumers and end-users to secure the energy that they need by commercial, regulatory, and financial means. Being autonomous often coincides as being independent and in the case of U.S.'s energy security, the aspect of autonomy refers to energy independence. Generally, energy independence for the U.S. has meant to stop being import dependent on oil and gas; to move into a "cleaner" energy mix, by lowering coal consumption and increasing gas consumption; to start exploiting its abundant shale gas reserves and producing a surplus, which would export to foreign markets such as the E.U., China, Korea, and Japan; and to start maintaining strategic oil and gas reserves for demand shocks. All in all, the U.S.'s energy independence was underpinned by five driving factors: **a)** technical change **b)** increased production from unconventional gas resources **c)** environmental and climate change policies **d)** liberalized domestic energy market **e)** and development of gas futures in financial exchanges. The U.S. has been exclusively a large importer of oil and gas from 1996 to 2007, when its energy independence begun. Technical change was the most significant factor that underpinned its independence by creating new production processes and markets. Exploiting its abundant resources of shale gas and using technological breakthroughs such as hydraulic fracturing (vast unconventional resources unlocked), horizontal drilling (increased amount of gas from a single pad), and improvements in seismic imaging (better information on

[37] http://environmentallaw.uslegal.com/federal-laws/clean-air-act/
[38] http://scholarship.law.duke.edu/cgi/viewcontent.cgi?article=1207&context=delpf
[39] http://www.epw.senate.gov/envlaws/cleanair.pdf?

drill locations), domestic shale gas production has increased fivefold from 2006 to 2010[40]. The augmented domestic production of shale gas has given the opportunity to the U.S. government to move to a higher proportion of consumption of domestic natural gas, mitigating the increase in greenhouse gases, which would otherwise augment from rising U.S. coal use (Medlock, Hartley, & Pyle, 2008). Additionally, the already mature and deregulated energy markets[41] have reinforced the use of financial derivatives such as gas future contracts. Independent firms that was generating and selling electricity to traditional electric utilities used gas future contracts to cover the cost of their output, and simultaneously they could bid to sell electricity at a fixed price in the future. The main advantage of using such derivatives was that the firms could contract with a natural gas supplier to buy gas future contracts and to convert the uncertain market price in the future to a specific level and bid. The U.S. gas markets are mainly composed of large producers who want to sell production forward and large consumers who seek to fix their raw material cost. So, by selling gas forward, upstream companies could increase their funding of exploration programs and eventually boost supply, as well as investors can gain a certainty of associated risk revenues.

The evolution of shale gas in 2007 created the ideal conditions for the U.S.'s domestic natural gas producers to begin exporting worldwide, because the anticipated domestic gas and oil production far exceeded the domestic consumption. According to E.I.A. (2011) shale gas production in the U.S. is projected to reach 12 Tcf per year by 2030, accounting to 46% of the total U.S. natural gas production (Energy Information Agency, 2011). The emergence of shale gas, the increasing oil prices during the past decade, and the globally rising demand for natural gas have turned the U.S. from a net natural gas importer to a net natural gas exporter. Having been an emerging supplier since 2015, the U.S. needed to safeguard potential buyers and to seize arbitrage opportunities. It has been necessary to develop a dynamic exporting strategy that would provide a comparative advantage against traditional suppliers of L.N.G. and pipeline gas. First and foremost, it was necessary to mitigate the associate costs of building new infrastructure to exploit its huge exporting capacity potential. In other words, it should develop a cost-competitive strategy of its new liquefaction plants. So, instead of building new liquefaction plants, Cheniere Energy[42] proposed that the most optimal solution would be to exploit the already existing infrastructure and network of processing plants, pipelines, storage, and loading facilities. Still, to turn a regasification plant into a liquefaction plant requires huge capital investments. Even so, these existing facilities reduced greatly the costs relative to those that would be incurred by a greenfield L.N.G. facility. Their cost-competitiveness against other foreign liquefaction projects lies in the fact that the latter are integrated standalone projects that would produce, liquefy, and export stranded natural gas. Therefore, these projects would require much more new developments, entailing not only the construction of the liquefaction plant from the ground up, but also storage, loading and production facilities, as well as pipeline and natural gas processing facilities. While the additional developments for integrated standalone projects adds highly to their cost, they can be sited at locations where they can make

[40] http://www.eia.gov/dnav/ng/hist/n9130us2a.htm

[41] Gas and electricity markets have been deregulated since 1990 and 1992 respectively with the Energy Policy Act.

[42] Cheniere Energy owns and operates most of regasification plants in the U.S. Gulf.

use of inexpensive or stranded natural gas resources that would have minimal value independent of the project. Furthermore, while these projects may require processing facilities to remove impurities and liquids from the gas, the value of the separated liquids can improve the overall project's economics. On the contrary, liquefaction plants proposed for the lower-48 U.S. are going to use pipeline gas drawn from the largest and most liquid market in the world. Natural gas in the U.S. pipeline system has a much greater inherent value than stranded natural gas, and most of the valuable natural gas liquids have already been removed. Secondly, future opportunities for the U.S. to profitably export depend on the future of global natural gas markets and on the inclusion of relevant terms in specific contracts to export natural gas. Indeed, the flexibility of the U.S. L.N.G. contracts is of more importance than their absolute volume for potential buyers (Fattouh, Rogers, & Stewart, 2015). The U.S.'s liquefaction projects are based on the U.S. Gulf and their L.N.G. contracts exclude rigid destination-restricted clauses. That is, reselling from the initial buyers will be permitted, allowing them to cooperate and optimize their availability of LNG. In addition to their flexibility, U.S.'s L.N.G. pricing mechanism lead to a more robust development of the spot L.N.G. market around the globe, turning it to the new swing supplier between Europe, Asia, and South America. Considering that Asian and European buyers seek more diversified pricing structures for their importing volumes, established L.N.G. exporters face pressure to offer more flexible price indexation than that of the U.S.'s Henry-Hub index basis. Finally, the U.S.'s approach to energy security give also emphasis to strategic decisions on top of economic ones. For example, additional goals for the U.S.'s energy security is to maintain a strategic petroleum reserve, reduce physical threats to energy infrastructure, and prevent the multiplication of nuclear weapons in "non-nuclear weapon states" and non-signatories to the Nuclear Non-Proliferation Treaty such as Iran and North Korea (Brown & Sovacool, 2011).

2.6.SOUTH-EASTERN MEDITERRANEAN

The region of south-eastern Mediterranean (i.e. Egypt, Israel, Jordan, Turkey, Greece, and Cyprus) accounts for many recent huge discoveries and if its exports truly come online in 2019, south-eastern Europe's liquidity will increase. It is a well-known fact, that diversity of energy sources is of great importance to south-eastern Europe and will require substantial investment that needs to be supported from the cooperation of the region's governments. The recent discovery of the mega gas field Zohr in Egypt has given light to new prospects for its regional gas markets. Due to its major gas discovery, Egypt is evolving as a new area for energy investors. Additionally, Israel is now working to overcome its regulatory problems and evaluate new partnerships for the development and monetization of Leviathan. Generally, south-eastern Mediterranean is one of the key regions in European natural gas supply and is described as a potential supplier, which will probably start exporting natural gas regionally by late 2019. Moreover, the region has been a major player in the global chart of natural gas producers since 2009, because of the recent discoveries in the Levant Basin: **a)** the Tamar (2009) and Leviathan (2011) gas fields in Israel **b)** the Aphrodite gas field in Cyprus in late 2011 **c)** and the Zohr field in Egypt on August 2015. Furthermore, in 2010 the U.S.G.S. estimated that the volumes of undiscovered technically recoverable resources of natural gas in the Levant Basin could be up to 122,378 Bcf (billion cubic feet)[43]. These large-scale discoveries have changed the market dynamics of natural gas in the region, especially in the power generation sector, where there has been a shift from oil-fired to gas-fired generators. In fact, according to I.E.A. (2014) natural gas accounted for 78.7% (135,177 GWh) of Egypt's electricity generation and for 48.43% (29,457 GWh) of Israel's[44]. Yet, trade patterns and production levels are significantly affected by geopolitics and gas prices, which will surely come under pressure. For example, in 2014, Egypt's supply was halted by continuous terrorists' attacks in the Arab Gas Pipeline along the year[45], creating an import shortage in Israel. The U.N.'s economic and social commission for Asia and the Pacific report ST/ESCAP/2494 (2008), stated that energy security is the protection against shortages of affordable fuel and of energy resources. Israel's net imports in 2014 were at 85 Mcm (million cubic meters), while its consumption and production quantities were at 8,015 Mcm and 7,901 Mcm respectively. Net imports result from the differential of consumption minus production So, net imports should probably be at 114 Mcm and not at 85 Mcm, thus, implying a shortage of 28 Mcm. After the major discoveries of Leviathan and Tamar fields, Israel was able to satisfy its own needs, as well as it could have been a potential exporter regionally and globally. There are also discussions for construction of a pipeline between Israel and Turkey that could allow Israel to penetrate indirectly the European supply market. All in all, Israel would be expected to begin exports from its Leviathan field by late 2019, if regulatory and government approvals were to be granted as hoped[46]. Regarding Cyprus, its Aphrodite field is estimated between 5 to 8 Tcf, but its intends to start exporting will be realized after the end of 2019. Now, there is neither inland infrastructure to exploit the field nor a domestic pipeline system. That is an issue of energy security concerning the element of availability, making problematic the development of the field for domestic consumption. Nonetheless, two projects have been proposed: a) the construction of an L.N.G. export terminal, which would send gas to Europe directly form Aphrodite b) or the construction of a pipeline from Aphrodite to L.N.G. terminals from surrounding countries like Egypt, and then export it indirectly to Europe (Ratner, 2016).

Due to the discovery of the mega-field Zohr from the Italian company ENI, the whole scene of Egypt's domestic market, as well as the regional and neighboring markets of Israel and Cyprus are changing. In fact, its reserves hold up to 30 Tcf (trillion cubic feet) and are valued at over 100 billion dollars[47], turning into the largest gas field in the region until today and one of the largest recent discoveries globally. Egypt, whose domestic primary energy consumption relies heavily on natural gas met its own gas demand in 2017, when the first quantities from the field reached its domestic markets. Eventually, it will have an option to export up to 29% of the extracted gas, while reserving the rest for its domestic needs[48]. Additional supplies from Egypt would contribute in the development of the regional energy

[43] https://pubs.usgs.gov/fs/2010/3014/pdf/FS10-3014.pdf

[44] https://www.iea.org/statistics/statisticssearch/report/?country=EGYPT&product=electricityandheat&year=2014

[45] https://en.wikipedia.org/wiki/Arab_Gas_Pipeline

[46] http://www.reuters.com/article/us-israel-natgas-idUSKCN0V90D4

[47] https://www.eni.com/docs/en_IT/enicom/media/press-release/2015/08/PR_EniEgypt_eng.pdf

[48] http://www.egyptoil-gas.com/

sector and would also help in safeguarding south-eastern Europe's energy security and liquidity. Yet, by doing so, it would face strong competition from Europe's traditional suppliers (i.e. Russia, Norway, Algeria, and Qatar), as well as from emerging L.N.G. exporters (i.e. U.S.A.). Egypt's proved natural gas reserves are totaled at 77 Tcf, making it the largest producer among the region and the fourth largest in whole Africa[49]. Overall, Egypt could potentially be the driving force of import diversification of south-eastern Europe and Turkey, which has low production and it depends mainly in Azerbaijan for imports through TANAP (Trans Anatolian Pipeline). Regarding Zohr, Egypt is developing twelve natural gas projects with a total investment of 33 billion dollars[50]. However, geopolitical tensions must be addressed. Although Egypt is now a large producer and formerly a net exporter (it used to export gas to Israel, Jordan, and Syria in early 2000s) it became a net importer in 2015, because of energy policies that subsidized the cost of fuel consumption, thus, creating additional demand and natural gas shortage in the domestic market. Additional national policies, which have forced natural gas producers to sell a percentage of their production locally, at prices well below the global benchmark, have underpinned the shortage and have created constraints in novel reserve developments, decreasing its total domestic production. The resulted shortage caused disruptions to industrial production, as well as electricity power outages. Furthermore, let us not forget that political turmoil in the country has ever had a negative impact in production and development. Such has been the political uprising against the President Hosni Mubarak, which has decreased investment in exploitation of novel reserves of gas. Generally, Egypt's L.N.G. imports were estimated to skyrocket in 2017 (4.5 Mt) and then start falling until 2022, were the country is estimated to become self-sufficient again[51]. With the new discovery of Zohr, Egypt's gas production may surpass its consumption by 2020, leaving a surplus for export[52]. Nevertheless, while global market factors and domestic needs negate Egypt's ability to immediately turn Zohr field into a huge export potential, it provides the necessary resources for Egypt to become once again energy self-sufficient, in turn positively affecting its economic climate. Its domestic industrial base could find that it can confidently resume manufacturing capacity expansions, and foreign investors may grow to look more favorably at industrial investment in Egypt[53].

