INTERNATIONAL HELLENIC UNIVERSITY

Security of energy supply in the EU

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SCHOOL OF SCIENCE & TECHNOLOGY

A thesis submitted for the degree of

Master of Science (MSc) in Energy Systems

JANUARY 2017

THESSALONIKI – GREECE

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Abstract

This dissertation outlines the multidimensional concept of security of supply in the EU based on international literature. Initially, the concept of the term is being investigated, accompanied by a thorough analysis of the energy state of the EU, which depicts the significant dependency of EU in external suppliers. Subsequently, geopolitical aspect of energy is being addressed, more specifically the case of gas, to stress the complex nature of energy. Following, the legal framework and policy of the EU on energy issues is being presented, as being the EU's tool to tackle all the aforementioned issues, while particular emphasis is given to technology as a way of moving towards security of supply. Finally, the key points of the dissertation are summed up to provide a brief yet comprehensive view of the topic.

Evangelos Papanikolaou

2/1/2017

Acknowledgements

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To a more personal level, I would like to thank my family and friends, as none of these could have been achieved without their constant and firm support. Special thanks to my beloved Fotini for the vast patience and understanding that she showed throughout this academic journey.

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1 Introduction

1.1 Concept of Security of Energy Supply

Energy is of paramount importance for every country's modern lifestyle and economy. It is such an integral part of our everyday lives, that it's an undeniable fact for most people that pumps shall always have fuels to move their cars, that with the push of button their homes shall be heated and their appliances shall be operating without any possibility of disruptions or unavailability. Additionally, all this energy is expected to be affordable price wise.

That fact describes in essence the concept of "security of energy supply" or "energy security", as defined by IEA. More specifically, the IEA describes energy security as "the uninterrupted availability of energy sources at an affordable price" [1], which is a brief yet comprehensive interpretation of the concept (Figure 1).

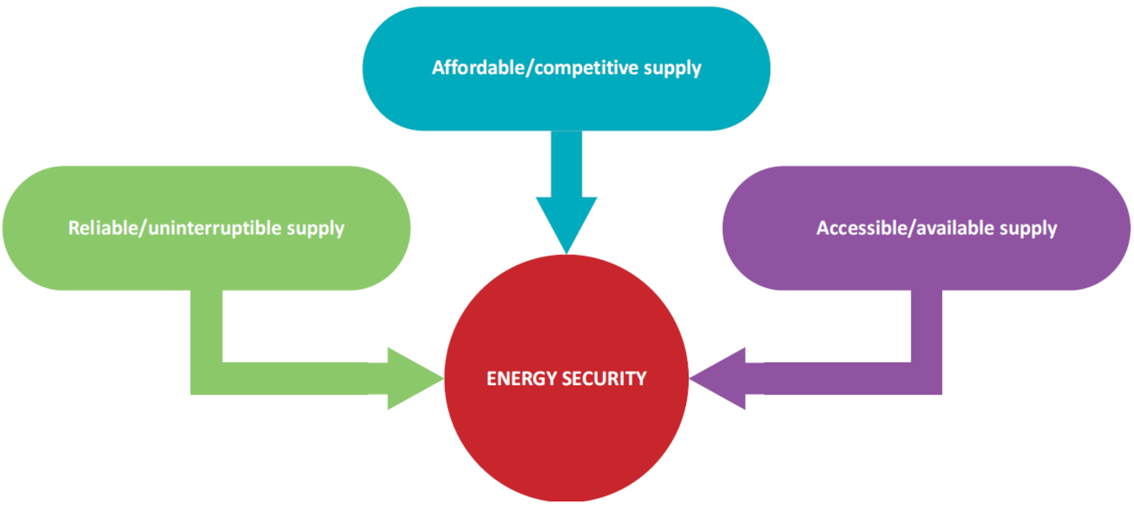

Figure 1: Energy security concept [IEA]

Energy security, though, is a far multidimensional concept, depending on the angle of study. As regards the time aspect of energy security for example, IEA distinct the concept in: "long-term energy security which mainly deals with timely investments to supply energy in line with economic developments and sustainable environmental needs" and "short-term energy security that focuses on the ability of the energy system to react promptly to sudden changes within the supply-demand balance". Another distinction that can be found in the literature is the economic/political perspectives, with the first implying that energy issues are subject solely to market operation, therefore supply, demand and prices are regulated on their own without political intervention, and the later supporting that energy security is a matter of national security, due to the increasing nationalization and politicization of energy resources.

1.2 Dissertation Scope

Based on the multi-lateral aspect of security of energy supply, the scope of this thesis is to analyze how the EU addresses this topic of different levels. Chapter 2 contains an in-depth analysis of the current EU energy state, in terms of production, consumption, imports of primary energy sources and energy products for final use, in order to provide a clear picture of EU dependence on imports. Chapter 3 presents the geopolitical aspects of energy issues in the case of gas, so as to highlight the complexity on assessing energy issues and forming efficient strategies and partnerships. Gas have been chosen for this analysis, as it is the energy source most heavily promoted in the EU and due to its infrastructure sensitivity. Chapter 4 provides a thorough look on EU legal framework on energy, by analyzing the actors participating in forming EU legislation, presenting EU legislation progression though the years and finally summing up presenting the relevant to energy security existing and forthcoming EU policy, which in fact is the strategy of the EU. Chapter 5 is dedicated to the potential contribution of technology to EU's energy security strategy. Several energy technologies are being analyzed, emphasizing on the next steps necessary to enhance their efficiency and cost, while also agreed targets between the members of the SET Plan Steering Group regarding those technologies' progress are being stated. Finally, chapter 6 concludes all the aforementioned topics, providing the key points of this dissertation.

2 EU Energy State

This chapter aims to present the current energy state of the European Union and its corresponding energy import dependency, while focusing on each energy source and energy product separately in terms on consumption, production, and imports.

In order to have a clear view of the energy flow within the EU, its basic form is depicted in Figure 2. Input consists of both indigenous production and imports. Part of the energy inserted is directly carried-over, while the rest is being transformed and refined to be used in various appliances. Notably, a fraction of the available energy is also being exported.

All data illustrated and commented in this chapter are extracted from the official energy datasheet of the European Commission [2], which is based on Eurostat's surveys regarding the energy profile of the EU and all its Member States. Data is available until the year 2014, with the next official update estimated in February 2017.

2.1 Consumption

2.1.1 All energy sources

Energy consumption is a complex concept with many aspects. Several energy consumption indicators can be used to serve different needs when examining energy trends and issues. As far as European Union's energy dependence is concerned, two indicators shall be examined, gross inland energy consumption and final energy consumption.

According to Eurostat [3] gross inland energy consumption (also known as total primary energy supply) is the total energy demand of a country or region. It represents the quantity of primary energy necessary to cover inland consumption of a certain area. The difference between gross inland energy consumption and gross energy consumption is that in gross energy consumption the transformation output (electricity or heat produced from other energy sources) is included, meaning that gross energy consumption is a product-specific consumption and does not reflect the demand for primary energy. (primary production+imports-exports-bunkers)

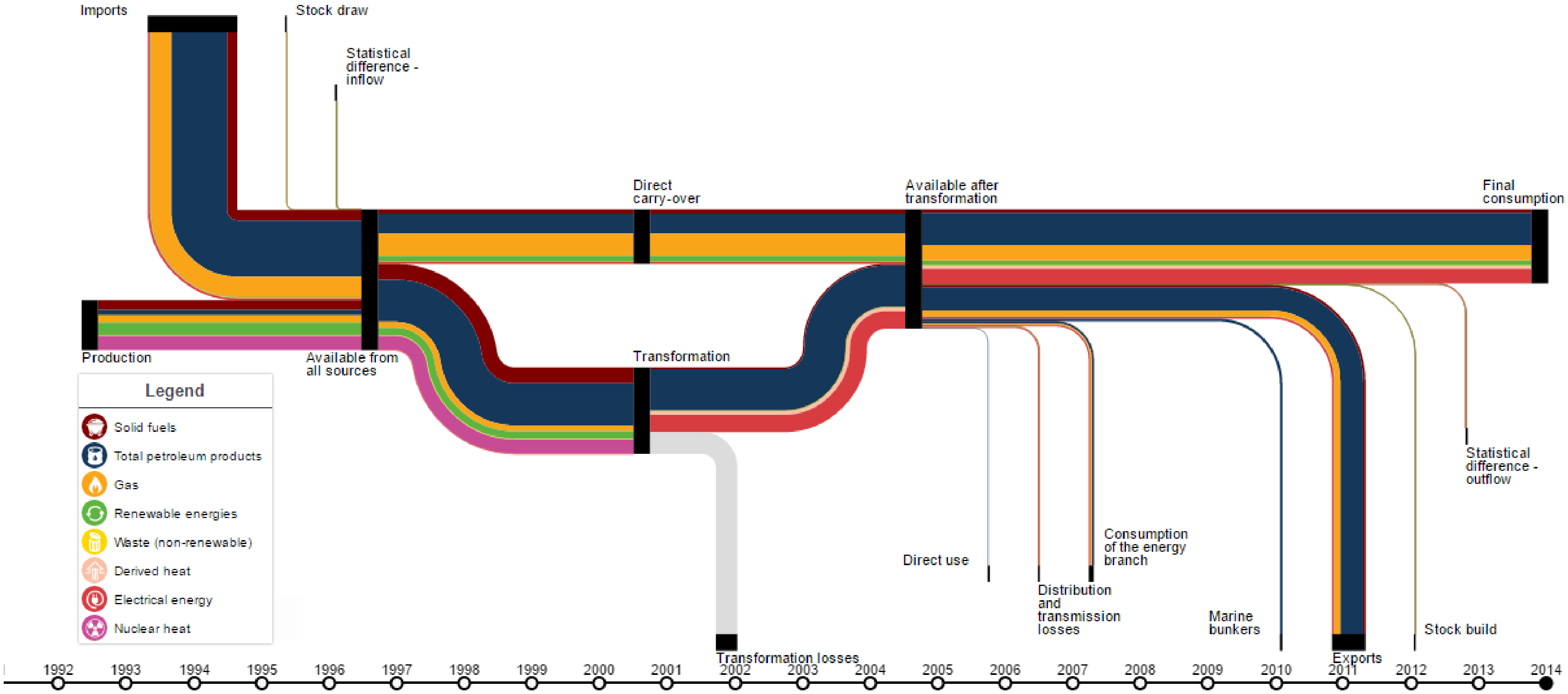

Figure 2: European Union energy balance flow [Eurostat]

On the other hand, final energy consumption represents the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself. Final energy covers quantities consumed by private households, commerce, public administration, services, agriculture, industry, road transport, air transport (aviation), other transport (rail, inland navigation), services, other.