3. THE FIVE IMPORTANT CHALLENGES OF EUROPEAN ENERGY SECURITY & HOW THEY CAN BE MEASURED

Although it is hard to quantify energy security, there have been striking attempts from the academia and research centers to create a more formal concept through the introduction of indicators. The use of robust quantifiable indicators proves necessary to clarify such an elusive context, which is based on conceptual parameters such as the four As[54]: availability (elements

[49] Energy information Administration (2015). *Egypt-International Energy Data and Analysis*.
[50] http://www.lngworldnews.com/egypt-to-up-gas-production-by-2019/
[51] http://www.bloomberg.com/news/articles/201606-17/egypt-exports-rare-lng-cargo-in-midst-of-newfound-buying-binge
[52] http://www.economist.com/news/business/21663249-italian-energy-giants-strategy-seems-bepaying-euregas
[53] http://www.mei.edu/content/at/zohr-gas-field-boon-egypt
[54] A classification scheme proposed by the Asia Pacific Energy Research Centre in the "A Quest for Energy Security in the 21st Century".

related to geological existence), accessibility (geopolitical elements), affordability (economic elements), and acceptability (environmental and social elements). Kruyt *et al.* (2011) used the previous classification to analyze the relationship between climate change policies and energy security developments in O.E.C.D. countries, by applying various energy security indicators (simple and aggregate) through scenario-based modeling. More specifically, they captured the impact of climate change policies on energy security developments using the TIMER model, which is a regional model that describes long-term developments of the energy system (de Vries, van Vuuren, den Elzen, & Jansen, 2001). Their assessment provided four conclusions: **a)** the use of a single indicator cannot lead to unambiguous results; therefore, it is preferable for policy makers to use multiple indicators in their assessments. **b)** the use of aggregate indicators may cause trade-offs between comprehensiveness, transparency, and subjectivity of the four As. **c)** scenario analysis show diverging trends with respect to energy security: availability indicators show declining trends in energy security, whereas accessibility indicators show increasing trends. **d)** the effects of climate change policies on energy security have pros and cons: decreased rate of depletion for fossil fuels and reduced imports, but increased supply concentration in the oil and coal markets; reduced impact of reserve depletion on oil prices, but increased use of more expensive fuel types challenges affordability elements (Kruyt, van Vuuren, de Vries, & Groenenberg, 2011).

3.1.LIMITED AVAILIABILITY OF INTERNAL EXHAUSTIBLE ENERGY RESOURCES

Although, gas resources are valuable for Europe, only the suppliers of the North Sea (i.e. Norway, the U.K., the Netherlands, and Denmark) have sufficient resources to satisfy domestic consumption and produce an export surplus. Yet, low oil and gas prices raise significant barriers for the future availability and production outputs of gas resources from the North Sea. Another drawback of low gas prices is that they do not give the incentive to invest in new natural gas plants, limiting the future availability and liquidity of the commodity. Instead, lower coal prices make more favorable to investors the already existing coal plants and prevent coal-to-gas substitution. Such cases raise important concerns about the efficiency and security of energy supply in the E.U. In 2015, production from the North Sea was at around 120,000 Mcm, of which 60% belonged to Norway, 30% to the U.K., and the remaining 10% to the Netherlands. Due to falling oil and gas prices during the last decade, the upstream activities in the North Sea have been decreased, following the same trend of upstream investments in the region. It seems that production from the continental shelves of the Netherlands and the U.K. will continue declining, thus, creating grave issues of increased decommissioning of essential infrastructure. Moreover, maintenance costs increase, leading to higher break-even prices for natural gas. Additionally, in the Netherlands production has decreased, due to a production cap in Groningen field imposed by the government to avoid earth-quakes that started to worsen as the field started to deplete. More specifically, the most recent cap was set at 24 Bcm, which was half the level of Groningen production in 2013 and at 27 Bcm from October 2015 to September 2016. Generally, low oil and gas prices will probably affect production rates and availability by causing a decrease in investments for exploration and production. While cost deflation will help cushion some of the impact of lower prices, Norwegian gas production could start drifting lower early next decade unless investments recover (International Energy Agency, 2016). In the end, North Sea's states governments have been trying to mitigate the impact of low oil and gas prices, by introducing tax reductions. According to I.E.A. (2016), the upstream sectors in the U.K. and the Netherlands have been advocating tax concessions to maintain both production and exploration outputs stable at best. Finally, Egypt's production rates dropped to 45.6 Bcm in 2015 from the high 62.7 Bcm in 2009 (17.76% decline), even though it is the largest producer of the region. The main reasons behind Egypt's production decrease are: the decreasing offshore resources, political unrest and domestic policies. Nevertheless, the country is targeting to reach production outputs between 5.5 and 6 Bcf per day by the end of 2019 [55].

While demand for natural gas is increasing due to environmental and climate change policies, the increase is slower than that of previous years. According to I.E.A. (2016), slower power generation growth, extremely low coal prices and the rapid development of renewable sources make natural gas's production growth slower. Additionally, the global demand growth will increase by 1.5% on average until 2021, which is lower by 1% from that of 2010 to 2016. Overall, weaker demand growth and lower gas and oil prices are the main reasons of a slower global natural gas production. The downturn in global oil and gas prices has caused a major slowdown in the development of natural gas resources and made the regional markets more competitive to each other than five years ago. In fact, many of the proposed upstream projects that were described as costly, difficult, or problematic have been put on hold because companies no longer have the capital resources or motivation to develop them[56]. This has decelerated the development and exploration of new discoveries, also pushing the region of South-Eastern Mediterranean (i.e. Israel, Egypt) to find new markets for its natural gas exports: markets like Asia that would pay a higher bid for its natural gas than that of the E.U., giving the opportunity for the region to arbitrage. The current low-price environment not only leads to a sharp cutback in upstream investments, but also increases the possibility of supply instability from countries dependent on oil and gas revenues such as Russia and OPEC, exacerbating feed gas issues. An additional drawback of the falling oil and gas prices is that FIDs may be postponed for longer periods or not be finalized at all. That is, proposed liquefaction and regasification projects will not be constructed and/or operational in due time, causing revenues from investments in infrastructure to deteriorate. For example, Eni's Coral FLNG, which has originally expected to take F.I.D. in 2015, has been delayed. Thus, not only there are no incentives for investors to build new L.N.G. terminals, but also some of the existing projects remain underutilized. Because of the falling prices in gas and oil markets, there has been a reduction by 10 Bcm in FIDs from 2014 to 2015 (International Energy Agency, 2016). Eventually, the actual availability and the form (i.e. exhaustible or renewable) of energy resources form a crucial element of energy security.

A quite simple and straight-forward index of availability of finite energy resources (i.e. oil, gas, coal, and uranium) is the reserves-to-production ratio (RPR). It is a widely used

[55] http://www.lngworldnews.com/egypt-to-up-gas-production-by-2019/

[56] The prices are so low that cannot replace the production and exploration costs of these projects.

measure for estimating remaining local, regional, and global energy resources' reserves[57]. It is also used by companies and governments to determine the life of a project, future income and whether more exploration must be undertaken to ensure continued resource supply. The ratio's magnitude is inversely related to the annual rate of production, which may depend on geological features and the stage of the resource development[58]. New discoveries, regulations, technical change, and economy can significantly affect the outcome of the ratio[59]. Additionally, it is often used as an energy security indicator. The ratio is calculated by taking the total proven reserves at the end or at the beginning of the examined period and dividing by the production occurred in that period. The primary advantage of RPR is that it is very easy to comprehend and interpret, as well as it can be compared across different energy sources, showing trends of energy mix transitions across different regions. Exactly because of its simplicity and transparency, it can be useful for gaining insight into the long-term production potential for a given resource, as well as for providing information about the agents of the global hydrocarbon market that are likely to play key roles in its development (Cavallo, 2002). On the other hand, its disadvantage relies in its static nature. Feygin and Satkin (2004) provide an analysis of the factors that affect oil RPRs in a dynamic manner. They found out that the magnitude of RPR is significantly dependent on the stage of oil-field development. Its variations also include factors such as the quality of reserves, as well as country specific factors that change with time (Feygin & Satkin, 2004). Generally, reserves-to-production ratios can be used to predict future supply disruptions under the assumption of resource depletion. Yet, RPRs do not provide any information on the optimal path to resource depletion rates, because they do not consider significant factors of change in production rates such as prices, costs, and institutional settings. Nevertheless, by exploiting the knowledge of existing proven reserves and current production technology and methods, scientists can predict the depletion rates of finite resources and provide a timespan (in years), within which global or domestic reserves are going to be depleted. For example, we can calculate the depletion rate of an exhaustible resource by setting $U(t)$ as the annual consumption of an exhaustible energy resource (i.e. oil, gas, and coal); $S(0)$ as the existing total reserves of the resource at period 0 (e.g. at the beginning of the year); g as the annual growth rate of consumption; and T as the period within which the reserves are predicted to deplete. Then, a mathematical formation of the above problem can be formulated as follows:

$$S(0) = \int_0^T U(0)e^{gt}dt \therefore T = \frac{\ln\left(1 + g\frac{S(0)}{U(0)}\right)}{g}$$

Regarding reproducible environmental resources, their optimal extraction rates depend on the consumption rates of past periods and on the rate with which they reproduce. For example, if

[57] Reserves are defined as the amount of a resource known to exist in an area and to be economically recoverable under the existing production conditions.

[58] Typically, there is high initial RPR during the early phases of development, and then the RPR sharply declines towards the maximum level of production.

[59] Government policies may deliberately slow production, thereby increasing the RPR in the interests of prolonging reserve life, whereas a company may inject water and/or gases into a reservoir to increase production, thus decreasing the RPR.

there is an excess consumption of a particular environmental resource (i.e. fauna and flora), which is already depleting, there might be a chance that it will take longer time before it will be replenished, or it will not be able to reproduce itself at all. To understand better the relationship between current availability, past consumption, and the rate of reproducibility, a mathematical framework is necessary. Let's set S_t the available reserve of a reproducible resource at the beginning of the period t; H_t the consumption during the period t; and G_t the amount of the resource that is being reproduced during the period t. Then, the change of the reserve between different periods will be denoted as the difference between the amount that is being reproduced and the amount that is being consumed. Particularly, this relationship can be denoted as follows:

$$DS_t = S_{t+1} - S_t = G_t - H_t$$

The amount of the reproducible resource that can be increased is a function of two parameters: **i)** the current reserve of the resource S and **ii)** the maximum transmitted capacity (MTC) of the environment. The latter could be defined as the maximum capacity of the environmental reproducible resource, which would have been still existed in the nature, if humans would not have consumed that resource at all. In other words, if the existing reserves equal with MTC, then the increase of the resource would be zero, meaning that there is no room for further development of the particular resource.

In order to link economic growth and natural resources, Solow (1974) used the properties of a Cobb-Douglas function with Hicks-neutral[60] technical change to show that in the absence of technical progress the only way that depletion of energy resources can be maintained is only through fast enough capital accumulation, suggesting that continued technological progress is likely to be necessary for sustainability. He also stated that exhaustible resources should be optimally used according to the general rules that govern the optimal use of reproducible assets. In that time, Solow made an important remark regarding sustainable development; he concluded that earlier generations are entitled to deplete the exhaustible reserves, so long as they add to the stock of reproducible capital (Solow, 1974). It is an actual fact that technical change is the most significant factor regarding economic and environmental sustainability, even in the case of depleting energy resources. More specifically, let us assume that $X(t)$ represents the current reserves of a finite energy resource (i.e. gas, oil, coal) in the period t and that $E(t)$ denotes the amount of the resource that is being extracted and used in the same period t. Then, the relationship between E and X with respect to time can be as follows:

$$\dot{X}(t) = -E(t)$$

The use of the dot above X denotes the first factor of the variable with respect to time. For simplicity, let us assume that the economy uses the resource as the sole input in the production process, thus ignoring physical and human capital (by placing these factors in the production function, it would not change the general conclusion, but it would make the algebraic

[60] According to Neoclassical growth theory, if technological progress simply multiplies the production function by an increasing scale factor such that $Q_t = A_t F(K_t, L_t)$, it is defined as Hicks-neutral.

operations more complicated). Then, according to neoclassical growth economics, using a Hicks-neutral technical change factor, the production function would take the following form:

$$Y(t) = A(t)E(t)$$

Where, Y and A represent the G.D.P. and a technological scaling factor respectively. If the factor A remains unchangeable through time, then the variable Y would fall to 0 for the economy due to the rule of diminishing returns and because the energy resource is finite, meaning that it cannot be extracted forever. On the other hand, technical change allows the technological factor to increase through time with an exogenous rate g such that:

$$\hat{A}(t) = \frac{\dot{A}(t)}{A(t)} = g$$

Neoclassical economists used the above simple algebraic framework to address issues of economic sustainability and growth, regarding natural resources. Particularly, an important question that needs to be answered is "Which is the cost-benefit relationship between capital production and depletion of finite energy resources today, so that capital could be produced in the future?". We can formulate this problem, by assuming that ε is the extraction rate (the percentage of the reserve that is being extracted per period), which is constant:

$$E(t) = \varepsilon X(t)$$

Because ε is constant, it is easy to see that the remaining reserves of the resource would decrease exponentially through time. Thus, if $X(0)$ is the amount of the resource that existed in period 0, then:

$$X(t) = X(0)e^{-\varepsilon t}$$

Therefore, the production level in period 0 and its rate of change are linked through the extraction rate ε as follows:

$$Y(0) = A(0)(\varepsilon X(0))$$

So, lower levels in ε lead to a lower level in capital production Y. To see the rate of change in the variable Y, we would have to transform it into a logarithmic function and then differentiate with respect to time, observing that the extraction rate of the resource would be equal to the rate of change in the reserve. In the end, that would give us the next equation:

$$Y = A + E = g - \varepsilon$$

The above equation shows that a higher extraction rate lead to a lower increase in the rate of capital production (lower economic growth). Indeed, if the extraction would be very high, then the growth rate of the economy would be negative. Moreover, there would also be a specific level of extraction, which would correspond to zero economic growth. However, by setting the production growth rate equal to zero in the previous equation, we would get a steady production level equal to ε^*. In other words:

$$\varepsilon^* = g$$

In that case, if the extraction rate would be higher than ε^*, then the level of production would surpass the level of sustainable growth, but it will be reduced in the long-term. Finally, if it would be lower than ε^*, then the level of production initially would be lower than that of sustainable growth, but it would be expected to increase in the long-term.

At that point, it is worth mentioning that the forefather of the analysis for the optimal resource depletion rate was Harold Hotelling (1931), who established that the price of an exhaustible resource must grow at a rate equal to the rate of interest, both along in an efficient extraction path and in a competitive resource industry equilibrium. Hotelling wanted to establish a more dynamic path to obtain economically optimal depletion rates, especially in the cases of oil and gas, where large uncertainties surround their extraction potentials and their economic output. He found that static equilibrium models were insufficient to explain the changes of production rates in the energy industry, because fluctuations in production arise naturally through time and it is impossible to hold it steady. This dynamic relationship is expressed through a non-linear equation as follows:

$$p_t = p_0 e^{rt}$$

Where, p_t is the price of the exhaustible resource in period t; p_0 is the price in the initial period; and r is the interest rate. He also emphasized the impact of present net value of a finite resource on its future prices and its rate of depletion, in respect to producers' behaviors (Hotelling, 1931). Hotelling showed that the competitive resource owner would deplete energy resources at a socially optimal rate. Therefore, the conservationists' pleas for public intervention cannot be based on any inherent tendency for competition to exploit a resource too rapidly, assuming no divergence between the private and social discount rate (Shantayanan & Fisher, 1981). Additionally, if price elasticity is decreasing as quantity increases, the monopolist will deplete more slowly (Lewis, 1976). Furthermore, if demand shifts over time, becoming more elastic, the same result follows (Stiglitz, 1976). In other words, the monopolist takes advantage of the relatively inelastic demand in the early periods by restricting output. The same reasoning applies to decreasing elasticity (over time): it would lead the monopolist to accelerate depletion in the early periods and to restrict output in the later periods. Partha Dasgupta and Geoffrey Heal (1974) showed that uncertainty in future demand for an exhaustible resource, leads to a bias towards current depletion. Sudden demand shocks may affect depletion strategies. Such is the case of an introduction of a renewable resource, which acts as a substitute, preventing the price of exceeding a certain level. Additional cases might be the possibility of government regulation, when the price of the resource drastically increases, accelerating current extraction of the resource. In the long-term, the limited availability of fossil fuels, along with their technological importance, would begin to act as a constraint on the economy's growth potential (Dasgupta & Heal, 1974). Moreover, Smulders Sjak and Michiel Nooij (2003) developed a general equilibrium growth model to investigate the interaction among energy use, technological change, and economic growth. They assumed that economic growth is driven by steady growth rate of energy inputs and endogenous technological change. The aim of their work was to identify energy as an essential input to growth models under the assumption of endogenous technical change, which drives long-run economic growth (Sjak & de Nooij, 2003). General equilibrium models follow a "top-down" approach and their main advantage is their ability to incorporate the impact of energy policy on international trade and economy, under the assumption of perfectly competitive markets. On the other hand, partial equilibrium models have a significant disadvantage: they illustrate only the energy system and do not include possible linkages of the energy sector and the rest sectors/industries of the economy (Dagoumas, Papagiannis, & Dokopoulos, 2006). Empirical research on whether the availability and/or the level of conservation of energy resources cause economic growth or vice versa is inconclusive. Yet, meta-analysis finds that the role of energy prices is central to understand that relationship (Stern, 2004).

3.2. ACCESSIBILITY TO A DIVERSIFIED PORTFOLIO OF SUPPLIERS

High concertation of suppliers is an energy security problem for the European market. A feasible solution to the concertation problem is diversity. Regarding natural gas, diversity can be achieved between a portfolio of pipeline and L.N.G. suppliers. Pipeline gas is more concentrated than L.N.G., because the main sources are Russia, Algeria, Norway, and Azerbaijan. On the other hand, L.N.G. sources are multiple: Australia, Indonesia, Malaysia, Cameroon, the U.S., Canada, Egypt, Nigeria, Russia, Qatar, and Venezuela. Thus, L.N.G. can offer better chances for diversification compared to pipelines. Additionally, new supply sources multiply, pressing prices to be more competitive and, thus, narrowing the extreme price differentials. Qatar is the largest exporter of L.N.G. worldwide, but the recent shale boom in the U.S. can easily put a halt against Qatar’s dominant position in the L.N.G. global market. That is, most of the additional volumes from the U.S. that are contracted by aggregators and portfolio players, will be sold in the spot market. Moreover, Australia’s liquefaction projects that have come online during 2015 to 2018 had an immediate impact in Qatar’s dominant position in Asian L.N.G. markets. Overall, the main advantage of the new L.N.G. volumes from Australia is displacing spot volume imports in Japan and providing additional volumes for Chinese markets that are not under long-term contractual prices. Canadian L.N.G. exports from the U.S.’s Gulf Coast through the expanded Panama Canal will also put an additional player in the diversification game. Finally, volumes from Russia, Canada, and East Africa that are mainly conducted under long-term contracts, will significantly increase the volume of spot L.N.G. and the liquidity of L.N.G. spot markets. Furthermore, the recent period of high spot L.N.G. prices in Asia is going to be challenged over the next decade, considering that the only strong constraint for production growth is transportation cost of pipelines and development costs of liquefaction plants. Additionally, the already existing plants will add a significant capacity in the global market, because many of the costs associated with the movement of L.N.G. to distant markets have fallen, thus creating new opportunities for L.N.G. to compete with pipeline gas, as well as creating new opportunities for diversification. Indeed, global L.N.G. trade reached the record of 244.8 MTPA (million tons per annum) in 2015, which was a plus of 4.7 MT from 2014 and surpassed the previous high of 241.5 in 2011. According to I.G.U. (2016), global nominal liquefaction capacity in January 2016 was at 301.5 MTPA and the proposed new liquefaction capacity reached 890 MTPA; global nominal regasification capacity in January 2016 reached 757 MPTA, of which 10% (77 MTPA) accounted for floating L.N.G. (FLNG) (International Gas Union, 2016).

According to Yergin (2006), diversification must not be excluded from the broad concept energy security. To secure affordable and reliable energy supplies, diversity must be applied both to imports of energy resources and to energy mix. Andrew Stirling (1994) visualized diversity as a combination between: variety (number of available categories), balance (the spread across the categories), disparity (the nature and degree to which categories are different from each other). In that context, he argued that a representative index of measuring diversity must be "complete". In other, words, it should address at the same time all three components of diversity. Although the issue of completeness is very complex, mainly because of the component of disparity, an index that satisfies both variety and balance in an even way, according to Stirling (1999), is the "Shannon-Wiener" diversity index (SWI). It was first introduced to measure diversity in ecology[61]. However, due to its robustness, often finds significant use in measuring "dual-concept" (variety and balance) diversity as an element of energy security. It is formulated as follows:

$$SWI = -\sum_{i=1}^{n} p_i \ln p_i$$

As an energy security indicator, p_i represents the proportion of fuel category i available in the Total Primary Energy Supply (T.P.E.S.) or the total energy mix. Stirling (1994) used the properties of diversity from SWI to deploy a simple static equilibrium model, which optimizes U.K.'s electricity supply mix. The model focuses on diversity optimization, which, according to Stirling, can be defined as the electricity supply mix that maximizes the sum of the utility of the performance of the individual options and the utility of the diversity of the portfolio. The mathematical formulation is expressed as follows:

$$\max(U)\; U = \sum_i r_i p_i - d \sum_i p_i \ln p_i$$

Where, $\max(U)$ is the maximum value that can be taken by the total utility (U) of a portfolio of i options, r_i is the performance utility, and p_i the proportional contribution of each option. The coefficient d is expressing the marginal utility of diversity in terms commensurate with the measure of option performance utility employed in setting r_i. It is also stated, that the application of the Shannon-Wiener diversity index in static equilibrium models, which aim at optimizing energy supply portfolios under several appraisal criteria, presents a more suitable approach than that of conventional portfolio theory (Stirling, 1994).