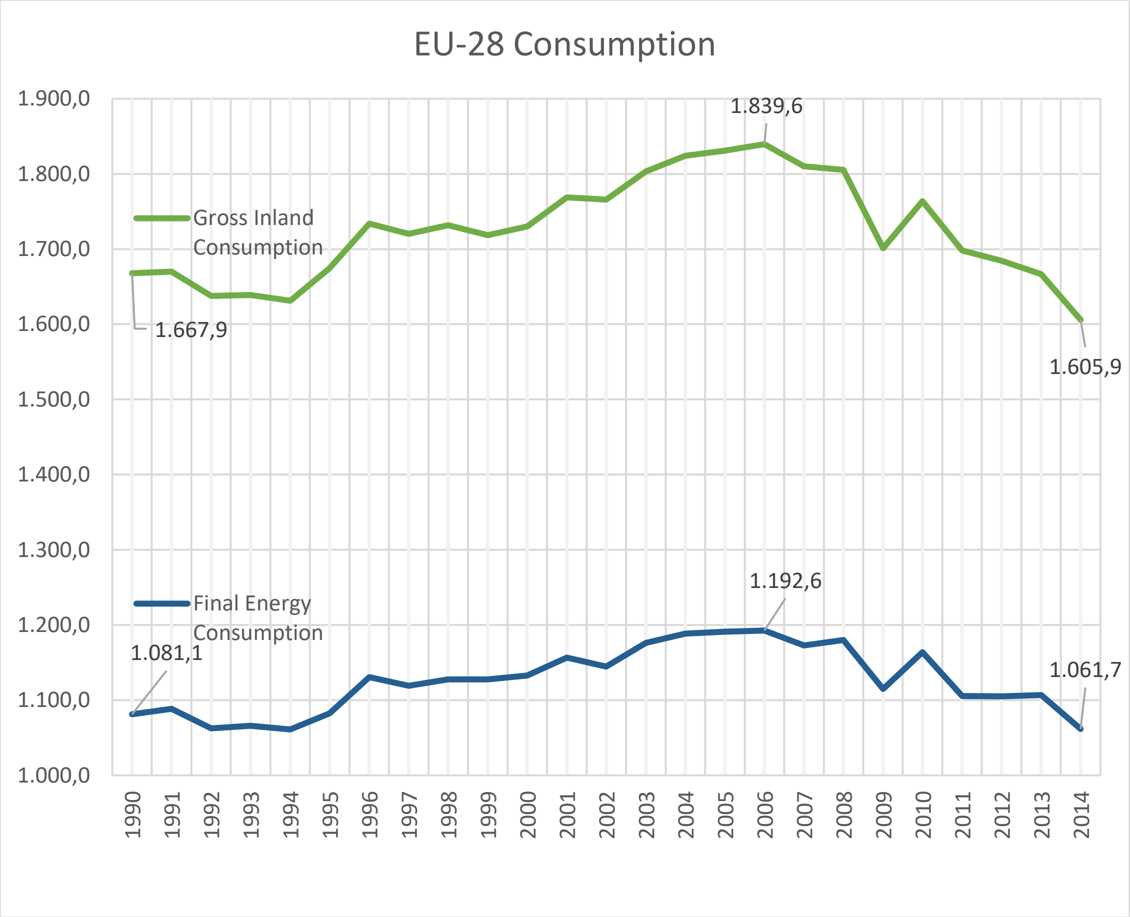

Figure 3:EU gross inland and final energy consumption 1990-2014 [mtoe]

The examination of statistical data regarding EU's gross inland energy consumption though the last two decades lead to two opposite trends divided in time, as illustrated in Figure 3. Gross inland energy consumption had been inclining during 1990-2005, mostly due to the economic growth that the European Union was experiencing. On the contrary, after 2006 and till 2014 there was a substantial decline in consumption figures. The global financial and economic crisis is considered to be one of the major causes behind this swift, while the pattern of energy consumption is considered to be practically unaltered. Notably, after almost 10 years of consecutive falling figures, 2014's gross inland consumption dropped below the respective figure of 1990, which is the start of the available time series. Compared to the peak of 2005, gross inland consumption of 2014 was 12,3% lower.

The corresponding figure of EU-28's final energy consumption during the same time frame of 1990-2014 confirms the general trend on the first hand, but also denotes the difference between the two energy consumption indicators on the other. Comparing the figures during 2011-2014, it is clear that final energy consumption seems to be stable, while gross inland energy consumption illustrates a fall of 1,8%. Generally, EU-28 final energy was equivalent of almost 2/3 of gross inland consumption during the available time series.

As denoted in Table 1, six counties account for 70% of EU-28's energy consumption of 2014, the top of which is Germany with a share of almost 20%. France and the United Kingdom follow with a cumulative share of 25%, while Italy, Spain and Poland account for another 20%. The sum of Netherlands', Belgium and Sweden consumption is approximately 10%, which leads to the fact that the rest 19 countries of EU-28 account only for 10% of the total share.

Table 1:EU member states' share on energy consumption

	Gross inland energy consumption (%)		Final energy consumption (%)	
Germany	19,5	69,3	19,7	69,2
France	15,5		13,4	
United Kingdom	11,8		12,2	
Italy	9,4		10,7	
Spain	7,3		7,5	
Poland	5,9		5,8	
Netherlands	4,8	11,1	4,5	10,6
Belgium	3,3		3,2	
Sweden	3,0		2,9	

As illustrated in Tables 2 and 3, half of EU-28 countries appear to have reduced their gross inland energy consumption during the timeframe under consideration, while on the contrary the other half have increased theirs. It is interesting to note that both groups consist of both large and small consumers.

Table 2:EU member states which reduced gross inland energy consumption from 1990 to 2014

	Gross inland energy consumption				
	1990 (mtoe)	2014 (mtoe)	2014 to 1990 (%)	Share in 2014 (%)	Total Share in 2014 (%)
Germany	356,3	313,0	-12%	19,5	**42.6**
United Kingdom	210,6	189,3	-10%	11,8	
Italy	153,5	151,0	-2%	9,4	
Poland	103,3	94,3	-9%	5,9	
Czech Republic	49,9	41,5	-17%	2,6	
Romania	58,1	32,3	-44%	2,0	
Hungary	28,8	22,8	-21%	1,4	
Bulgaria	27,6	17,7	-36%	1,1	
Denmark	17,9	16,9	-6%	1,1	
Slovakia	21,8	16,2	-26%	1,0	
Croatia	9,5	8,2	-14%	0,5	
Estonia	9,9	6,7	-32%	0,4	
Lithuania	15,9	6,7	-58%	0,4	
Latvia	7,9	4,5	-44%	0,3	

Table 3:EU member states which increased gross inland energy consumption from 1990 to 2014

	Gross inland energy consumption				
	1990 (mtoe)	2014 (mtoe)	2014 to 1990 (%)	Share in 2014 (%)	Total Share in 2014 (%)
France	227,8	248,5	9%	15,5	**57.6**
Spain	90,1	116,7	30%	7,3	
Netherlands	66,7	76,8	15%	4,8	
Belgium	48,6	53,4	10%	3,3	
Sweden	47,4	48,2	2%	3,0	
Finland	28,8	34,6	20%	2,2	
Austria	25,0	32,7	31%	2,0	
Greece	22,3	24,4	9%	1,5	
Portugal	18,2	22,1	21%	1,4	
Ireland	10,3	13,6	32%	0,8	
Slovenia	5,7	6,7	17%	0,4	
Luxembourg	3,5	4,2	20%	0,3	
Cyprus	1,6	2,2	38%	0,1	
Malta	0,6	0,9	52%	0,1	

The energy mix forming the above figures of gross inland energy consumption during 1990-204 is depicted in Figure 4. Overall, there was a gradual incline in the share of renewables and gas, while petroleum products and solid fuels lost a significant part of their share in European Union's energy mix. Regarding the cumulative share of petroleum products and solid fuels, there was a substantial loss in shares of 14,5% between

1990(65%) and 2013(50.5%), which reflects the move to more environmentally conscious era. It is also important to note that the minor incline in 2014 was probably due to low oil prices during that period. By contrast, the corresponding shares of renewable energy and gas appear to have an almost gradual increase through the timeframe examined. Renewable energy sources used to account for only 4,3% back in 1990, while their corresponding share in 2014 is approximately 3 times higher (12,5%), with a steady inclining trend Respectively, gas' share in 1990 was 17,9%, while in 2014 was 21,4%. However, gas's peak was in 2010 with a share of 25,4%, a fact that evokes questions regarding the ease of gas supply after 2010. As for the nuclear energy, its contribution peaked in 2002(14,5%) and then its share remained relatively unaltered till 2014(14,1%), while it appears to be the most stable fuel regarding its contribution during 1990-2014.

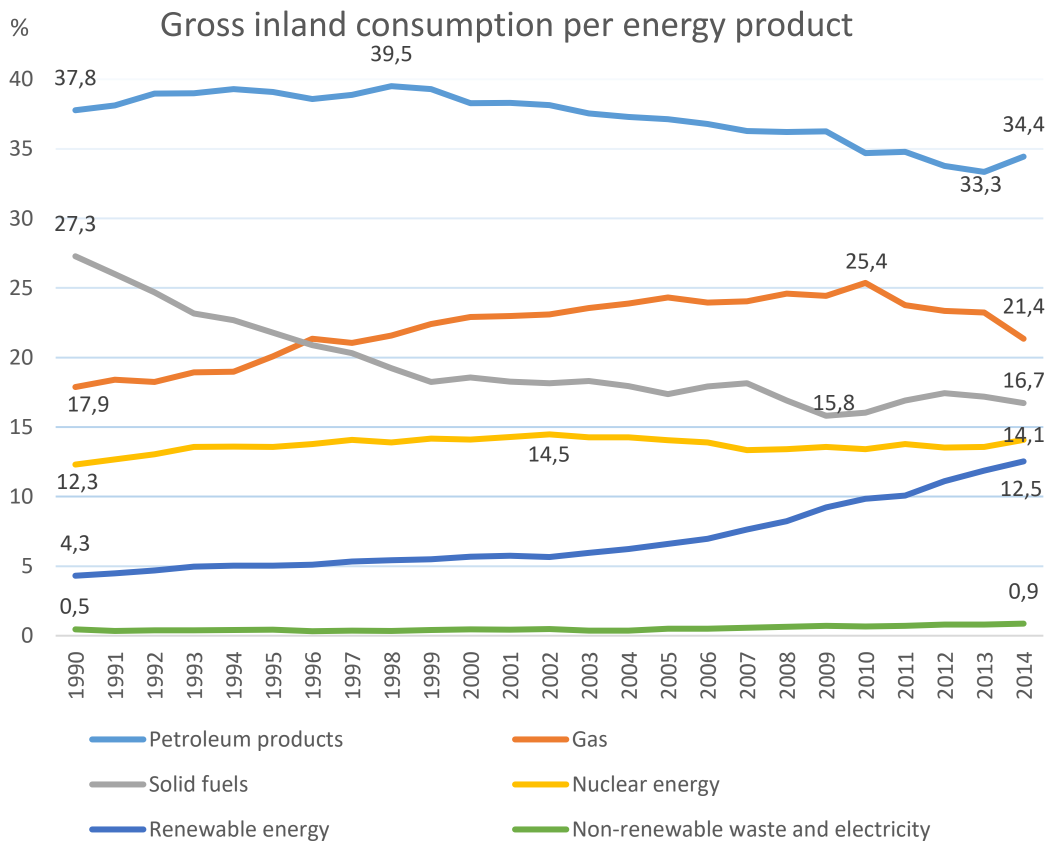

Figure 4:EU gross inland consumption per energy product 1990-2014 [%]

As for final energy consumption development per energy product, which is illustrated in Figure 5, the shares between energy products are relatively more stable than the ones of gross energy consumption. Petroleum products dominate the shares with an average of 42% during 1990-2014. The last decade there was a declining trend which ended in 40% in 2014. Gas was also steady during the examined timeframe with an average of 23%, having the second larger share after petroleum products. Gas' share was 22% in 2014. The same applies for electricity regarding 2014 share. Electricity was one of two products with continuous inclining figures during the years. In the beginning of 1990 its share was 17%, in the mid 2000 it had raised to 20%, ending up in 22% in 2014.Rewneables, as in the case of gross final consumption, appear to have to most drastic change over the years, having doubled its share from 1990 to 2014, from 4% to 8%. Solid fuels and derived heat account for another 4% each on the final consumption energy mix.

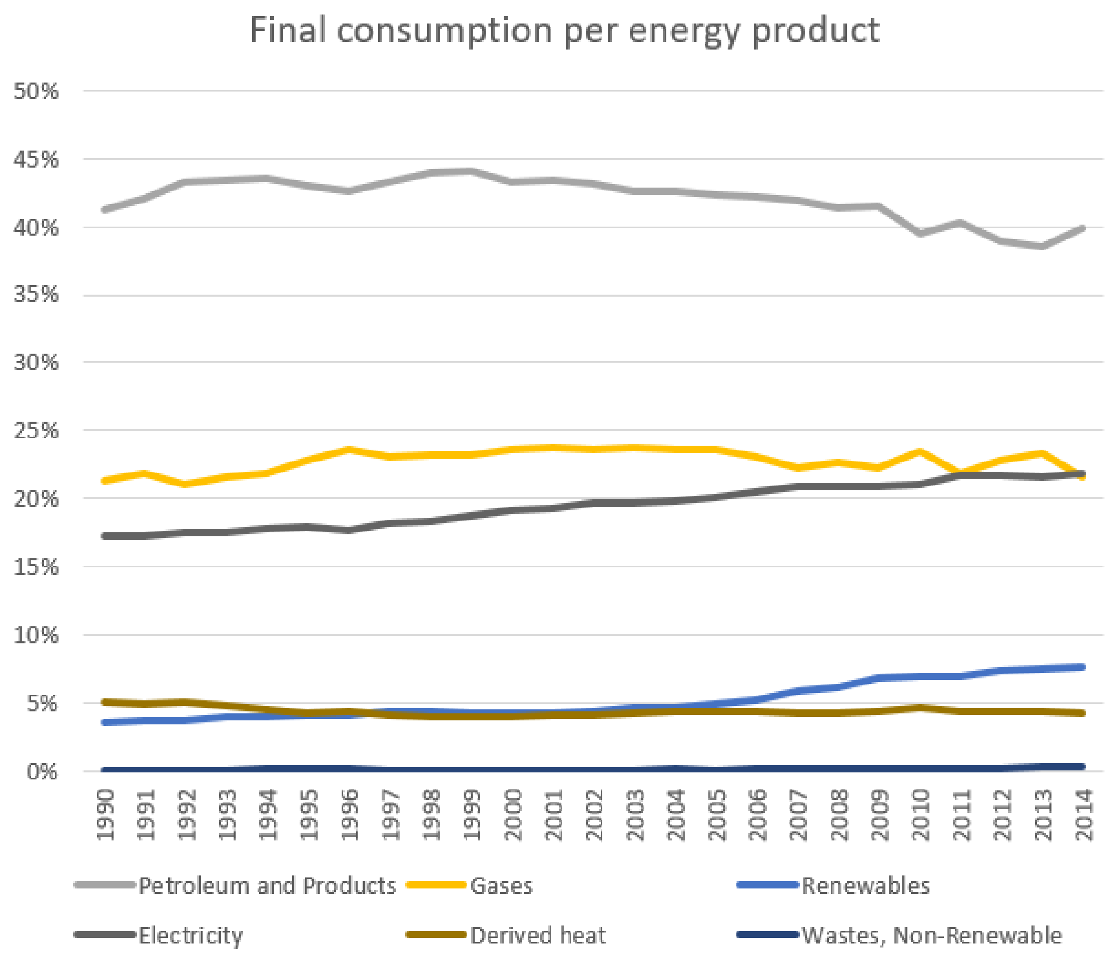

Figure 5: EU final consumption per energy product 1990-2014 [%]

A further analysis of the final energy consumption in 2014 depicts three major sector dominating end usage, as shown in Figure 6. The highest consumer sector is transport (33,2%), followed by industry (25,9%) and households (24,8 %). The rest 16,1% comes from services, agriculture and forestry and other. Figure 7 confirms the cumulative figures, illustrating the quantitative shares of final energy consumption per sector per country.

Transport covers the energy used for all transport activities. The main part of transport sectors consumptions comes from road use (energy used for the propulsion of road vehicles). It is important to note that 94% of transport energy use comes from petroleum products, while 4% is covers by renewables in 2014. Industry sectors uses mostly gas (32%) and electrical energy(31%). Solid fuels and total petroleum products account for 23%, while renewables use is 7%. Residential use appears to have a more or less common fuel segmentation with the industry. Gas (35%) and electrical energy (28%) are the most used. Renewable energy follows (15%), a bit higher than total petroleum products (13%). The renewable energy used from the residential sector is higher than the cumulative renewable energy used in both transport and industry sectors.

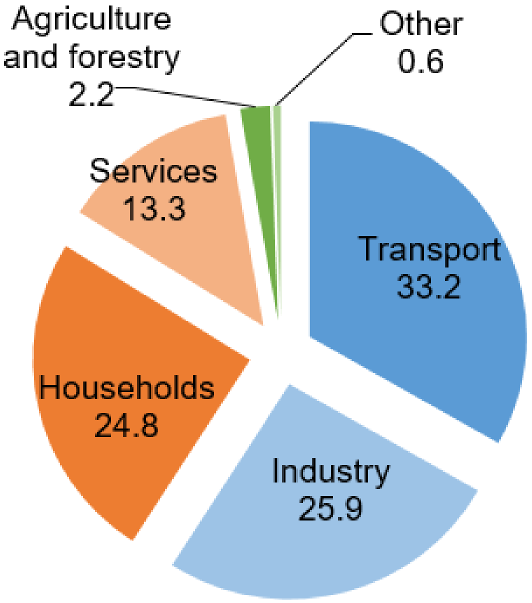

Figure 6:EU final energy use per sector[%]

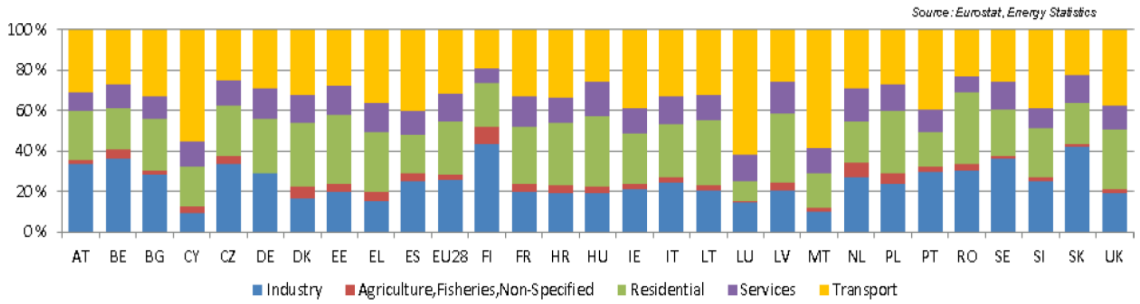

Figure 7: Final energy use per sector per country [%]

2.1.2 Analysis per energy source

2.1.2.1 Total petroleum products

As total petroleum products about 34% of gross inland consumption, oil remains the principal fuel in the EU energy mix. If considered a unified country, the EU is the second biggest consumer with a portion of 15%, following the USA [4]. The largest consumer of oil in the EU is transportation, followed by the petrochemical industry. Its use in power generation and heating has declined significantly throughout the years. There are special cases though, like Cyprus and Malta, in which petroleum products are the main fuel for power generation. Generally, total petroleum products consumption in the EU has demonstrated a declining inclination which has advanced due to the financial crisis in 2008. Consumption has diminished by 12,9% since 2005 (average -2,0%/year) as well as by 10,5% since 2008 (average -3,0%/year).

Following 2005, a decrease in total petroleum products consumption has been reported throughout most of Europe. There are only four Member States (Finland, Greece, Poland and Sweden) that have shown a rise of crude oil consumption between 2004 and 2014. The decrease was especially abrupt in Croatia, France and Romania, countries in which crude oil consumption declined by more than 30% in the period 2004-2014.

2.1.2.2 Natural gas

The need for gas in the EU before the crisis began was around 450mtoe. The consumption of gas in 2014 deteriorated below 350mtoe, which was the lowest levels since the start of the 21st century. Germany and the UK are the biggest consumers of gas, while other important consumers are Italy, Spain, the Netherlands and France.

Most of the gas is being consumed in households (108mtoe) and in electricity production (107mtoe), more than half of which (59mtoe) is utilized as input in CHP plants. Nearly 19% of the electricity produced in the EU originates from gas and for several Member States the portion of gas in electricity production is considerable (>40% in the Netherlands, Italy, Luxembourg, Lithuania and Ireland). In respect of non-household consumers, services consume 43,5mtoe, when in fact the greatest industrial consumers are parts of chemical and petrochemical industries, generation of non-metallic minerals, food as well as tobacco production. Generally, 25% of gas is consumed by the industry, 40% on final use and 30% for electricity production and CHP input.

2.1.2.3 Solid fuels

EU is the third biggest consumer of solid fuels after China and North. Demand for solid fuels in the EU was plummeted by 20% in the period between 1995 and 2014 and that accounts for all Member States. After the recession in consumption in 2009, demand began rebounding and 2012 was the fourth year in a row of higher solid fuels consumption. However, consumption remains to lower than pre-recession levels and undeniably at approximately 15% lower than 90's level. Approximately 70% of solid fuels is utilized as transformation input to CHP, electricity and regional heating plants.

The UK, Poland and Germany continue being the biggest consumers of solid fuels, leading in 2014 to a consumption increased by 4% on a yearly basis in Germany, up by 27% in the UK, and reduced by 4% in Poland. Numerous Member States have shown a double-digit rise in consumption in the period 2011-2012, notably Portugal (+33%), Spain (+23%), France (+12%), Ireland (+16%) and the Netherlands (+10%), despite the fact that consumption is still below post-crisis levels. The fall in coal and carbon dioxide prices and the increased gas prices guaranteed provide a powerful competitive advantage to coal against gas for use in power generation.

2.1.2.4 Nuclear energy

Electricity production dominate nuclear consumption, with 131 nuclear power plants in the EU (Belgium, Bulgaria, Czech Republic, Spain, France, Germany Hungary, the Netherlands, Slovenia, Romania, Slovakia, Sweden, Finland and the United Kingdom) in 2014 and another 4 being under construction in Slovakia, Finland and France. Approximately 30% of electricity produced in the EU accounts to nuclear power plants. Nuclear consumption for electricity production presented an inclining trend of 23% during 1990-2004, while during the last decade of 2004-2014 there was a decrease of 13,1%. Consequently, consumption peaked in 2004 with 260,3mtoe and gradually declined to 226,1 in 2014.

2.1.2.5 Renewable energy

Renewables presented a boom during the last decade in the EU energy mix. As regards gross inland energy consumption, there are numerous Member States with a significant share of renewables, such as Iceland(86.3 %), Norway(44.8 %), Latvia(36,2%), Sweden(35,8%), Austria(30%), Finland(29,4%), Denmark(26,2%) and Portugal(25%). The case for final energy consumptions is almost similar with Finland, Latvia and Sweden having more than one third from renewables. Sweden in particular is covered more than half (52,6%) of its final energy needs by renewables.

More than one fourth of gross electricity consumption in 2014 was due to renewables, with Austria(70%) and Sweden(63,3%) being the top Member States in this respect, mostly using solid biofuels and hydropower. The corresponding figure for the transport sector was almost 6% in 2014, with Finland(19,2%) and Sweden(19,2%) having the highest shares.

2.1.2.6 Refined products

Refining plays a significant role in transforming crude oil as well as other feedstock into oil products for final use. Transportation is the sector dominating refined oil and oil products consumption with a share of 64%, 83% of which accounts to road transport and 15% to aviation. Industry uses 22% and residential, agriculture and services utilize 14%.

The trend has been declining for all refined products since 2009. The total drop was 8% in 2014 and was mainly due to the reduction of gasoline(-17%), gasoil(-3%) and kerosene(-3%) consumption. Tax policies, implying lower fares in diesel, have shifted transportation sector form gasoline to diesel, which is the most significant change in EU refined products pattern thought the years.