Another robust indicator that competes with SWI in the sense of "dual-concept" diversity, according to Stirling (1999), is the "Herfindahl-Hirschman" concentration index (HHI). It was proposed by George Stigler (1967)[62] as a good measure of industrial concertation, helping to identify issues of monopolistic market structures, as well as antitrust behaviors in various markets, under sectoral and/or regional boundaries. It was also applied by Simpson

---

[61] Maguran, A. (1988). *Ecological Diversity and its Measurement.* London: Croom Helm

[62] Stigler, G. J. (1967, March). Comment. *The Yale Law Journal*, 76(4), pp. 718-720

(1949)[63] to measure diversity in ecology, thus known in ecologists as the "Simpson" diversity index. It is formulated as follows:

$$HHI = \frac{1}{\sum_{i=1}^{n} p_i^2} \equiv HHI = -\sum_{i=1}^{n} p_i^2$$

As an energy security indicator, it serves to measure diversity or concertation in suppliers' mix. That is, a lower value of the index denotes higher diversity (lower concertation or high competition), whereas a higher value shows denotes lower diversity (higher concertation or low competition). Overall, the two indices are both robust and simultaneously simple in measuring dual-concept diversity, but the question "Which of them is a more preferable index and why?" is out of scope for this paper, and therefore this analysis is excluded. However, more information on this matter can be found in Stirling's detailed analysis[64]. Konstantinos Chalvatzis and Alexis Ioannidis (2017) used these two indices to analyze how the energy security of five European indebted countries was affected from the 2008 monetary crisis. Particularly, they estimated the energy supply and import diversity in Greece, Spain, Italy, Portugal and Ireland from 1975 to 2015 using a combination of the SWI and HHI to measure fuel mix diversity and concertation from suppliers respectively. They found out that import diversity peaked at the height of the monetary crisis in 2009-2010 and followed a reduced trend in the subsequent years for all the examined countries except Ireland. That is, Ireland's HHI index of concertation is high, because its import mix consists of just about 5-7 countries whereas the other examined countries import energy from a pool of approximately 15-18 countries (Chalvatzis & Ioannidis, 2017).

Jansen *et al.* (2004) formulated four additional long-term metrics of energy security on a single index. Their contribution to the literature of energy security metrics, is that they used the simple Shanon-Wiener index as a basic indicator and creatively extended it into a more refined index. Specifically, they created four new indices that are incorporated in the basic S.W.I. in a successive manner, allowing for more aspects of long-term energy supply to be included. Additionally, each one of the indices includes a specific correction factor to adjust the value of the Shannon index in respect to the aspect that has been added. For example, the fourth index (I_4) captures all the aspects of long-term energy supply security: **a)** diversification of energy sources in energy supply **b)** diversification of imports with respect to imported energy sources **c)** long-term political stability in regions of origin **d)** the resource base in regions of origin, including the home region/country itself (Jansen, van Arkel, & Boots, 2004). As such, the index is formulated as follows:

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

[63] Simpson, E.H. (1949, April 30). Measurement of Diversity. *Nature*, 163(4148), pp. 688

[64] Stirling, A. (1999). *On the Economics and Analysis of Diversity*. SPRU Electronic Working Paper Series, Paper No. 28. Brighton, U.K.: University of Sussex

The Shannon-Wiener index S_i^v is adjusted to all the aspects and is incorporated in the correction factor c_i^4 as follows:

$$c_i^4 = [1-(1-r_{ik})(1-m_i)] \times \left[1-m_i\left(1-\frac{S_i^v}{S_i^{v,max}}\right)\right] \text{ with } S_i^v = -\sum\nolimits_j \left(r_{ij}h_j m_{ij}\ln m_{ij}\right)$$

$$\text{and } r_{ij} = \left\{Min\left[\frac{\left(\frac{R}{P}\right)_{ij}}{50}\right]^a ;1\right\} \forall a \geq 1\,, j=1 \rightarrow n$$

Where, $S_i^{v,max}$ is the maximum value of the aforementioned Shannon index, r_{ij} is the depletion index for resource i in import region j, r_{ik} is the depletion index for resource i in home region k, m_i is the share of net import in primary energy supply of source i (diversity in the fuel mix), m_{ij} is the share of imports of energy resource i from region j in total import of source i (diversity in imports), h_j is the extent of political stability in region j ranging from 0 (extremely unstable) to 1 (extremely stable), and $\left(\frac{R}{P}\right)_{ij}$ is the proven reserve to production ratio for resource i in region of origin j.

3.3.IMPORT DEPENDENCY

Major consuming countries such as the E.U., Japan, China, and India are highly dependent on oil and gas imports to cover their demand. In fact, in the O.E.C.D. Europe, in 2015, natural gas imports were at 454.72 Bcm (Billion cubic meters) and natural gas consumption was at 477.17 Bcm. In China, natural gas imports in 2015 amounted to 58.16 Bcm and consumption at 190.9 Bcm (International Energy Agency, 2016). Additionally, China is expected to emerge as key engine of growth in global gas demand and further expansion in regional liquefied natural gas (L.N.G.) trade over the outlook period, accounting for more than one-third of incremental global consumption. The I.E.A. estimates that lower gas prices, environmental regulation, and large L.N.G. contractual obligations with Qatar will underpin China’s natural gas consumption, leading to an increase from 190 Bcm in 2015 up to 320 Bcm in 2021 with a compound average annual growth rate at 9.1% from 2015 to 2021 (International Energy Agency, 2016). That increase in demand is evidence of growing import dependence, which may cause geopolitical tensions between major importing regions to secure potential supplies. In general, Asian energy demand, especially Chinese, is going to play a vital role in the future of the energy resources and economic growth worldwide. According to B.P.’s statistical review of global energy (2017), “During the last decade, the character of the cyclical adjustments has been increasingly affected by the long-run transition that has been shaping the global energy markets, led by the two most notable, rapidly developing economies: China and India” (British Petroleum, 2017). Given that imported energy entails more uncertainties than domestic production, the higher the net imports are, the greater is the dependency of a country on imports, as well as its exposure to these uncertainties, especially when the country of origin is politically unstable. Particularly, Eastern and Baltic States’ dependence on Russian gas is very close to 100% of their consumption and Europe as a continent relies on Russia for about one-quarter of its natural gas supply[65]. At this point, it is important to note that diversity and import dependence must be viewed as two distinct aspects of energy security and two different paradigms (Nuttall & Manz, 2008). Import dependency may occasionally deteriorate energy security under three conditions: **a)** if there is not diversity between the energy mix **b)** if there is not diversity between suppliers **c)** and the import routes are not flexible.

In 2012, according to E.C. (2014), the contribution of the different shares of energy sources to total energy import dependency, amounted to 53%. More specifically, natural gas import dependency of the O.E.C.D. Europe was at 66% with net imports accounted for 15% of total energy demand, crude oil import dependency was at 88% and its net imports represented 30% of total energy demand and import dependency of coal were at 42% and their net imports constituted 7% of total demand (European Commission, 2014). Therefore, the sum of the relative shares of the net imports by fuel in total demand represents the import dependency for all energy products. Additionally, according to I.E.A. (2016), total energy demand by fuel was 1,883.63 Mtoe and total imports at 1,493.3 Mtoe in 2014. This is evidence that E.U. is highly dependent on imports of fossil fuels. However, the rate of growth has been slowed down the past few years due to economic recession, improved energy efficiency of buildings, and increased home-produced renewable energy. As it seems, oil import dependency is the highest from all sources, and O.P.EC. is a major supplier, but E.U. has flexible access to crude oil and refined products by ship, roads, and railways from a variety of other suppliers. Regarding coal, the E.U. imports around a quarter of its total demand from Russia, but also has access to a variety of other sources for coal, which is transported around the world mainly by ships and railways. Moreover, due to environmental regulations, the use of coal has significantly decreased for the most of E.U. Member-States. Therefore, oil and coal import dependency, now, does not greatly affect E.U.'s energy security. Although E.U. has other sources than Russia that can import natural gas (i.e. North America, Norway, Nigeria, Qatar, Azerbaijan, and Algeria), these are not without problems. For example, Norway is already a substantial provider, but holds its output at a given quantity and does not raise it due to high production costs caused of high natural gas prices; North Africa has also become an unreliable supplier due to political turmoil; a feasible solution is to buy extra L.N.G. capacities, but that means E.U. must outbid the high import prices of Asian markets. Azerbaijan is the only region that has responded to E.U.'s Southern Corridor initiative to bring Caspian gas to European markets through "TANAP" (Trans-Anatolian Pipeline), which will be connected to "TAP" (Trans-Adriatic Pipeline) passing onshore through Greece, Albania, and then offshore to Italy. Overall, Russia's role on the E.U.'s natural gas imports is more significant than that of other suppliers' and that natural gas is more correlated to energy security issues than other energy sources such as oil, coal, uranium and renewables.

Import dependency metrics are widely used as simple disaggregated energy security indicators, which are often resembled by fractions of net imports to Primary Energy Supply (P.E.S.). Additionally, they can be applied to a single fuel category or to the total energy mix. Although import dependence indices are straight-forward and easy to comprehend, there have

[65] Russia supplies over one-third (66%) of Germany's requirements. Additionally, East and Baltic countries, which were closely integrated with Russia in the Communist era, are even more dependent.

also been used more refined versions. For example, A.P.E.R.C. (2007) applied an index combining fuel diversity and import dependence together. It measures an economy's import dependence weighted with its fuel diversity and it is derived from the Shannon-Wiener function as follows:

$$Net\ Economy's\ Import\ Dependence = \frac{\sum_i m_i p_i \ln p_i}{\sum_i p_i \ln p_i}$$

Where, m_i is the share in net imports of fuel i, and p_i is the share of fuel i in Total Primary Energy Supply (T.P.E.S.). A country's import diversity is mainly evaluated based on the variety of available suppliers, on the percentage in which each commodity is imported from each supplier, as well as on the variety of its fuel mix. Therefore, the above index shows that a higher value in the share of net imports and in the share of T.P.E.S. from a single fuel, result in a higher value of import dependence, which deteriorates energy security. Additionally, Eshita Gupta (2008) quantified the relative oil vulnerability of twenty-six net oil-importing countries for the year 2004 based on four market risk indicators and three supply risk indicators. Particularly, the seven indicators are linearly added up to one aggregate index called Oil Vulnerability Index (O.V.I.), whose function is the weighted average of its individual indicators[66]. Gupta used net oil-import dependence as an indicator of geopolitical risk, which is also a form of supply risk, and defined it as the ratio of net oil imports to oil supply[67]. The ratio of oil imports to G.D.P. is the most significant index between the seven and the oil share in T.P.E.S. the less significant, having their average shares counted to 21.9% and 6.6% respectively for the examined countries (Gupta, 2008). A measure to decrease Russian import dependency of gas is the so-called fuel-switching. However, in the short-term this will not be very effective, especially in the residential sector that consumes most of E.U.'s gas. The shale boom in the U.S., and changes in its energy mix has driven much of the coal supplies into Europe, where coal price is well below than that of the imported Russian natural gas. While gas prices are in a historically low level, they have not yet reached a level that would lead to a broad substitution of coal, except from occasional circumstances (International Energy Agency, 2016). The growth rate of fuel-switching is driven by three forces: **a)** the rate at which coal-fired generation is replaced by natural gas combined-cycle generators **b)** the access of long-term contracted supplies at competitive prices between other fuels and **c)** the rate at which natural gas can displace oil-based transport fuel, either directly or through natural gas-based substitutes. Another measure is the development of shale gas plays, which will rebalance the decreasing domestic production of conventional gas in countries like the Netherlands. Shale gas production was abandoned in the E.U. by legislative work for many years in the past, due to possible harmful effects in the environment. Yet, in 2014, the German government brought to the surface legislative proposals for shale gas exploration, and Total was allowed to do exploration tests for shale gas in Denmark. Operations have also been occurred to Poland, the U.K. and Romania, where possible reserves may exist. In my opinion, legislation must adapt to the long-term state of the market, through corrective action, and never comes as an obstacle.

[66] The weights were obtained using a multivariate technique of principal component analysis (P.C.A.).

[67] Net oil imports are the sum of imported crude oil and refined oil products; oil supply is the sum of crude oil domestic production (if there is any) and net oil-imports.

When problems of energy security, and import dependency arise one should do well to consider shale gas as an alternative possible solution.

3.4.VULNERABILITY TO GLOBAL ENERGY MARKETS

Since the "globalization" of gas markets started in 2007 (U.S. shale gas bloom), changes in prices in one regional market, lead to much more immediate impacts on supply-demand equilibrium in other markets. For example, shale gas developments in North America, as well as changes in the energy mix of Asia have impacts on Europe and vice versa. Particularly, a study has showed that as natural gas trade becomes more globalized and new producing and consuming markets emerge, so do regional prices adjust to new market balances (MacAvoy, 2008). New producers have emerged over the past decade with the ability to produce and export huge quantities of natural gas to whatever destination. The only incentive for a producer to begin exporting in other countries is arbitrage. Namely, there is a price differential between exporting and importing countries that defines the profitability of trade. Additionally, the condition that needs to be met is that there must be a consumer in a foreign market who is willing to pay a certain margin above the domestic price, which covers the cost of the trade. According to Medlock *et al.* (2008), the arbitrage value of L.N.G. volumes from North America into a Member-State of the E.U. can be expressed as follows:

$$AV = P_{US} - P_{FR} \times XR \times HC$$

Where, AV is the linear function of the arbitrage value measured in \$ per MMBtu and P_x $(x: US, FR)$ is the price of natural gas in the U.S. and France respectively to their transcripts. However, P_{US} is measured in $\frac{\$}{MMBtu}$ and P_{FR} is measured in $\frac{€}{KWh}$. Furthermore, we need to know the value of the trade from the side of the U.S., which is measured in \$ per MMBtu. Therefore, to link the different price units and gain the result in \$ per MMBtu we need to multiply P_{FR} with XR that represents the exchange rate between \$ and € in the form of a fraction (i.e. $\frac{\$}{€}$), and then with HC that represents the unit conversion factor (i.e. $\frac{KWh}{MMBtu}$), which is used to transform KWh to MMBtu. As it seems from the linear form of the above function, P_{US} is constant (function's intercept) and P_{FR} is variable with respect to its coefficient $XR \times HC$ (function's slope). The heating conversion factor is constant, but the exchange rate is an exogenous factor, whose changes affect the trajectory of trade between foreign markets. Specifically, AV changes are dependent on the value of P_{FR}, and the percentage upon which changes on the latter impact the former is shown by XR. Additionally, because the sign of the slope is negative, there is an opposite trajectory effect in the value of AV for every change of the price of natural gas in France P_{FR}, ceteris paribus. In other words, if the dollar weakens against the euro, XR will decrease and AV will increase and the opposite, all else equal. Thus, the movements of exchange rate are crucial for every producer who wants to export. Consequently, exchange rate is a that factor plays an important role on the number of FIDs that will take place, affecting the total export and import capacity of a producing and consuming country respectively (Medlock, Hartley, & Pyle, 2008). Nevertheless, globalization of gas industry will lead to the international integration of gas markets and therefore to the narrowing of these price differentials in the longer term. Then again, short-term factors, such as demand shocks, may be profitable arbitrage opportunities, which would occasionally increase export volumes, but they would not support large-scale capital investments. For example, lower production rates, ceteris paribus, would distribute cash flows more into the future, thus lowering the net present value of these investments (Medlock, Baker, & Baker, 2012).

The expansion of international gas trade has led to new large-scale investments. These investments gave way to specific transactional relations between suppliers and consumers of gas in the form of long-term contracts, which are legally binding and subject to international arbitration. The pricing terms of these contracts are linked to oil products, the so-called oil price indexation of gas contracts. They include a periodic price review (re-opener) every three years and an annual contract quantity bonded with a minimum take-or-pay clause, which obliges the buyer to buy 80% to 90% of the annual contracted quantity. That way, it can be said that the price risk belongs to the seller and the quantity risk to the buyer. Still, gas price volatility is largely mitigated, because prices are quarterly adjusted with respect to the average of oil prices in the preceding six to nine months. Thus, the price risk of the gas exporter is reduced by a three-month lag occurred by the adjustment period. The basic drawback of long-term contracts (LTCs) is that their price is not driven by supply and demand equilibrium, thus ruling out the prospects of competitive pricing. On the other hand, the only advantage of LTCs is that they provide an element of price certainty for huge traded volumes, when there is absence of storage and physical liquidity. Nevertheless, interregional and internationally traded quantities based on LTC pricing create price differentials, which lower the possibilities of successful energy market integration. Most of natural gas volumes traded in the borders of and within the E.U. is based on ad hoc formulas[68], which are linked to oil price escalation indices (Konoplyanik, 2010). In fact, from 1984 to 2007 gas volumes coming through the borders of Germany from Russia, Norway, and the Netherlands were based almost completely on LTCs, whose price formation mechanism was indexed to oil products. Although the German border price[69] was based on many individual contracts with some variation in specific price formula variables, the linkage to oil product prices appears to have been constant. But why would governments and NOCs relate gas prices to oil prices? The answer is that natural gas and oil were perceived to be substitutes, rather complementary commodities, both in the short and the long term. Pricing mechanisms were created to ensure that consumers continued to burn gas, rather than oil products; since most customers had switched to gas from oil, given a price incentive, the ability to switch back was deterrent. Additionally, with the inclusion of take-or-pay clauses in LTCs, fuel switch to oil was more preventive than would normally be. For example, if many customers (e.g. a percentage of a country's population) switch back to oil, this would not only deprive the importing country of its gas market but would also force it to suffer take-or-pay penalties form its LTC counterpart. Another reason for the preference of oil-indexed pricing mechanisms instead of gas-on-gas competition prices is profitability. Due to its low energy density, gas is

---

[68] Ad hoc arrangements allow for adjustment of the pricing formulas by changing the variables that determine the base price or through the weighting of petroleum products to include some reference to hub prices.

[69] The official average German border price (BAFA): $price\ in\ month\left(\frac{€}{MWh}\right) = 2.273 + 0.025977 \times \left(average\ of\ previous\ 9\ months\ gas\ oil\ prices\ in\frac{€}{ton}\right) + 0.029224 \times \left(average\ of\ previous\ 9\ months\ fuel\ oil\ prices\ in\frac{€}{ton}\right)$

more expensive to transport and store, compared with oil products and coal. Moreover, a basic factor that drives initial costs is the geological position upon which the site has been build. For example, an offshore facility would seem likely to be more expensive to build than an onshore. That basic difference has led to two distinct forms of pricing methods: the cost plus and the market value. According to the latter method, the gas price is negotiated based on the weighted average value of gas as a substitute for oil products, also adjusted for allowance of transportation and storage costs. When the costs of development and production are lower[70], this method can provide substantially higher revenues for governments and national oil companies.

Affordability of consumers' can be affected by oil-indexation in LTCs, because it is a form of price discrimination and oil-indexed prices are higher compared to gas-on-gas competition prices. Particularly, large firms and NOCs distinguish consumers in respect to their elasticity of demand and/or prevent resale of gas volumes to other regions. Both conditions are met on European and Asian markets (Dagobert & Hartley, 2007). In a more interconnected and globalized natural gas market, where there is enough flexible L.N.G. for arbitrage to link European gas trading hubs and Asian L.N.G. spot prices, the response of Russia is of pivotal role. With Asia continuing to attract flexible L.N.G. away from Europe, Russia's market power rises as its pipeline exports to Europe increase. Thus, Russia can achieve a higher level for European hub prices by supply management (Fattouh, Rogers, & Stewart, 2015). To summarize, two are the main parameters of Russian impact, which affect E.U.'s gas markets:

- Russia's ability to "balance the system" at a physical level, through managing export levels, and thus providing a "buffer" to the global L.N.G. system.
- Its consequent ability to influence the level of European hub prices.

Qatar's geostrategic position between Europe and Asia has created great opportunities for arbitrage: it has the ability sell gas to Europe when prices in Asia are low and to sell back in Asia when its prices are high. By placing L.N.G. loads in Europe to support Asian prices, it acts like a swing supplier. Namely, Qatar has the option to distribute its supply between Asian markets of high gas price but with low price elasticity and European markets of low gas price but with high price elasticity (Allsopp & Stern, 2012). Moreover, its optimal solution is to restrict supply to the high price market (Asia) to secure higher margins, and to divert a greater quantity from the low-price market (Europe) that would significantly reduce the premium market price (Asia) with little compensating increase in the European market price (Fattouh, Rogers, & Stewart, 2015). Qatar's role on these two markets may affect long-term economic welfare by raising regional energy prices. Firstly, most of Qatar's gas export volumes to Chinese markets are sold under long-term contracts at prices linked to crude oil through the well-known oil price index: Japan Customs Cleared Crude Oil Price (J.C.C.). Secondly, Southern E.U.'s gas import volumes are under long-term contractual obligations at prices linked to the prices of oil and/or oil products, adding more to the final consumption price of gas and other commodities such as electricity. Thirdly, Qatar can redirect spot volumes[71] away

[70] Development of an onshore rather an offshore reserve.

[71] Export volumes, which are spot priced or contracted, but have some flexibility.

from E.U. towards spot sales in Asia, the Middle East, and South America, where spot prices are above Asia's long-term contracts. Finally, it can optimize cargo deliveries between the E.U. and "premium" markets to maintain high L.N.G. spot prices in Asia, thus exercising its market power.

Because of the flexibility of the definition for energy security and its multiple aspects, some import dependency measures are indicative of vulnerability to fuel prices. Particularly, net oil imports expressed as percentage of G.D.P., form an index called the value of oil imports or the cost of oil in national income, and it is categorized as a market risk indicator, which is affected by global market fundamentals such as exchange rates and oil prices, and which in turn affects oil intensity (Gupta, 2008). Energy intensity is widely used as an index of vulnerability to high energy prices, as well as an indicator of welfare losses. Particularly, Johannes Bollen (2008) assumed that the driving factors that lower economic welfare are: **a)** high absolute values of import quotes **b)** increased share of oil and gas in the total fuel mix **c)** high overall energy intensity. Bollen constructed a "penalty" function to quantify welfare losses associated with energy security and supply risks. The function was incorporated in the MERGE[72] model measuring nations' willingness-to-pay to gain energy security. Moreover, the welfare loss resulting from a lack of security of energy supply directly relates to the willingness-to-pay for avoiding this deficiency, and it can be expressed as:

$$IMP_{t,r}\left(i_{t,r} : i_{t,r} > 0\right) = A_r\left(\frac{i_{t,r}}{i_{0,r}}\right)^{\alpha}\left(\frac{c_{t,r}}{c_{0,r}}\right)^{\beta}\left(\frac{E_{t,r}}{E_{0,r}}\right)^{\gamma} \; ; \; IMP_{t,r}\left(i_{t,r} : i_{t,r} < 0\right) = 0$$