2.1.2.7 Electricity

Electricity consumption had been increasing during the last years. In 2014, 26% of consumption account on industry, 33% on transport and 41% on residential use and services, with the trend being generally inclining for all sectors.

During the last 10 years, residential consumption of electricity decreased by 1,3%, mainly due to new generation efficient appliances and demographic issues, as the number of people living in households. Significant reductions occurred in Belgium(28,6%), Sweden and the United Kingdom. On the other hand, other Member States increased their consumption. Typical examples are Romania(48%), Lithuania(27%), Spain(22% and Bulgaria(21%).

2.2 Production

2.2.1 All energy sources

Production of primary energy in the EU-28 was 771 mtoe in 2014. As illustrated in Figure 8, production was steadily declining during the examined timeframe of the last decade, with only one exception in 2010, when there was a slight rebound. Generally, production fell 17.3 % from 2004 until 2014. The examination of earlier data depicts that production level had peaked in 1997 with approximately 990mtoe, after which the trend is steadily declining, concluding in the lowest level of 2014, which is the lowest since 1990.

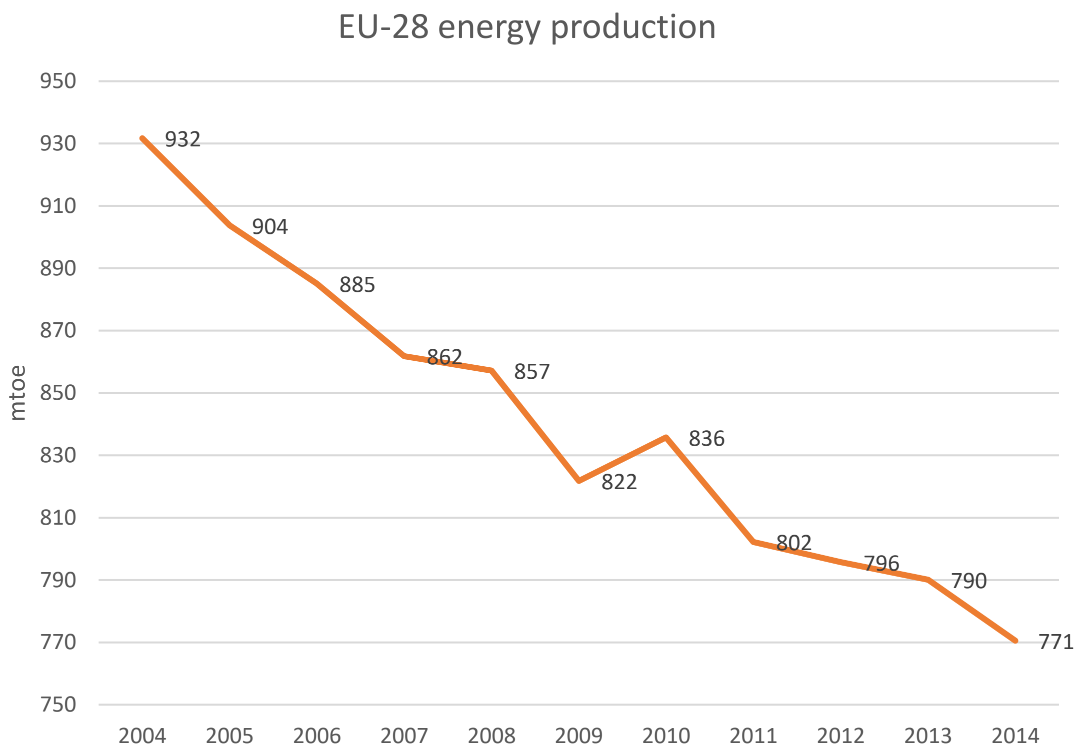

Figure 8: EU energy production 2004-2014 [mtoe]

In 2014, the highest primary energy producer in EU-28 was France with a 17.6 % share, followed by Germany with 15.6 % and the United Kingdom with 14.0 %. Examining the figures one decade earlier, the situation for most counties is fairly the same +-15%. However, two countries, the United Kingdom and Denmark appear to have decreased their production in half during 2004-2014. On the other hand, there are also some countries that increased their production significantly, those being Italy and Austria by almost 1/4 and Portugal and Estonia by more than half.

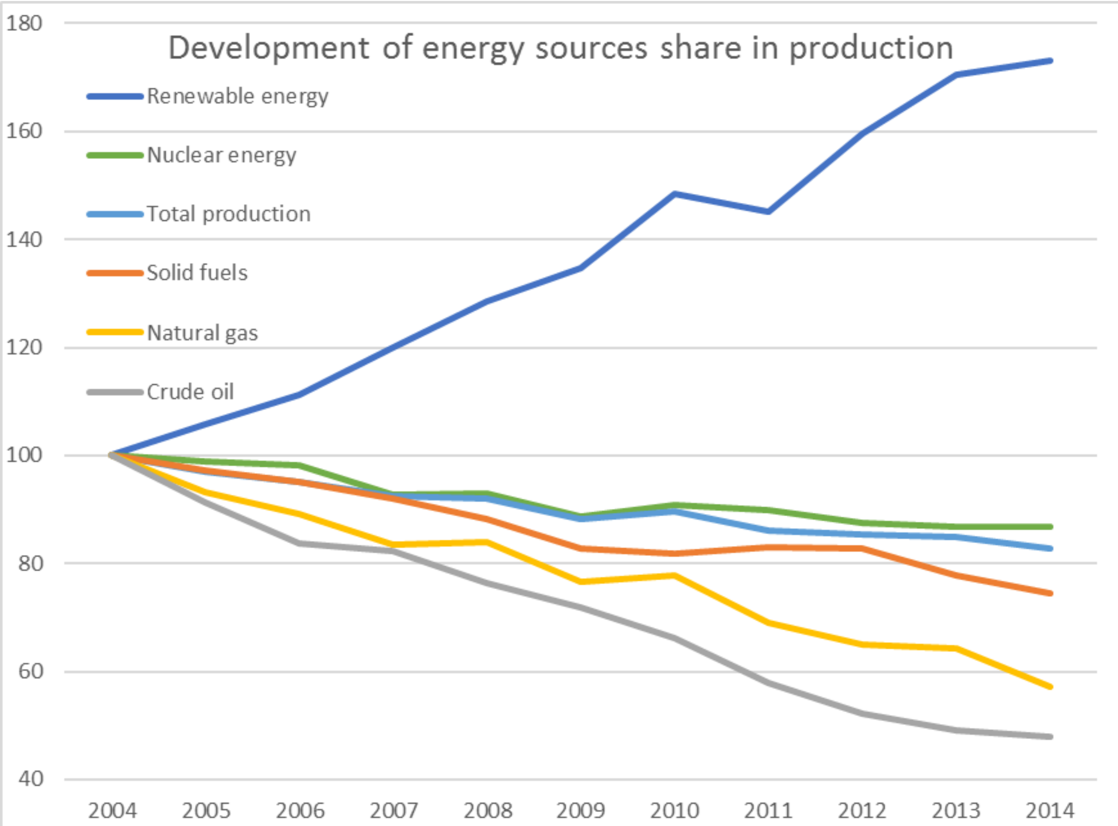

Figure 9: Development of energy sources share in EU production 2004-2014 [%]

In 2014, almost a quarter of EU-28's energy production was accounted to renewable energy sources, higher than all other energy sources apart from nuclear. Solid fuels accounted only for 19,4%, with natural gas coming next with a share of 15,2%. Crude oil complement the energy mix with 9.1%.

Renewables' aggressive integration into EU-28' energy production mix during the last years is the most significant change in the way the EU approaches the issue of security of supply. As depicted in Figure 9, renewables' share rose by 73,1% over the examined period, while crude oil, natural gas and other solid fuels fell by 52%, 42,9% and 25,5% correspondingly. Even nuclear energy, which has the biggest share in the energy mix, fell by 13,1%.

2.2.2 Analysis per energy source

2.2.2.1 Total petroleum products

In total 20 members of EU-28 produce total petroleum products, the biggest of which is the United Kingdom with a production of 41mtoe. Denmark and Italy follow with 8 and 6,1mtoe correspondingly. Romania, Germany, Ukraine and the Netherlands produce from

2 to 4mtoe of total petroleum products, while the rest 13 producer counties account for less than 1mtoe.

2.2.2.2 Natural gas

EU production dropped over the last years from 200mtoe in the late 90's to less than 120 mtoe in 2014. The greatest producer of gas in 2014 in the EU are the Netherlands with almost 60mtoe. Generation of the UK sunk to the level of 35mtoe in 2014, comparing to more than 90mtoe in the start of the decade. Exports are mainly towards Turkey, Switzerland and the Balkan area, representing a fraction less than 20mtoe.

EU’s gas reserves have been evaluated on the level of 1412 mtoe (1700 bcm) in 2012, translated in less than four years of complete EU consumption. Approximately 830mtoe are held by the Netherlands, followed by the United Kingdom with 166mtoe and finally each of Germany, Poland, Romania and Italy, hold 83mtoe. As a reference, Norway, a non-EU country but a country of the general European Economic Area(EEA), holds 1744 mtoe.

2.2.2.3 Solid Fuels

EU is a major solid fuels producer, with 150mtoe in 2014, a figure which is though decreased compared to previous years. More specifically the production has been decreased by 40% compared to mid-1990s levels. When considering the biggest EU producers, the Czech Republic, Poland and Germany, their production has been reduced by 25%, 37% and 40%, correspondingly. However, the figures remain relatively unaltered during the last 2 years.

2.2.2.4 Nuclear energy

As mentioned above, nuclear plants are in operation in 13 Member States; France, Belgium, Bulgaria, Germany, the Czech Republic, Spain, Hungary, the Netherlands, Romania, Slovakia, Finland, Slovenia, the United Kingdom and Sweden. The total production in 2014 was 226,1mtoe, with 2003 illustrating the highest production with 257mtoe.

The biggest nuclear power producer within the EU is France, almost covering half(49,8%) of EU’s total nuclear production. Germany is second(11%), followed by Sweden(7,5%), the United Kingdom(7,3%) and Spain(6,5%). Most of the producing Member States have increased their production during 1990-2014, with Germany, Lithuania, Belgium, Sweden and the United Kingdom being the only to lower their production.

2.2.2.5 Renewable energy

EU's production from renewable sources in 2014 was 196mtoe, which accounts for 25,4% of the total primary energy production of the EU. Renewables share boomed during 2004-2014 by 73,1%. The most significant source was renewable waste and solid biofuels with a share of 63% among all renewables production, only to be followed by hydropower with a share of 16,5%. Wind energy accounted for 11,1% , solar energy for 6,1% and lastly geothermal with 3,2%.

Germany is EU's bigger renewables producer(18,5%), with Italy being second(12%) and France third(10,7%). Spain(9,2%) and Sweden(8,5%) also have a considerable amount of renewables production. Climatic conditions and natural formations have a pivotal role to play on renewables deployment, a fact that is clearly depicted in renewables fraction in different Member States' energy mix.

2.2.2.6 Refined products

The EU, having 83 refineries and a production capacity of some 15 million barrels per day in 2012, which accounts for approximately 16% of international refining capacity, is the second biggest producer of oil products following the United States, while suffering from overcapacity.

The feedback from numerous EU refining plants to the recent market situation and future signs is to have refineries available for sale or to stop operations for some small periods and/or transform their sites to terminals. Closures are mostly prevented due to the high costs of clean-up procedures.