Where, IMP is the willingness-to-pay to avoid a problem of energy supply security; the subscripts t and r respectively refer to variables' time and region dependencies, while the exponents α, β and γ with respective values of 1.1, 1.2, and 1.3 allow for flexible assumptions regarding the convexity or concavity of the dependency of IMP; i is the import ratio and is defined as the imported energy, divided by the total national energy demand, both in terms of their energy content; c is the consumption ratio and is defined as the consumption of a given energy commodity, divided by the consumption of energy at large, again each in terms of their energy content; E is the energy intensity of the economy and is defined as the consumption of energy per unit of GDP; A is a country specific calibration constant and is expressed as an overall region-dependent scaling factor. Willingness-to-pay is zero, only if a country is not dependent on foreign energy imports (i.e. $i < 0$) (Bollen, 2008). Beltramo *et al.* (1986) developed a partial equilibrium model (G.T.M.) that aims at maximizing the sum of consumers' benefits (consumers' welfare) less the costs of production and transportation, subject to constraints on the prices and quantities traded. As the authors explained, producers' costs are described as the integral of the supply (marginal cost) function, while consumers' benefits in each sector are described as the area below the inverse demand (willingness-to-pay) function. Moreover, they developed a submodule to make projections for natural gas sectoral demand in the U.S. from 1990 to 2000, based on historical data, by estimating long-run cross-price and

[72] Manne, A. S., & Richels, R. G. (2004). MERGE: An Integrated Assessment Model for Global Climate Change. Stanford University

own-price elasticities. They found out that if all energy prices would remain constant, total gas demand growth would be proportional to the energy-using activities[73] (Beltramo, Manne, & Weyant, 1986). In their model, consumers' welfare is maximized using the following equation:

$$\sum_{j,k}\int_{v}^{z_k^j} g_{jk}(u)dt - \sum_{i}\int_{v=0}^{y_i} f_i(u)dt - \sum_{i,j} c_{i,j}x_{i,j}$$

Where, u denotes the variable of integration and v a lower bound on gas consumption in region j by sector k; $c_{i,j}$ is the cost coefficient; $x_{i,j}$ depicts the quantity transported from supply region i to demand region j; and y_i is the total quantity supplied by region i. However, GTM computes a static market equilibrium in which denoted natural gas prices are the only variables that affect demand and because of that it cannot be used directly to assess the optimal timing of resource extraction.

The reasons for modeling energy demand are as many as the ways with which energy is used in production process, making it one of the most complicated end-uses to analyze, and predict. Bohi (1981) made an extensive review of econometric models regarding consumers' behaviors and focused in econometric techniques that estimate energy demand elasticities, prices and long-run rates of adjustment on each sector (Bohi, 1981). The most common economic approach is related to the estimation of a system of factor demand equations derived from a generalized translog cost function (Christensen, Jorgenson, & Lau, 1973). A method extensively applied in studies investigating industry's energy demand (Polemis, 2007). For the estimation of this function, the iterative Zellner method or the Seemingly Unrelated Regression Estimation (SURE) is used. This method, which is equivalent to maximum likelihood estimation, gives consistent and asymptotically efficient estimates (Floros & Vlachou, 2005).Baltensperger *et al.* (2017) developed a spatial partial equilibrium model to analyze the changes in consumption, prices, and social welfare induced by the infrastructure expansions. The paper, based on model results, distinguish three categories of projects: projects increasing social welfare in all scenarios in most countries, projects increasing social welfare in the newly connected countries while social welfare drops slightly everywhere else, and projects with a marginal effect on the market. Model results indicate that if all proposed infrastructure projects are realized, the EU's single market will become a reality in 2019 (Baltensperger, Fuchslin, Krutli, & Lygeros, 2017). Deane *et al.* (2017) developed a detailed integrated electricity and gas model for the EU-28, towards identifying the impact of gas supply disruption on the power system operation and the gas flow in Europe. The model was developed using the PLEXOS software package, which allows for both gas and power objects within its framework. Model results show that interruption of Russian gas supply to the E.U. could lead to a rise in average

[73] Sectoral energy-using activities are proportional to: the number of mobile fleet for the transportation sector, the level of industrial production in the industrial sector, the level of electricity generation in the power generation sector, and the number of households in the residential sector, as well as the amount of floor space in the commercial and residential sectors.

gas prices of 28% and 12% in electricity prices. The model is also used to examine the importance of gas storage infrastructure (Deane, O Ciarain, & O Gallachoir, 2017).

3.5.CLIMATE CHANGE & OTHER ENVIRONMENTAL THREATS

It is a fact that climate change threatens the vitality of societies worldwide because it heavily impacts water accessibility, food productivity, health, and the environment. Societies can become stressed to the point of collapse, when environmental conditions deteriorate to the point, where necessary resources are unavailable (Jared, 2005). Generally, environmental stability is a significant factor for societal stability and population's well-being. On the other hand, environmental hazards such as climate change, air, water and land pollution, forest degradation, and biodiversity loss threaten every aspect of welfare. Climate change has tremendous consequences both on the environment and on societies and the evidence of change has mounted as climate records have grown longer, as our understanding of the climate system has improved, and as climate models have become more reliable. Over the past twenty years, evidence that humans are affecting the climate has accumulated inexorably, and with it has come ever greater certainty across the scientific community in the reality of recent climate change and the potential for much greater change in the future (Collins, Colman, Haywood, Manning, & Mote, 2007). Climate change has severe impact not only on the planetary habitat, but also on global economic growth and development. Indeed, it has been estimated that the overall costs and risks of climate change will be equivalent to losing at least 5% of the world's G.D.P. or 3.2 trillion dollars every year, and that if worse risks would be considered the amount could exceed 20% of global G.D.P. (13 trillion dollars), whereas the costs of action reducing greenhouse gas emissions to avoid the worst impacts of climate change can be limited to around 1% of global G.D.P. each year (Stern N. , 2008). In addition, every year climate change is attributable for the deaths of over 300,000 people, seriously affecting a further 325 million people, and causing economic losses of 125 billion dollars[74]. However, climate change impacts are not evenly distributed, and the developing countries suffer from the consequences the most. Developing economies rely heavily on climate sensitive sectors such as agriculture and tourism, meaning that they are significantly dependent on seasonality issues, as well as directly affected by changes in temperature, climate, and weather conditions. Furthermore, lack of important public services such as advanced health care and transportation systems, often found in poor developing countries, puts them at greater risk to adverse climate impacts. Finally, the consequences of climate change (e.g. rising sea level, deteriorating ecosystem services, social tension, and creation of environmental refugees) seem graver, when considering that less affluent countries have fewer ways to recover from the associated environmental costs; not only their assets are less likely to be fully insured, but also, they rarely have access to institutional remedy systems other than limited humanitarian aid donations.

The terms climate change and energy security are linked together within similar contexts. This linkage suggests that climate change policies and energy security strategies share a common element: social and environmental acceptability; and a common proposed solution: decarbonization of the economy. By lowering the inefficient use of fossil fuels, energy intensity

[74] https://ejfoundation.org//resources/downloads/no-place-like-home.pdf

will drop, and greenhouse gas emissions will decrease, thus improving social and environmental stability. The linkage between climate change and energy security is not misplaced. In fact, climate change is caused by humanity's inefficient use of energy; generated energy from fossil fuels causes global warming, the so-called greenhouse effect. Next, there is a series of chain reactions: the rise of global average temperature caused ice to melt in the north pole and next the sea level to rise, causing floods in coastal areas; then, changes in climate in some areas of the planet caused extreme weather conditions such as droughts, and violent storms that, in turn, breed national security problems from migration to border disputes and wars. Climate change is a threat multiplier, which has the potential to cause multiple chronic, destabilizing conditions globally (Mazo, 2010). Furthermore, in the U.S., the Congress ordered the National Intelligence Council, which produces government-wide intelligence analyses, to include in its 2008 report the first assessment of the national security implications of climate change (Broder, 2009). In other words, climate change should be recognized as an international security problem. Nonetheless, climate change may not only pose a threat to national security, but also to energy security. More specifically, mass migration of refugees seeking asylum from ecological disasters would destabilize regions of the world, threatening national and energy security (Brown & Dworkin, 2011). According to The New York Times (2010), with the prospect of worsening climate conditions over the next few decades, experts on migration say tens of millions more people in the developing world could be on the move because of environmental and climate disasters[75]. Environmental harassments such as air, water, and land pollution, biodiversity loss, and forest degradation can still threaten climate and cause the above-mentioned chain reactions. Therefore, climate change solutions should become part of energy security strategies and policies in national and universal level. On the other hand, there are voices supporting that energy security and climate change cannot be easily addressed together, due to trade-offs between them. That is, climate change policies may occasionally hinder energy security and vice versa. Gal Luft *et al.* (2011) stated that climate change has minor impact on energy security and that it is essential for policy makers to better understand of the trade-offs associated with linking climate change policies and energy security strategies. Thus, they clustered these trade-offs between positive and negative impacts of global warming on energy security. They also highlighted that there are five unintended security consequences of climate policies: **a)** increasing coal prices could deny poor communities in the developing world access to cheap base-load electricity **b)** shifting from base-load to intermittent sources of power like solar and wind can cause reliability problems **c)** shift to low-carbon nuclear power increases the risk of nuclear proliferation **d)** climate policy makes coal-to-liquids and unconventional oil like shale and tar sands prohibitive **e)** the shift from coal to natural gas can create dependency on unreliable natural gas exporters like Russia and Iran, increasing these countries' geopolitical power (Luft, Korin, & Gupta, 2011). Nevertheless, climate change not only poses threats to global social stability, but also has direct and indirect effects on global energy security.

Generally, climate change and other environmental hazards such as air and water pollution, act as threat multipliers for national stability and energy security in political unstable

[75] https://www.nytimes.com/2010/01/04/world/asia/04migrants.html

regions of the world. In fact, projected climate change will seriously worsen already marginal living standards in many Asian, African, and Middle Eastern nations, causing widespread political instability and the likelihood of failed states (CNA Military Advisory Board, 2007). Deficiencies in water supply and water quality have already caused about 4,500 deaths globally every day or 1.7 million deaths per year, 90% of these having been children (Organisation for Economic Co-operation and Development, 2008). In addition, air pollution can cause acid rain, which can be as catastrophic as water pollution and water shortages. In actual fact, acid rain not only destroys aquatic life, human crops and animal habitats, but also can travel for a long distance causing severe damages internationally (Eglene, 2002). The effects of acid rain can cause tremendous political and socio-economic consequences on regions that are dependent on fishing for food and trade. More specifically, depletion of fishing resources domestically might lead to significant market disasters, as well as political and societal conflicts over the remaining aquatic resources. Eventually, acid rain affects not only the source, but also other nations that have nothing to do with its production, causing national security consequences in less diversified economies with undeveloped political systems. For example, countries that depend on aquatic resources and are threatened by acid rain, might turn to hostilities against the countries that are the sources of the rain. Altogether, global warming, climate change, and environmental threats in general cause the so-called principal-agent problem, where the benefits or costs (mainly the costs) of a polluting action are not borne by the country taking the action (i.e. the principal), but they are transmitted to another country (i.e. the agent) regardless the distance between them. Particularly, some of the top CO_2 emitting countries[76] are not so vulnerable to climate change, whereas poor regions such as Africa that contribute least to G.H.G. emissions are affected the most by climate change (Mendelsohn, Dinar, & Williams, 2006). The so-called principal-agent problem underscores the need for systematic implementation of measures promoting energy and end-user efficiency (Brown, 2001).

Global warming threatens to worsen these conditions, magnifying the prospect of mass migration of refugees seeking asylum from ecological disasters, including the above-mentioned environmental hazards. Environmental sustainability means that in order to safeguard energy security, a nation needs to promote efficiency for the end-users (citizens) by mitigating the externalities of associated environmental hazards. In fact, energy efficiency can help to reduce energy security vulnerability in a timely fashion, while improving economic and environmental performance (Elkind, 2010). Yet, according to Marilyn A. Brown (2011), structural efficiency through governmental action is a first order condition to realize end-user efficiency. Energy efficiency and environmental performance can also be improved with the use of renewable energy sources. Overall, energy generation from renewable sources can serve multiple purposes: **a)** mitigation of national and energy security risks caused by global climate change and improvement of air and water quality, by decreasing net greenhouse gas emissions **b)** promotion of energy independence by reducing energy imports from foreign suppliers **c)** promotion of sustainable development, by providing environmental sustainability and social stability **d)** alleviation of the negative political and environmental externalities associated with

[76] In 2006, among the top ten CO_2 emitters were Japan (9.78 tons/capita), the U.S. (19.78 tons/capita), Canada (18.81 tons/capita), the U.K. (9.66 tons/capita), and Germany (10.4 tons/capita), and South Korea (10.53 tons/capita).

imported fossil fuels, by increasing domestic energy generation. Unfortunately, there are physical obstacles, as well as financial, political, and regulatory uncertainties along the way that delay international implementation of structural, energy, and end-user efficiencies: **a)** insufficient infrastructure to integrate renewable energy sources with the rest of the grid, as well as to transfer biomass from rural to urban areas **b)** the stochastic nature causes intermittency problems, turning R.E.S. into an unreliable source of energy **c)** relatively high costs to establish offshore renewable farms and to connect them with the rest of the onshore grid. Nonetheless, both R.E.S. and energy efficiency are essential conditions to safeguard energy security, as well as to provide sustainable development by securing the welfare of future generations.

A.P.E.R.C. has developed the term acceptability (environmental & societal) to encompass environmental impact as an element of energy security. According to A.P.E.R.C. (2007), acceptability is an indicator of energy security, which is defined as an economy's transition away from a carbon-intensive energy mix. This term is mainly concerned with the link that exists between CO_2 and other G.H.G. emissions and energy security. As explained before, most of the environmental threats (i.e. global warming, climate change, air and water pollution etc.) are caused by human activities. Eventually, their consequences are catastrophic and affect not only national security, but also energy and environmental security, which in turn deteriorate, thus decreasing social welfare and economic growth locally and globally. A very simple and comprehensive metric that can be used to measure acceptability is by comparing the carbon content of fuels to their energy content (e.g. CO_2/GJ). In fact, by measuring the amount of CO_2 emissions from different fossil fuels in relation to the energy produced when they are burned, denotes the carbon intensity of the fuel. More specifically, coal from anthracite emits 228.6 pounds of CO_2 /MMBtu, coal from lignite emits 215.4 pounds of CO_2/MMBtu, whereas natural gas emits only 117 pounds of CO_2/MMBtu. More plainly, higher carbon intensity means lesser acceptability and vice versa[77]. For example, coal is a less acceptable energy source given its high carbon intensity, whereas natural gas is more acceptable. Indeed, natural gas is primarily content of methane (CH_4) rather than carbon dioxide, making its energy content higher and its CO_2-to-energy content lower compared to other fossil fuels. In addition, acceptability can also be measured by the share of R.E.S. (including nuclear energy) in TPES. Other simple metrics can be the aggregate sulfur dioxide (SO_2) emissions and carbon dioxide emissions, which eventually reveal how far countries have gone towards mitigating G.H.G. emissions, acid rain, and noxious air pollution (Sovacool & Brown, 2011). All in all, decarbonizing the economy leads to higher environmental and societal acceptability, and thus to higher energy security. Still, the choice of the acceptability metric is difficult because there are many different ways[78] in which an energy source can be ranked as acceptable, as well as because acceptability is often an expendable virtue[79] (Hughes & Shupe, 2011).

[77] https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11

[78] These can range from emissions associated with different energy sources to the impact of the energy source on indigenous peoples in the places where the energy is produced.

[79] What is considered unacceptable one day may be considered acceptable the next. For example, much of the U.S. continental shelf was closed to offshore oil and natural gas development until President Barack Obama decided to lift a large part of the moratorium in the spring of 2010.

4. CONCLUSIONS

It cannot be denied that one of the most important forms of security is energy security. It is trite to mention that enough, reliable, affordable, and secure supplies of energy are essential for any economy to smoothly function; to generate electricity, to heat houses, to move cars and buses, to construct buildings and roads, and generally to produce industrial and/or agricultural products. The idea that the availability of energy resources does not play a vital role on the level of economic growth because of international trade is quite narrow and it represents the one side of the coin, because it rules out some fundamentally significant factors such as the reliability of the supplier, the affordability of the consumer, diversity of supplies, sustainability, and the rate of depletion of finite energy resources. For example, the inefficient depletion of exhaustible reserves harms the future availability of energy resources, as well as sustainable development and economic welfare. That is, the planet cannot recover from a deficit of resources. Countries may discover novel reserves of gas that are nominally added up to countries' reserves, but globally the aggregate planet's reserves are finite, and with every use they are being depleted, leaving lesser quantities to use in the future. Thus, consuming finite energy resources inefficiently now, may challenge the social welfare of future generations. At first, politicians and scientists believed that energy security was limited to importing countries, but technical change and the robust development of new energy markets and sources have turned energy security into a primary concern of every country, either being a producing, a consuming, or a transit one. However, there is neither a universal definition for energy security, nor a uniform quantitative framework to measure it. In the second chapter, it is apparent that energy security holds a multidisciplinary concept, which includes political, socio-economic, geological, and technological elements. Additionally, the definitions that have been given to energy security differ as much as national approaches and strategies differ from country to country, because of distinct region-specific factors regarding their level of development, their geographical location, the level and diversity of their natural resources, their political and market settings, and their international relations. Moreover, in chapter two, it became obvious that while energy importing countries (i.e. the E.U. and China) want security of supply and low prices, energy exporting countries (i.e. Russia, Qatar, and North America) pursue security of demand[80], so that their fiscal revenues can be predictable and sustainable in the long-term. It is also worth mentioning that some of the energy exporting regions such as the Middle East and South-Eastern Mediterranean face domestic supply problems driven by robust economic and population growth, and policies concerning subsidized prices for electricity and transportation fuels.

To prevent severe consequences from taking place, policymakers, country leaders, and governmental actors need to consider energy security as a wider concept and pay attention not only to context related material, but also to a variety of aggregate indexes as outlined in chapter three. Additionally, in chapter three it became obvious that the E.U. faces various challenges regarding its energy security: **a)** limited availability of internal energy resources and economic sustainability **b)** high concentration of suppliers **c)** import dependency on unreliable suppliers **d)** vulnerability to global markets **e)** climate change and environmental sustainability.

[80] The assurance that their production will be purchased at what it considers to be a fair price over the long term.

Integration into energy markets is a well-regarded measure to promote sustainable competition across E.U.'s internal energy market and augment its energy security. Still, there is no complete integration and the internal market should have been completed by 2014, to allow natural gas and electricity to flow freely. A factor preventing integration is that Member-States do not speak with one voice yet, due to substantial differences in their institutional settings and national policies. Without diversification and without enough infrastructure, dependency on global market developments is higher and may eliminate the prospects of affordable and competitive prices, increase energy intensity, and lead to lower aggregate social welfare and thus, to lower economic growth. Moreover, due to energy price fluctuations: the higher the exposure of an economy is to the global energy market through international trade, the higher the risk of negative economic consequences is. To manage energy security problems from unreliable suppliers E.U. needs to diversify the energy mix and keep a well-balanced supply portfolio to avoid increased levels of concentration both in energy sources and suppliers. Secondly, decentralization of energy markets will increase consumers' welfare and their affordability and will provide a smoother transition into an integrated market, which will narrow the existing price differentials and facilitate internal cross-border trade. Thirdly, technical change will increase economic growth by lowering energy intensity, as well as it will help in the direction of sustainable development by creating more efficient energy technologies, which will help balancing production between exhaustible energy resources and renewable energy resources. Finally, energy efficiency measures buffed by technical change will act as a cure for climate change and other environmental threats. Overall, energy is the fuel of economies and its security the shield of societies.

BIBLIOGRAPHY

Aling, B. (2014). *A New Cold War in International Gas Markets.* Gaffney, Cline & Associates.

Allsopp, C., & Stern, J. (2012). The Future of Gsa: What are the Analytical Issues Relating to Prices? In J. Stern (Ed.), *The Pricing of Internationally Traded Gas.* Oxford, U.K.: Oxford University Press.

Asia Pacific Energy Research Centre. (2007). *A Quest for Energy Security in the 21st Century: Resources and Constraints.* Tokyo: Institute of Energy Economics.

Atsumi, M. (2007, July 13). Japanise Energy Security Revisited. *Asia-Pasific Review, 14*(1), pp. 28-43.

Baltensperger, T., Fuchslin, R. M., Krutli, P., & Lygeros, J. (2017, August). European Union Gas Market Development. *Energy Economics, 66*, pp. 466-479.

Beltramo, M., Manne, A., & Weyant, J. (1986, July). A North American Gas Trade Model. *The Energy Journal, Vol 7*(3), σσ. 15-32.

Bohi, D. R. (1981). *Analyzing Demand Behaviour: A Study of Energy Elasticities.* Washington, D.C.: Resources for the Future.

Bollen, J. (2008). *Energy Security, Air Pollution, and Climate Change: An Integrated Cost-Benefit Approach.* Bilthoven: Milieu en Natuur Planbureau.

British Petroleum. (2011). *BP Statistical Review of World Energy.* London: B.P.

British Petroleum. (2016). *BP Statistical Review of World Energy.* London: B.P.

British Petroleum. (2017). *BP Statistical Review of World Energy.* London: B.P.

Broder, J. M. (2009, August 9). Climate Change Seen as Threat to U.S. Security. The New York Times.

Brown, M. A. (2001, November). Market Faillures and Barriers as a Basis for Clean Energy Policies. *Energy Policy, 29*(14), σσ. 1197-1207.

Brown, M. A., & Dworkin, M. (2011). The Environmental Dimension of Energy Security. In B. K. Sovacool, & B. K. Sovacool (Ed.), *The Routledge Handbook of Energy Security* (1st ed., pp. 176-190). London, U.K.: Taylor & Francis Group.

Brown, M. A., & Sovacool, B. K. (2011). *Climate Change and Global Energy Security: Technology and Policy Options.* MIT Cambridge, London, England: The MIT Press.

Buchan, D. (2014). *Europe's Energy Security-Caught between Short-Terms Needs and Long-Term Goals.* University of Oxford. Oxford: The Oxford Institute for Energy Studies.

Cavallo, A. j. (2002, September). Predicting the Peak in World oil Production. *Natural Resources Research, 11*(3), pp. 187-195.

Chalvatzis, K. J., & Ioannidis, A. (2017, May). Energy Supply Security in Southern Europe and Ireland. *Energy Procedia, 105*, σσ. 2916-2922.

Cheng, J. Y. (2008, April 3). A Chinese View of China's Energy Security. *Jouranl of Contemporary China, 17*(55), pp. 297-317.

Christensen, L. R., Jorgenson, D. W., & Lau, L. J. (1973, February). Transcendental Logarithmic Production Frontiers. *The Review of Economics and Statistics, 55*(1), σσ. 28-45.

CNA Military Advisory Board. (2007). *National Security and the Threat of Climate Change.* Washington, DC: The CNA Corporation.

Collins, W., Colman, R., Haywood, J., Manning, M. R., & Mote, P. (2007, August). The Physical Science Behind Climate Change. *Scientific American, 297,* pp. 64-73.

Dagobert, B. L., & Hartley, P. R. (2007). Expectations and the Evolving World Gas Market. *The Energy Journal, 28*(1), σσ. 1-24.

Dagoumas, A. S., Papagiannis, G. K., & Dokopoulos, P. S. (2006, January). An economic assessment of the Kyoto Protocol application. *Energy Policy, 34*(1), σσ. 26-39.