Even though there had been cut-offs in capacity of 1,8 million barrels per day in Europe since 2008, in accordance to the IEA, with regard to refinery terminations, transformation of refineries into import terminals or capacity diminishing. In spite of these cutbacks, it is considered that the area is still being tormented from overcapacity and that more refineries continue being at a risk of closing in the years to come. Depletion of capacity have a negative effect on supply security, as every refinery generates specific products that are essential from a security of supply standpoint. The final result is that the EU shall become more reliant on imports and on the relevant infrastructure.

2.2.2.7 Electricity

EU's electricity production in 2014 was 3,19TWh. The figures depict two trends, an inclining trend since 2008, when electricity generation peaked at 3,387TWh, and a declining one till 2014.

Germany is the biggest electricity producer (19,5%) in the EU, followed by France(17,8%) and the United Kingdom(10,6%). As regards the energy sources used, fossil fuels account for almost half of EU's production(47,6%), followed by nuclear(27,4%), hydropower(13,2%), wind energy(8,3%) and solar energy(3,2%).

2.3 Imports – Import Dependency

2.3.1 All energy sources

Imports as a term also has multiple interpretations. EU imports energy, but at the same time has exports too. In this study, the need is to reflect which part of the energy is actually used to serve final use. Therefore, when the term of imports is being used, it shall always reflect the term of net imports, which according to Eurostat, is the total imports minus the exports.

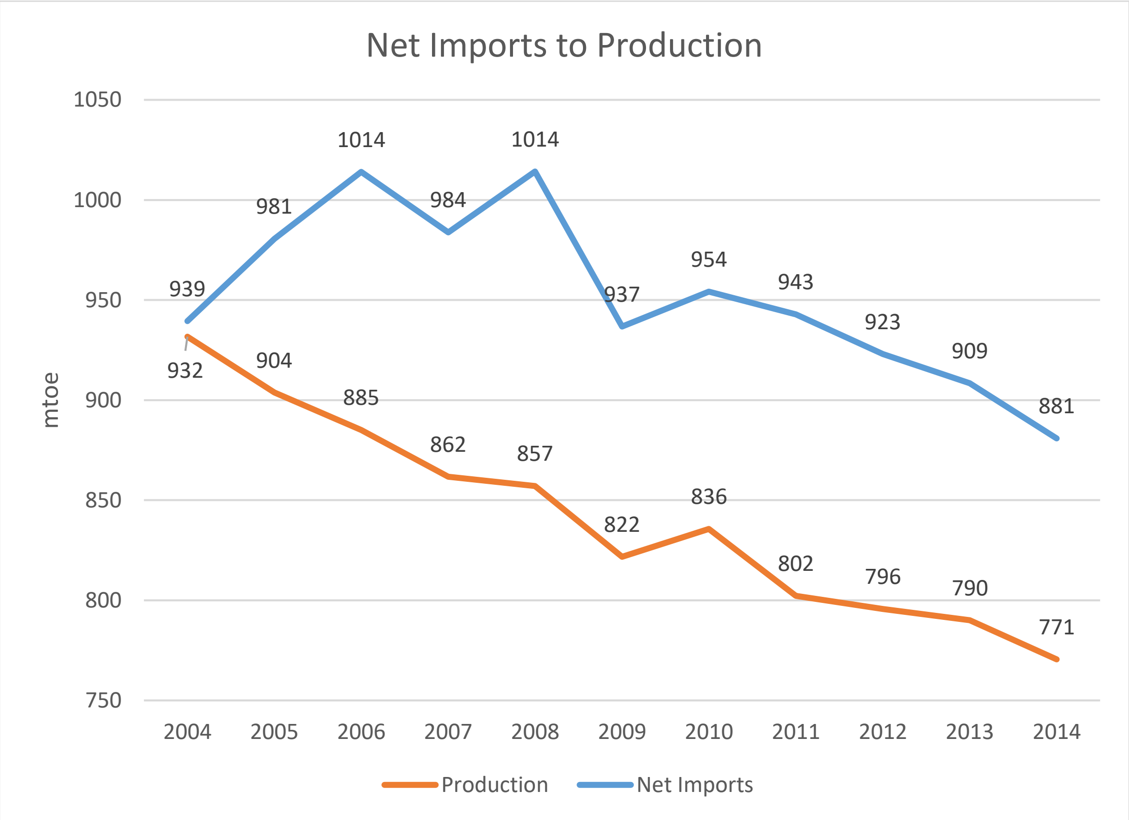

Figure 10: EU net imports to production 2004-2014 [mtoe]

The deterioration in the leading production of hard coil, lignite, crude oil, natural gas, and currently nuclear energy has caused a situation where the European Union was progressively depending on basic energy imports so that they may meet demand, despite the fact that this situation was balanced in the outcome of the financial and economic crisis. As illustrated in Figure 10, net imports generally follow the trend of production, which of course goes along the corresponding trend of consumption-demand. In 2014, the imports of basic energy, made by the EU-28, surpassed exports by some 881 mtoe.

The greater net importers of energy were in general the most populated EU Member States, except for Poland (a country with some remaining domestic deposits of coal). Denmark was the sole net exporter of primary energy in 2013, amid the EU Member States. However, Danish energy imports surpassed exports in 2013, in a way that any other Member States that were net exporters of energy, no longer existed (see Table 2). In relation to the extent of the population, the greatest net importers were Luxembourg, Malta and Belgium in 2014.

Between the 1980s and 2014, EU-28 reliance on energy imports has risen from less than 40% of gross energy utilization, to 53,5%, as illustrated in Figure 11. This more recent figure pointed a small decline in the dependency percentage, which in 2008 had peaked at 54,5%. In 2014, the most significant energy dependency rates were reported for crude oil (88,2%) as well as for natural gas (67,4%). The EU's reliance on countries that are not members of the EU, for supplies of natural gas, increased during the last decade (2004-2014) 13,8 percentage points, quicker than the advance in dependency for crude oil (7,5 percentage points) and solid fuels (7,4 percentage points). By 2004, the EU-28's net imports concerning energy, have been more significant than its basic production; greater than half of EU's gross domestic energy consumption was provided by net imports.

As depicted in Figure 12, in 2014, the Member States that were the least reliant, were Estonia (8,9%), Denmark (12,8%) and Romania (17,0%), succeeded by Poland (28,6 %), the Czech Republic (30,4%), Sweden (32,0%), the Netherlands (33,8%) as well as Bulgaria (34,5%). On the contrary, the uppermost energy reliance rates were reported for Malta (97,7%), Luxemburg (96,6%), Cyprus (93,4%), Ireland (85,3%), Belgium (80,1%) and Lithuania (77,9%). Amidst the five Member States using up the greatest amounts of energy, the least reliant on energy imports were the U.K. (45,5%) and France (46,1%), in comparison with Germany (61,4%), Spain (72,9%) and Italy (75,9%). Additionally, it should be stated that nine Member States reported in 2014, their most reduced energy dependency rates since 1990, those countries being: Bulgaria, Estonia, Latvia, Italy, Luxembourg, Malta, France, Romania and Portugal. On the contrary, the Czech Republic is the sole Member State reporting a top of its energy reliance in 2014.

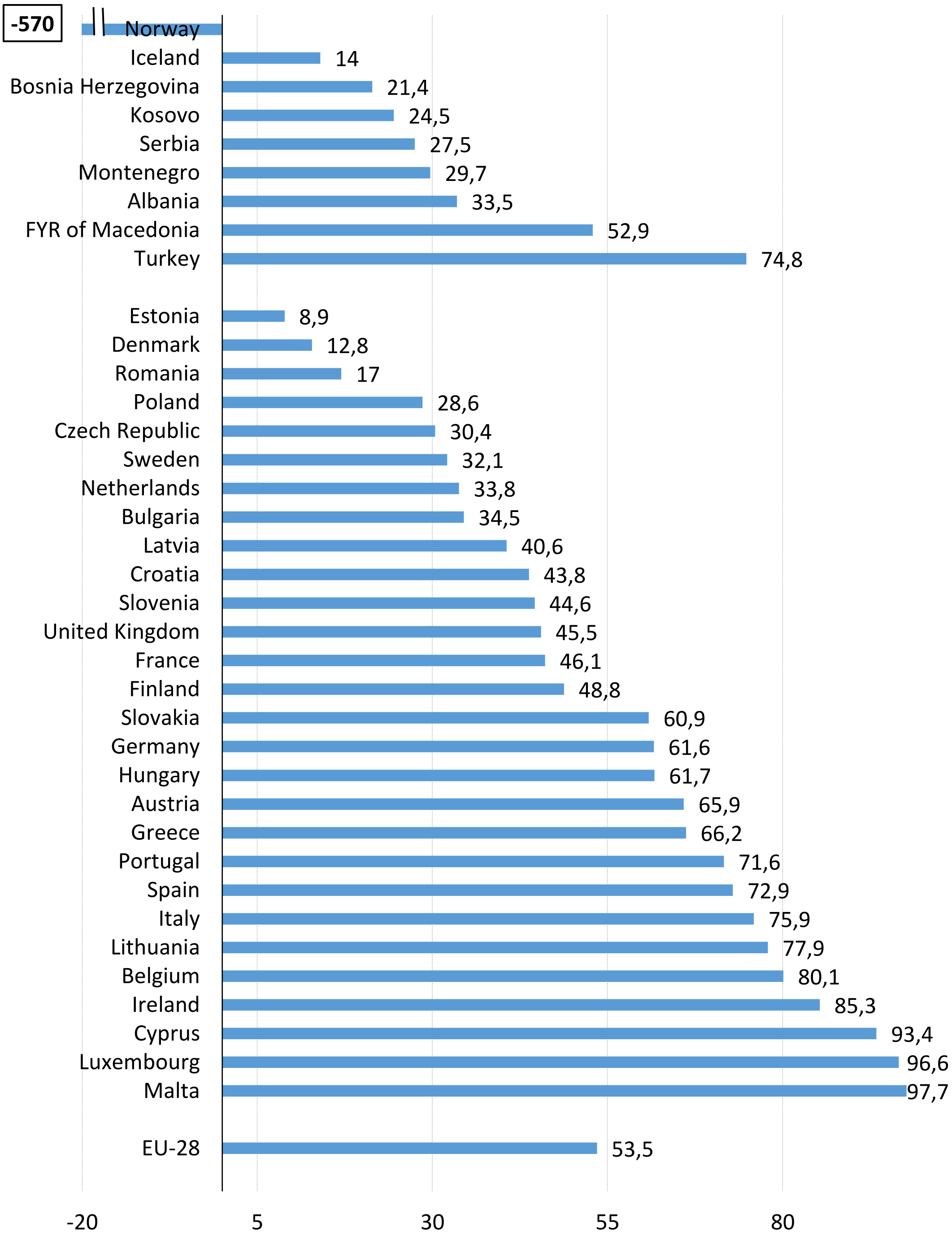

Figure 11:EU energy import dependency per member state 2014 [%]

2.3.2 Analysis per energy source

2.3.2.1 Total petroleum products

Reliance in import of crude oil, indicated as a percentage of consumption, kept on rising during the years reaching 88,2% in 2014, which is considered the peak level among fossil fuels, as illustrated in Figure 12, costing approximately €320billion per year.