Dagoumas, A., & Charokopos, M. (2016). Gazprom's Strategy: Natural Resources as Foreign Policy Tools. *Geopolitics of Energy, 38,* pp. 14-24.

Dasgupta, P., & Heal, G. (1974). The Optimal Depletion of Exhaustible Resources. *The Review of Economic Studies. Symposium on the Economics of Exhaustibel Resources, 41*(5), pp. 3-28.

de Vries, B. J., van Vuuren, D., den Elzen, M., & Jansen, M. (2001). *The Timer IMage Energy Regional (TIMER) model: Technical Documentation.* Bilthoven, the Netherlands: National Institute for Public Health and the Environment.

Deane, J. P., O Ciarain, M., & O Gallachoir, B. P. (2017, May 1). An Integrated Gas and Electricity Modelof the E.U. Energy Systemto Examine Supply Interruptions. *Applied Energy, 193,* pp. 479-490.

Eglene, O. (2002). Transboundary Air Pollution: Regulatory Schemes & Interstate Cooperation . *Albany Law Environmental Outlook,* pp. 129-145.

Elkind, J. (2010). Energy Security: Call for a Broader Agenda. In C. Pascual, & J. Elkind (Eds.), *Energy Security: Economics, Politics, Strategies, and Implications* (pp. 119-148). Washington, D.C.: Brookings Institution Press.

Energy Information Agency. (2011). *Annual Energy Outlook 2011 with Projections to 2035.* Washington, D.C.: E.I.A.

European Commission. (2014). *In-Depth Study of European Energy Security.* Brussels: E.C., SWD(2014) 330 final/3.

Fattouh, B., Rogers, H., & Stewart, P. (2015). *The U.S. Shale Gas Revolution and its Impact on Qatar's Position in Gas MArkets.* Columbia University, Ceneter on Global Energy Policy. New York: Columbia SIPA.

Faulin, J., Lera-Lopez, F., Arizkun, A., & Pintor, J. M. (2009). Energy Policy in Renewables and its Economic and Environmental Consequences at the Regional Level: The Case of Navarre (Spain). Στο N. B. Jacobs, & N. B. Jacobs (Επιμ.), *Economic Effects, Security Aspectsand Environmental Issues* (σσ. 223-256). New York: Nova Science Publishers.

Fernandez, R., & Palazuelos, E. (2014, January 6). A Political Economy Approach to the European Union Gas Model: Continuities and Changes. *Journal of Common Market Studies, 52*(3), pp. 495-511.

Feygin, M., & Satkin, R. (2004, March). The Oil Reserves-to-Production Ratio and Its Proper Interpretation. *Natural Resources Research, 13*(1), σσ. 57-60.

Floros, N., & Vlachou, A. (2005, May). Energy Demand and Energy-Related CO2 Emissions in Greek Manufacturing: Assesing the Impact of a Carbon Tax. *Energy Economics, 27*(3), σσ. 387-413.

Gupta, E. (2008, March). Oil Vulnerability Index of Oil-Importing Countries. *Energy Policy, 36*(3), σσ. 1195-1211.

Haase, N. (2008). *European Gas Market Liberalization: Are Regulatory Regimes Moving Towards Convergence?* University of Oxford, NG24. Oxford: Oxford Institute for Energy Studies.

Hotelling, H. (1931, April). The Economics of Exhaustible Resources. *Journal of Political Economy, 39*(2), pp. 137-175.

Hughes, L. (2009, June). The Four R's of Energy Security. *Energy Policy, 37*(6), pp. 2459-2461.

Hughes, L., & Shupe, D. (2011). Applying the Four A's of Energy Security as Criteria in an Energy Security Ranking Method. In B. K. Sovacool, & B. K. Sovacool (Ed.), *The Routledge Handbook of Energy Security* (pp. 356-380). New York: Taylor & Francis Group.

International Energy Agency. (2006). *Energy Technology Perspectives: Scenarios and Strategies to 2050.* Paris: O.E.C.D.

International Energy Agency. (2016). *Gas Medium-Term Market Report.* Paris: I.E.A.

International Energy Agency. (2016). *Key Worls Energy Statistics.* Paris: I.E.A.

International Energy Agency. (2016). *Natural Gas Information.* Paris: I.E.A.

International Energy Agency. (2017). *Key World Energy Statistics.* Paris: I.E.A.

International Gas Union. (2016). *World LNG Report.* I.G.U.

International Group of Liquified Natural Gas Importers. (2016). *The LNG Industry: GIIGNL Annual Report.* France: GIIGNL.

Jansen, J. C., van Arkel, W. G., & Boots, M. G. (2004). *Designing Indicators of Long-term Energy Supply Security.*

Jared, D. (2005). *Collapse: How Societies Choose to Fail or Succed.* New York: Penguin Group.

Kessels, J., Bakker, S., & Wetzelaer, B. (2008). *Energy Security and the Role of Coal.* London: I.E.A. Clean Coal Centre CCC/131.

Kleber, D. (2009, June). The U.S. Department of Defense: Valuing Energy Security. *Journal of Energy Security,* σσ. 12-22.

Konoplyanik, A. (2010). *Evolution of Gas Pricing in Continental Europe: Modernization of Indexation Formulas versus Gas-to-Gas Competition.* International Energy Law and Policy Research Paper Series.

Kruyt, B., van Vuuren, D., de Vries, B. J., & Groenenberg, H. (2011). Indicators for Energy Security. In B. K. Sovacool, *The Routledge Handbook of Energy Security.* London: Routledge.

Leal-Arcas, R., & Rios, J. A. (2015, January 29). How Can the E.U. Diversify its Energy Supply to Improve its Energy Security? *(Legal Studies Reasearch Paper No.190/2015)*. Queen Mary School of Law.

Lewis, T. R. (1976, October). Monopoly Exploitation of an Exhaustible Resource. *Journal of Enevironmental Economics and Management, 3*(3), pp. 198-204.

Li, D. D. (2006, April 4). Large Domestic Non-Intermediated Investments and Government Liabilities - Challenges Facing China's Financial Sector Reform. Tsinghua University: Center for China in the World Economy.

Logan, J., & Venezia, J. (2007). Weighing U.S. Energy Options: The WRI Bubble Chart. In *WRI Policy Note on Energy Security and Climate Change.* Washington, DC: World Resources Institute.

Luft, G., Korin, A., & Gupta, E. (2011). Energy Security and Climate Change: A Tenuous Link. In B. K. Sovacool, & B. K. Sovacool (Ed.), *The Routledge Handbook of Energy Security* (pp. 43-55). Taylor and Francis Group.

MacAvoy, P. W. (2008). *The Natural Gas Market: Sixty Years of Regulation and Deregulation.* Yale University Press.

Manning, R. A. (2000). The Asian Energy Predicament. *Survival, 42*(3), pp. 73-88.

Mazo, J. (2010). *How Global Warming Threatens Security and What to Do about It* (1st ed.). Taylor & Francis Group.

Medlock, K. B., Hartley, P. R., & Pyle, D. (2008, August 25). Energy Market Consequences of an Emerging U.S. Carbon Management Policy. Rice University: James A. Baker III Institute for Public Policy.

Medlock, K., Baker, S., & Baker, J. (2012). *U.S. LNG Exports: Truth and Consequence.* Rice University. Houston, U.S.A.: James A. Baker III Institute for Public Policy.

Mendelsohn, R., Dinar, A., & Williams, L. (2006, April). The Distributional Impact of Climate Change on Rich and Poor Countries. *Environment and Development Economics, 11*(2), σσ. 159-178.

National Statistic Authorities . (2013). *GPCA Analysis.* Qatar: NSA.

Nuttall, W. j., & Manz, D. L. (2008, October). A New Energy Security Paradigm for the Twenty-First Century. *Technological Forecasting and Social Change, 75*(8), σσ. 1247-1259.

Olz, S., Sims, R., & Kirchner, N. (2007). *Contributions of Renewables to Energy Security: International Energy Agency Information Paper.* Paris: OECD.

Organisation for Economic Co-operation and Development. (2008). *Costs of Inactionon Key Environmental Challenges.* Paris: OECD Publishing.

Polemis, M. L. (2007, March). Modeling Industrial Energy Demand in Greece Using Cointegration Techniques. *Energy policy, 35,* σσ. 4039-4050.

Ratner, M. (2016). Natural gas Discoveries in the Eastern Mediterranean. Congressional Research Service.

Ratner, M., Belkin, P., Nichol, J., & Woehrel, S. (2013). *Europe's Energy Security: Options and Challenges to Natural Gas Supply Diversification.* Congressional Research Service.

Sevastyanov, S. (2008, March). The More Assertive and Pragmatic New Energy Policy in Putin's Russia: Security Implications for Northeast Asia. *East Asia, 25*(1), pp. 35-55.

Shannon, C. E., & Weaver, W. (1949). *The Mathematical Theory of Communication.* Urbana: University of Illinois Press.

Shantayanan, D., & Fisher, A. C. (1981, March). Hotelling's "Economics of Exhaustible Resources": Fifty Years Later. *Journal of Economic Literature, 19*(1), pp. 65-73.

Sjak, S., & de Nooij, M. (2003). The Impact of Energy Conservation on Technology and Economic Growth. *Resource and Energy Economics, 25*, pp. 59-79.

Solow, R. (1956, February). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics, 70*(1), σσ. 65-94.

Solow, R. (1974). Intergenerational Equity and Exhaustible Resources. *Review of Economic Studies. Symposium on the Economics of Exhaustible Resources, 41*, pp. 29-46.

Sovacool, B. K. (2010). *The Routledge Handbook of Energy Security.* (B. K. Sovacool, Ed.) Routledge.

Sovacool, B. K., & Brown, M. A. (2011). Measuring Energy Securtiy Performance in the OECD. Στο B. K. Sovacool, & B. K. Sovacool (Επιμ.), *The Routledge Handbook of Energy Security* (σσ. 381-395). New York: Taylor & Francis Group.

Stern, D. (2004). Economic Growth and Energy. In D. Stern, *Encyclopedia of Energy* (1 ed., pp. 35-51). United States: Elsevier.

Stern, N. (2008, May). The Economics of Climate Change. *American Economic Review, 98*(2), pp. 1-37.

Stiglitz, J. E. (1976, September). Monopoly and the Rate of Extraction of Exhaustible Resources. *American Economic Review, 66*(4), pp. 87-94.

Stirling, A. (1994, March). Diversity and Ignorance in Electricity Supply Investement:. *Energy Policy, 22*(3), σσ. 195-216.

Troner, A. (2000). *Japan and the Russian Far East: The Economics and Competitive Impact of Least Cost Gas Imports.* Rice University: The James Baker III Institute for Public Policy.

U.K. Department of Trade and Industry. (2006). *UK Energy Sector Indicators 2006.* London: Department of Trade and Industry.

United Nations Economic and Social Commission for Asia and the Pacific. (2008). *Energy Security and Sustainable Development in Asia and the Pacific.* Geneva: UNESCAP, April, ST/ESCAP/2494.

United States Agency for International Development. (2008). *Energy Security Quarterly: USAID South Asia Regional Initiative for Energy.* Washington, DC: U.S.A.I.D.

United States Geological Survey. (2012). ***An Estimate of Undiscovered Conventional Oil and Gas Resources of the World.*** **USGS, World Petroleum Resources Project.**

World Economic Forum. (2009). ***Global Risks 2009: A Global Risk Network Report.*** **Davos: World Economic Forum.**

Yergin, D. (2006, March-April). Ensuring Energy Security. ***Foreign Affairs, 85*****(2), σσ. 69-82.**

Zhaofang, D. (2010). ***China's Market Outlook.*** **Beijing: Research Institute of Economics and Technology.**