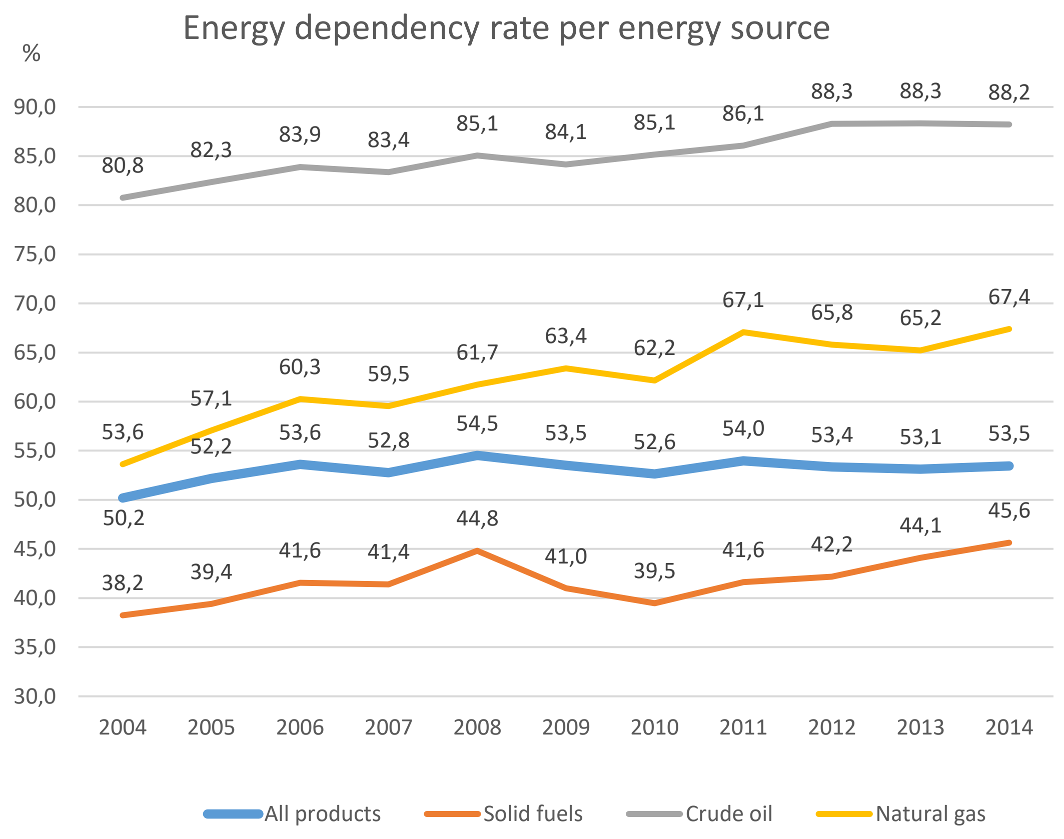

Figure 12: EU energy dependency rate per energy source 2004-2014 [%]

Germany, Spain, France, the Netherlands and Italy continue to be the biggest net importers of crude oil, despite the fact that, except for Spain, the outright worth of net import declined in the aforementioned countries between 1995 and 2012. In 2014, one third of extra-Eu imports of crude oil and NGL derived from Russia, succeeded by Norway (13%), Nigeria(9%), Saudi Arabia (9%) and the rest from numerous countries, though with small proportions.

Even though the market for oil is liquid and global, there is a concentration of suppliers that are exposed to geopolitical issues, resulting in possible disruption events or high prices. As regards its transportation, imported petroleum products are 90% carried by the sea, making it easy and flexible to alter suppliers if needed. What is limiting though, is that most refineries are designed to process specific types of petroleum products.

Most processing facilities are based on the coast, thus having direct connection to oil originating from producing countries of the globe. Regional inland processing facilities au contraire, are commonly supplied by the Druzhba pipeline with oil deriving directly from Russia. The specific pipeline distributes about 50 million tons of oil per year, nearly 30% of the entire Russian imports to the EU.

2.3.2.2 Gas

Gas imports are 60% higher compared to the corresponding demand. The largest net importers of gas are the greatest EU economies including Germany and Italy. In the last decade, net imports to Italy and Germany have been comparably balanced (in 2012 lowered by 8% and 12% correspondingly from the top in 2006). The UK turned into a net importer in 2004 with import volumes rising thirty-fold in less than a ten-year period to reach 31mtoe in 2012. Denmark and the Netherlands are net exporters of natural gas. In 2014, 38% of imported gas derived from Russia, succeeded by Norway (32%), Algeria(12%), Qatar (9%) and numerous more countries but with very limited capacity.

The level of reliance and diversification of suppliers and supply roads are significantly diverse among Member States. A number of northern and eastern Member States rely on a sole supplier, and frequently on one supply road, for their complete natural gas consumption, when at the same time other Member States have a well set portfolio of import partners.

Gas is an energy source that has characteristics that distincts it from the other sources. The most important features is that is mainly transported though fixed pipelines that create a direct and firm inter-dependence between the producers and the consumers. Another important note is that gas reserves are highly nationalized and concentrated in specific regions, thus no global gas market exists. The combination of those facts make gas a source extensively used as political leverage. A full detailed view on gas geopolitical role is analyzed in Chapter 3.

2.3.2.3 Solid fuels

The EU is the third biggest consumer Hard coals imports to the EU are flourishing in order to make up for the decrease in domestic coal generation and satisfy the current rise in demand by power services set in motion by the drop in coal import prices and the competitive spot of coal in the power sector. Overall imports in 2014 rose at a faster pace compared to consumption. Russia continues to be the most significant exporter of solid fuels to the EU consisting up to 29% of imports to the EU, with Columbia (21%) and the US (20,5%) following in its steps. Supplies coming from Columbia and the United States have taken the place of imports from Indonesia and South Africa, while Australian imports have been replaced by North American competition.

Germany, the UK, Spain and Italy are the biggest EU importers of coal. In the period 2011-2012, there has been a drop in hard coal net imports to Germany since higher consumption was met by flourishing domestic generation and less stock building.

When compared to other fossil fuels, the dependence of the EU on net imports of solid fuels coming from countries outside the EEA is relatively low, despite the fact that it has doubled since the mid-90s and has been higher 40% in the late years, following a peak at 45% in 2008. Hard coal comprises practically the total of solid fuel imports to the EU. This is due to the fact that solid fuels markets are very competitive and diversified. As a result, nor disruptions, nor spice spikes have been observed in the solid fuels market, in contrast to the relevant global oil markets and the regional gas markets. Lastly, solid fuels transportation is flexible, as both railroad, pipelines, trucks or ship can be used.

2.3.2.4 Nuclear

Indigenous mining of uranium and its processing accounts for approximately 5% of the EU needs, meaning that the EU is highly reliant on imports. Even though the actual dependency of uranium is significant, it is supplied through numerous supplier countries. Kazakhstan is the biggest supplier accounting for 21,2% of EU’s uranium supplies, followed by Canada(18,5%), Russia(18,1%), Niger(13,1%), Australia(11,8%) and others. Some of EU’s uranium import partners as Canada and Australia are long term and reliant cooperators, further reducing risks.

Dependency on imported uranium had been generally constant since the 1990’s. The corresponding reliance on imports, as regards conversion processes and enrichment procedures, was 20% in the 1990’s and reached almost 40% in 2012, mostly due to the transition of France to enrichment technology. Moreover, another troubling issue is that nowadays more reactors are dependent on fuel fabricated by Russia, as their design are based on Russian know-how. In the 1990s this was true only for Finland, while at this stage it also applies to Hungary, Slovakia, the Czech Republic and Bulgaria.

Generally, uranium is considered to be quite diversified, thus secured, in terms of supply, despite of its high reliance and issues associated to conversion, enrichment and fuels fabrication.

2.3.2.5 Renewables

Calculating and analyzing imports and import dependency of renewables is a very challenging process, due to two major obstacles arising [5]. First of all, feedstock used for biofuels can be also utilized for non-energy purposes. A typical example is wood, which can be used as a construction material, as raw material for furniture fabrication etc. Secondly, data regarding the input of feedstock used to produce biofuels are scarce. Therefore, the process to calculate and analyze renewables' dependency figures, and more specifically figures that can be directly compared to the corresponding figures of fossil fuels, is of significant difficulty and complexity.

2.3.2.6 Refining

If net imports are considered, the EU presents almost zero imports. However, this is not accurate, as EU is both a net importer and net exporter of refined products. The EU has excess in gasoline production, which export basically to North America, and shortage in jet fuel and diesel, which imports basically from the USA, Middle East and Russia.

The "dieselization" of the transport sector, the decommissioning of EU refineries, that were described in previous sections, and shale oil production in the USA, that will result in less import from the EU, are expected to further deteriorate EU's security of refined fuels supply in the following years.

2.3.2.7 Electricity

Almost all energy sources are utilized to produce electrical energy. Its dependency therefore depends on the corresponding import dependency of those sources and the share of each source in each Member State's power generation mix. Consequently, arriving to an absolute value for electrical energy's import dependency is rather difficult.

Nuclear and renewables accounted for 56,6% of EU power generation in 2014. With the first being a well-diversified energy source and the latter being practically non-dependent on imports, more weight is on the solid fuels utilized in power production.

As mentioned in the section regarding consumption, 70% of solid fuels are being utilized in electricity and CHP plants. This accounts to 25,3% of the total EU power mix in

2014. Countries with a high share of solid fuels in their power mix and high solid fuel import dependency, such as the United Kingdom, the Netherlands, Ireland, Denmark and Croatia, are vulnerable in possible disruption of electricity and heat production in the case of supply events of the solid fuel market.

In 2014, 15,4% of power generation was accounted to gas. In the same principle as in solid fuels, countries such as Spain, Greece, Belgium, Ireland, Latvia, Luxembourg, Portugal, Hungary and Lithuania, having high gas import dependency and high share of gas in their power sector are sensitive in gas market fluctuations. As analyzed in former sections, gas supply is more volatile than solid fuels one, making EU power generation more sensitive to gas shortages than solid fuels disruptions.

Petroleum products account for less than 2% of power production in the EU. However, Malta and Cyprus are two Member States that are both almost fully dependent on petroleum products for their power generation(98% and 92,7% in 2014) and fully dependent on imports of petroleum products.

3 Geopolitics

This chapter aims to present the geopolitical aspect of energy security, mainly by analyzing the case of gas, as gas is heavily promoted as the next big thing in EU's energy mix, while at the same time features a distinct difference to all other primary energy sources; it's highly infrastructure dependency. If combined with the general nationalization of energy resources, gas have the potential to serve as a significant geopolitical tool and used as political leverage.

3.1 Geopolitical aspect of energy

The fundamental term of energy security of supply it that it is the uninterrupted availability on energy sources at an affordable price. However, issues such as the reliability of import partners, the risks related to transit counties and ensuring the investments needed are crucial and further develop the term of security of energy supply. The geopolitical aspect of fossil fuels is mainly due to the following facts:

- they are depletable
- they are concentrated in few regions Nine countries, with 5% of the global population, account for 80% of the world's oil and 13 counties possess 80% of the global gas resources. The Middle East alone, account for 62% of oil and 45% of proven gas reserves [7].

Therefore, implications on the geopolitical level arise from numerous perspectives. To begin with, the majority of the fossil fuels are located in areas that are politically unstable. For example, three out of the seven countries that EU had officially associated with terrorism are big producers of oil and have major oil reserves (Iran, Iraq, Libya).

Moreover, political events and developments in producing counties may negatively affect energy supply to import countries. The case of Venezuela is a typical example, with the nationalization of the oil sector in 2006, after Hugo Chavez was reelected, creating major supply issues to the global market. Another relevant example is Russia, with its president Vladimir Putin utilizing the vast energy resources of its country as a leverage to achieve various objectives and strengthen Russia's global position. The cut-off gas supply from Russia's side to Ukraine in 2009, leaving numerous EU Member States without gas for period, was a dynamic reminder of the strength Russia possesses on the EU's energy security.

This situation basically operates through the national energy companies that have recovered control of energy resources during the last years. While, the "Seven Sisters"(BP, Exxon-Mobil, Chevron, Total, Royal Dutch Shell and ConocoPhilips) had control of over 85% of the global gas and oil capacity in the 1960's, now it is major national energy companies(Gazprom (Russia), Aramco (Saudi Arabia), PDVSA (Venezuela), NIOC (Iran), CNPC (China), Petronas (Malaysia) and Petrobras (Brazil)) that are in control. The conclusion remains that, as described above, politicization of energy may cause problems in the operation of the global energy market, as it vulnerable ideological or political ambition of people in charge.

Future scenarios anticipate that internationally the demand for primary energy sources will rise by 36% during 2008 -2035, with the fossil fuels accounting for over half of that increase. Gas request is expected to rise by 24% in the period 2005-2025 in the EU. This could be attributed to the global policy of lowering CO_2 emissions, considering natural gas's more environmentally friendly nature and the fact that it can substitute other fuels in power generation. Additionally, the accident in Fukushima nuclear power plant in 2011 will probably contribute towards gas side, even if oil is expected to remain at the top of the global primary energy mix [6]. Combining this expected increase with the infrastructure dependency of gas, which requires enhanced external relations with transit counties and further boosts import dependency, implies the particular geopolitical dimension in the gas sector compared to other energy sources. Consequently, gas has been chosen as a case study to be analyzed, to illustrate the complexity of geopolitics in the energy sector.

3.2 Gas geopolitical chess game

3.2.1 Players and their interests

This part illustrates the key actors involved with the future of the EU's energy policy, either due to them influencing, or because they will contribute to the gas supply market. It will look at every single actor on a case-by-case basis so as to verify the motivations of that actor as well as what role it will play in the future of the EU's energy policy, additionally to how crucial the actor will be in the grand scheme of it.

3.2.1.1 The European Union

The aim of the European Commission is to enhance security of energy supply, merely though multidimensional energy policy. Multi-lateral policies, however, are sensitive to external leverage. The most significant external influence on energy issues comes from US and Russia. Even though the EU aims to decrease its dependency in Russian imports, this decrease is not expected to be significant, as massive investments already made on gas networks and infrastructure make it economically irrational for both sides. As regards the USA, it is of paramount importance for them to have access and influence over the world's second largest energy market, as the EU is also one of its traditional allies.

Moving to internal EU, a troubling fact for the EU is that three of its eastern Member States, Latvia, Estonia and Lithuania, are ex-Soviet Union states, thus being more sensitive to Russian influence, while also being totally dependent on Russian imports. This situation creates a major energy security issue for the EU, as an integral part of the Union is actually being controlled by an external EU force in terms of energy. Another issue to be considered that highly affects energy security is the current state and stability of energy transit countries which serve as pathways to energy imports. Ukraine is a typical example in this term, as almost all the gas pipelines supplying Europe with gas pass thought it, creating a major threat in cases of internal instability. The Russian – Ukraine gas dispute which evolved to the Ukrainian Crisis of 2014 and energy-wise resulted in several cut-offs of Russian gas, depicted how vulnerable the EU is in Russian disruptions.

To conclude, the EU needs to interact with both the West and the East to address the topic of security of energy supply and tackle critical internal issues on this term.

3.2.1.2 The United States

The United States in the EU energy security scheme is rather interesting, as they mostly play a role of monitoring EU state, rather than suppling the EU. This is mostly due to the fact that the US is interested in fighting EU's dependency on Russian imports, as Russia is being considered a rival international player. Moreover, the close relations, both economic and political, between the US and the EU are driving this US stance.

Lastly, the US considers Europe as a potential importer of US shale in the foreseeable future, which is something that will both empower US's place inside Europe and act towards diminishing Russia's power. In that respect, John Kery, US secretary of state, has stressed US' support towards the evolution of US-EU gas trade and the EU's need to avoid Russian dependency [8]. Even though such a transition requires structural reforms on EU's gas market and is not possible on the short term, it is obvious that the US is and will continue to be one of the major actors influencing the EU energy agenda.

3.2.1.3 Russia

Russia, by being Europe's greatest gas supplier, has acquired enormous financial benefits and influence. Even though it seems that Russia has the advantage on this relationship, it is argued that in a large-scale Russia's dependence on the EU is at the same levels. In the case of gas disruption, both sides would lose on different levels. Moreover, the financial relationship of the EU with Russia includes major investments through Foreign Direct Investment(FDI). If such financial flows are cut, Russia could enter to a substantial crisis. Moreover, EU oil stock introduced by EU energy policy further push Russia' side.

In order to maintain its influence and benefits, Russia uses the power of its national gas giant, Gazprom, as well as its favorable geostrategic location to establish partnerships with regions that EU targets as alternative suppliers, such as the Caspian Sea area and the Levant Basin area. The strategic actions of Russia on these regions of interest are analyzed in the following section.

3.2.1.4 Cyprus

Major hydrocarbon reserves(Figure 19) had been discovered in 2011 in the Cypriot Exclusive Economic Zone (EEZ), making Cyprus a special case for the EU energy security. The gas reserve discovered is the second biggest of the EU, estimated to be around 7 tcf [9]. As Cyprus is a Member State of the EU this capacity is considered to be EU's capacity, therefore enhancing the EU dependency on several aspects. Moreover, Cyprus is becoming a key player inside the EU and the global stage.

Nevertheless, Cyprus, Greece and Turkey tensions regarding the separation of Cyprus island and the declaration of the Turkish Republic of Northern Cyprus, which is solely recognized by Turkey, is a major obstacle on proceeding with the exploiting of the field. Turkey implies that the reserves also belong to the northern part of Cyprus, while no international recognition of this state means that is does not included in the Exclusive Economic Zone (EEZ). Therefore, there is an immediate need of addressing this issue through diplomatic action, as this region could prove a significant addition to the EU portfolio and enhance its energy security. Moreover, the means of transportation and extraction have to be agreed on during the diplomatic process.

3.2.1.5 Israel

Israel is a similar case to Cyprus, as major hydrocarbon reserves had been found during the last decade(Figure 19). Israel's reserves(33tcf) is estimated to be able to cover their needs for over 200 years,

Israel could also serve as an additional supplier of gas to the EU, further enhancing the current relationship between the two sides. Its proximity to the EU and its potential partnership with Cyprus regarding the required infrastructure also favor such a move, while Israel's geographical position ensures that it won't monopolize specific Member States, like in the case of Russia.

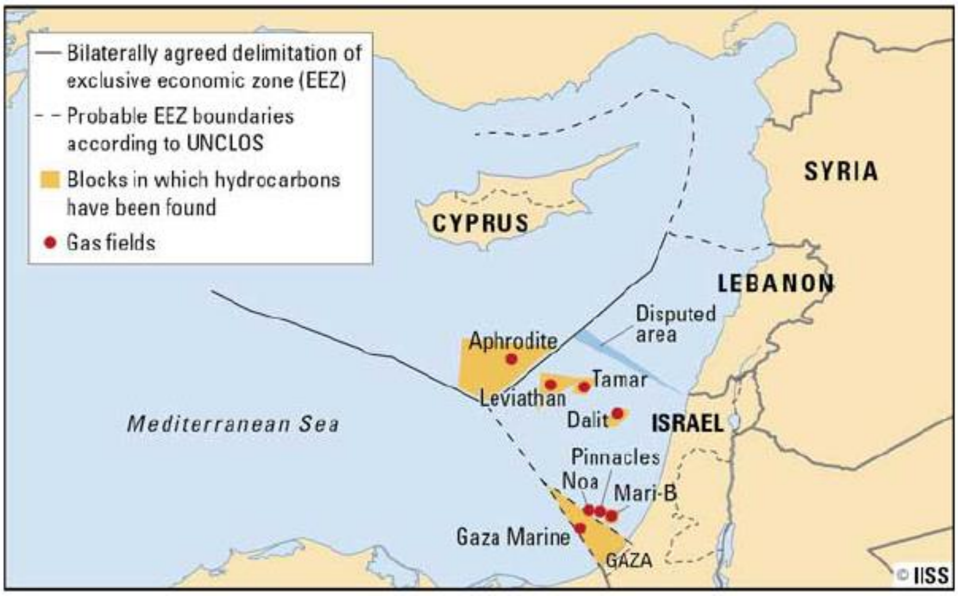

Figure 13: Eastern Mediterranean newly discovered hydrocarbon reserves

Even so, the EU would also have to keep in mind the relationship of Israel with Russia, as Russia has already attempted to attain exclusive rights regarding the development and export of all LNG of the Tamar field(Figure 19). Consequently, Russian influence needs to be considered when forming EU's strategy regarding a cooperation with Israel.

3.2.1.6 Iran

Iran is being gradually put back on the global discussions, as sanctions are being slowly lifted after the productive discussion outcome regarding its nuclear energy program. Iran has enormous amounts of gas in the South Pars field and even though Iran international commercial and financial activity is still progressing slowly, the possibility of Iran serving as an EU supplier is significant. This fact is further empowered if considering that Iran has signed a Memorandum of Understanding to supply TANAP in the future.

3.2.1.7 Qatar

Qatar is the world's biggest LNG producer, exploiting the North Field, which is one of the biggest global gas fields. The infrastructure for LNG is not that expanded in the EU, so Qatar only supplies 11% of EU's gas supply in the form of "conventional" gas.

Qatar is one of the most prominent future gas suppliers, as the strategy of both Qatar and the EU, is to move towards LNG. Qatar's aim is to provide 1/3 of its LNG production to the EU by 2030, while the EU favors LNG as it tackles the infrastructure dependency aspect of "conventional" gas. LNG terminal are in process of development throughout the EU.

3.2.1.8 Turkey

Turkey's role in EU gas scheme is quite interesting, as in contrast to all other countries it does not supply the EU with energy supplier. Its significance is due to its geographical location, which can be described as a crossroad between the EU and its major future energy suppliers, such as the Caspian Sea area, Cyprus, Iran, Israel and even Russia.

In the following section, all areas of interest to the EU energy security are being analyzed. The fact regarding Turkey is that almost all of the EU's new prominent energy supplies pass thought its soils to reach the European energy market. Consequently, even though Turkey is not a supplier of energy to the EU, its role has become of paramount importance for EU security of energy supply in just a few years.

This situation is fairly beneficial for Turkey, both economically, but more significantly due to the influence that it acquires both at EU and international level.

3.2.2 Regions of interest and geopolitical aspects

Three regions of major importance for the future of EU energy security regarding gas supply are analyzed in this part; the Persian Gulf area, Levant Basin area in south-east Mediterranean, and the Caspian region.

3.2.2.1 Persian Gulf area

The relationship between the EU and Middle East and the Persian Gulf (Iraq, Iran, United Arab Emirates, Saudi Arabia, Oman, Qatar, Yemen and Kuwait) had been quite stormy in terms on energy supply, as the Middle East Crisis of the 70s was the event that triggered the EU concerning security of energy supply. The area accounts for almost 40% of international gas reserves, which includes the Qatari North Field, the biggest non associated gas field. As mentioned in the previous section, Qatar accounts for almost 10% of EU's gas imports, being by far the largest supplier from this area, while, to compare, the respective figure from African nations is 20%, depicting the state in which the EU-Persian Gulf energy partnership currently states.

Even so, considering the needs of the EU and the enormous capacity of the Persian Gulf, returning this partnership to its former state could potentially prove very beneficial. What makes this relations reflation more interesting is the fact that Persian Gulf primarily focuses on LNG. Figure 17 depicts forthcoming LNG terminal projects in several countries of the area, highlighting the anticipation of the area for the future of LNG. As mentioned before, reliable LNG supplies could help towards achieving the EU's goals of energy sources diversification and decreasing dependence on transit countries. Moreover, the major capacity of the Persian Gulf could help the EU decreasing the Russian influence on the long term.

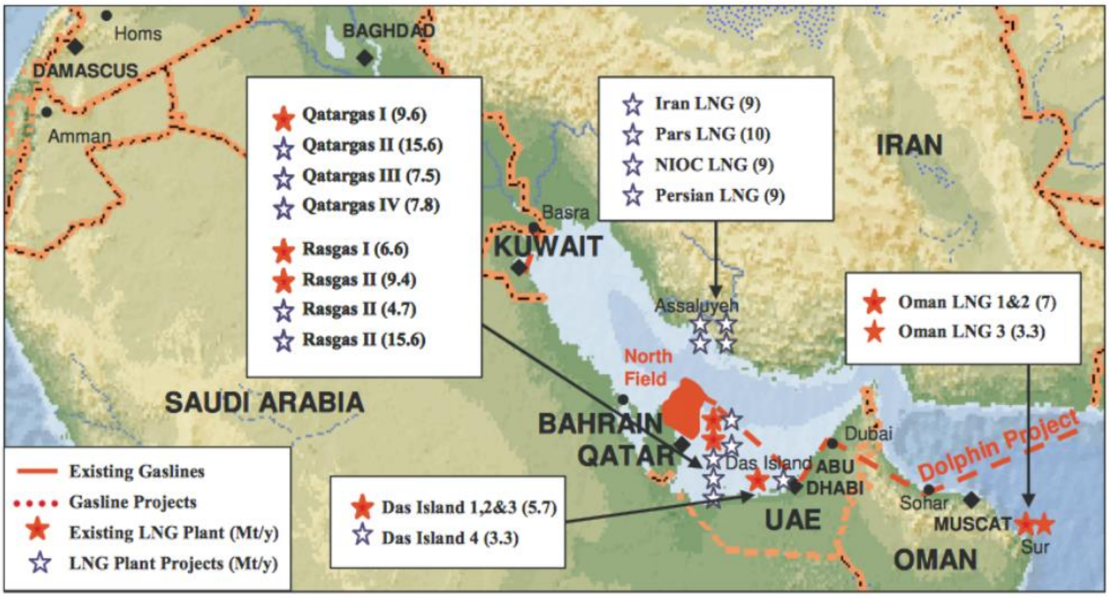

Figure 14: LNG existing and planned projects in the Persian Gulf area

Iran and Qatar are the two countries of the area that lead the way regarding the EU request for gas. What is needed form the EU stand point to develop the LNG infrastructure required to cope with the future demand, despite the fact that they are far more expensive than traditional gas pipelines. Numerous LNG gasification terminals are being designed in the EU, to that extend, two in Spain, two in Italy, one in France, one in Brussels and two in the United Kingdom. EU's LNG imports in 2014 were about 80 bcm, with expectations that this figure will be doubled by 2020. The development of this infrastructure, even though being costly and requires a lot of time to be completed, will generally enhance EU’s flexibility on gas supply, and that does not apply only to Persian Gulf gas. Lastly, improving relations with Iran and pushing its economic recovery by importing gas, may lead to a more harmonized Persian Gulf area, creating a more stable neighborhood for Europe.

3.2.2.2 Levant Basin area

Levan Basin area consists of the waters between Israel, Cyprus, Lebanon, Syria and Egypt, as can be seen in Figure 13. This area of major interest for the EU, as major discoveries of gas reserves have been made during the last decade. Moreover, this area also includes Cyprus, which is an internal part of the EU. The reserves found between Israel and Cyprus accounts for more than 40tcf, with research estimating that 122 tcf more are being undiscovered[9]. To stress the significance of those figures, Russia, which is the largest country in the world and with far multiple population, holds gas reserves that are only 6 time bigger. The obstacles that arise towards the exploitation of those reserves are mainly political arguments between neighboring counties, translating to supply routes issues.

Israel decided in 2014 that 40% of its gas reserves would be exported[10], thus a supply route was needed. Israel faces the issue of being a Jewish nation in a Islamic area, which translates to tensions in the general neighboring area [11]. Therefore, on shore transportation through Lebanon and Syria faces issues on security and needs to be avoided. Numerous pathways have been examined for the Israeli gas to reach the EU market, with the most possible being:

- through a pipeline that goes directly across to Turkey
- a joint LNG terminal in Cyprus.

Both scenarios require a tight partnership of Israel and Cyprus. Moreover, both options apply for Cyprus as well, as Cyprus is also evaluating the ways to supply the EU gas market with its own gas reserves

On the case first case, illustrated in Figure 15, the pipeline would be built far across the Lebanon and Syria coastline, so as to avoid possible disruptions due to historical tension of Israel, Lebanon and Syria. This route commencing from the Israeli Leviathan field, passing through Cyprus exclusive economic zone and reaching the Turkish Ceyhan port requires the pipelines to be set up deep at approximately 2000metres, which is fairly costly compared to a case on building the pipeline closer to the coastline. Despite that fact it would still cost three times less(merely $2.5 billion) compared to the case of the LNG port[12].

Figure 15: Proposed pipeline connecting Leviathan gas field to Turkey

An obstacle on that respect is the fact that Cyprus has claimed that it won’t allow the construction of the pipeline through is EEZ, unless Turkey officially recognizes the Republic of Cyprus and acts towards solving their 40 year conflict, which also relates to the exploitation of the Aphrodite gas reserves. This conflict originates back in 1974 with the division of the island and the formation of the Turkish Republic of Northern Cyprus (TRNC), a nation that is recognized solely by Turkey. A potential reconciliation and therefore move towards the construction of the pipeline would prove beneficial for all associated parties, as:

- The EU would access an alternative gas supply
- Israel would be able to supply its resources towards a major energy market
- Cyprus would be able to use that pipeline to economically supply its gas of the Aphrodite field to the EU. Moreover, Cyprus could also benefit from a project of

Turkey to supply the TRNC with water, since water is one the basic issues of the island of Cyprus, with frequent shortages and disruptions. There could also be a possibility of trading those two such valuable resources for the area, as water for gas.

- Turkey would lessen Russian influence and further empower its position in the EU and international level

The stabilization of the area, due to the mutual interest economic partnerships that are going to be formed, should not be neglected.

On the second case, Cyprus has been examining the construction of and LNG terminal in its Vassilikos port, in order to reach the EU market and avoid Turkey's influence if a pipeline is to be used. However, a multibillion dollar investment cannot be justified at this moment, as Cyprus does not have the required amount of recoverable gas to fully utilize it [13]. In order for this terminal to be feasible, either Cyprus would have to discover additional reserves in its EEZ or Israel would need to participate and supply it with vast amounts from its Leviathan field. As regards the first scenario, Cyprus would face delays on exporting gas to the EU [14].

Another interesting factor regarding the reconciliation of Cyprus and Turkey and the creation of this new gas supply route to the EU, is that it is highly brokered by the US [15]., as one of their best interest to diminish Russian influence on this are and on the EU. Despite that fact, neither the EU nor the US can avoid Russian influence in this area, as Russia has close relations with both Israel and Cyprus. Notably, Russia has managed to secure exclusive right to develop and export LNG from the Israeli Tamar field. As a result, Russia would still have the power to influence EU energy scheme, even indirectly, despite of the EU efforts to diversify.

The example of the Levant Basin showcases how complex can issues of energy become and how geopolitics can direct their development. Levant Basin has attracted global interest to turn into an area in which multidimensional agreements are necessary, in order for its potential to be exploited.

3.2.2.3 Caspian Region and strategic pipelines

A third possible area for the EU to explore as an addition to its gas portfolio is central Asia, particularly the Caspian area, as Kazakhstan, Azerbaijan and Turkmenistan possess large untapped gas fields [16]. Azerbaijan is estimated to produce approximately 30 to 70 bcm of gas annually by 2020, with the production stabilizing till 2030. Turkmenistan's annual production is approximately 50bcm, but it is expected to reach even 120bcm yearly due to upcoming reserve discoveries. The same applies for Kazakhstan with current 30 bcm expected to reach 90bcm till 203o Consequently, the Caspian area demonstrates promise of being an area with adequate quantities of gas for the capital being invested in its infrastructure, for each pipeline costs up to $4billion[17].

While the size of gas reserves in the Caspian region are pretty extensive, yet current gas system was designed to supply Russia and thus is controlled by Russia. In order to access this region this region without the Russian influence, a system of pipelines needs to be installed. Three pipelines were originally planned to create the so called east-west corridor: TAP, TANAP, and Nabucco, which are depicted in Figure 16. On the other hand, Russia also planned to create the South Stream pipeline, in order to avoid Ukraine as an unstable transit country and directly supply Europe through Bulgaria, with the pipeline passing through the Black Sea. These pipelines not only depict a competition of attempting to reach the EU gas market first, but also a hard attempt from EU-side to move away from Russian influence. EU's Nabucco was competing with all three pipelines, as the South Stream was overlapping its whole length, the TANAP pipeline was overlapping its eastern section and TAP was overlapping its western section.

The construction of the Trans-Anatolian gas pipeline (TANAP) was announced in 2017 by Turkey and Azerbaijan, as a pipeline that will supply southern Europe(through Greece) with natural gas from the Caspian Sea's Shah Deniz fields via Turkey. This pipepline, serving less countries than Nabucco, was forecasted to be more affordable than its competitor (€5billion for TANAP, €8billion for Nabucco) and was consequently favored by the Azeri gas company [18].Its construction began on February 2015, starting from a Kars, an eastern region of Turkey. TANAP is anticipated to be completed by 2020 and will originally transport 16 bcm of gas on a yearly basis, with a forecast to increase its capacity to 31 bcm by 2026. Consequently, the Nabucco project was cut back, turning into the "Nabucco-West" project, in order to be supplied by TANAP and link the Greek-Turkish border and Austria. Additionally, as mentioned in previous sections, TANAP may also serve the supply of gas from Middle Eastern countries, such as Iran, as well as from the Levant Basic region(Cyprus, Israel)

Furthermore, in 2013, the Trans-Adriatic Pipeline project (TAP) [19] was selected by the Shad Deniz II consortium as the sole pipeline that would carry TANAP gas from the

Turkish-Greek border to Europe, mainly due to the fact that its route was 500km shorter than the one of Nabucco-West. Therefore, the TANAP/TAP project formed the new “Southern Corridor” and the ambitious Nabucco project was terminated[20].

Figure 16: Gas pipeline projects

As regards Russia, the termination of the Nabucco project was a positive development for South Stream, however Gazprom had legal European energy policy issues to tackle, due to its vertical integration. In 2013 the European Commission announced that South Stream does not comply to the Third Energy Package [21], and more specifically the rule on unbundling, which require that the owners of generation, sales operators and, transmission grid’s owners have to be different. In response to this development and the Commission’s stance on this issue, Russia drastically altered its strategy to supply Europe, by jointly announcing with Turkey in December 2014 the termination of South Stream and the construction of the Turkish Stream[22], which would serve as the replacement of the South Stream. Its capacity is expected to be about 63bcm annually, while all of the gas supplied thought Ukraine is approximately 80bcm, thus meaning that this new pipeline is capable of almost fully substituting the Ukrainian pathway. Turkish Stream follows 2/3 of the original path of South Stream through the Black Sea and then leads to the Western part of Turkey, while South Stream led to Bulgaria, as can be seen in Figure 17.

Figure 17: South Stream and Turkish Stream routes

What is even more important to note regarding the South Stream termination and Turkish Stream development, is that Gazprom will be the only supplier of the Turkish Stream, while South Stream would be supplied also by European companies, as ENI(Italy), Wintershall(Germany) and EDF(France). Therefore, the EU was left with no control on the Russian pipeline and increased dependence on Turkey, now serving as a transit country for two major gas pipelines.

While Russia secured a victory with the Turkish Stream pipeline, the EU will still have a diversified supply form the Caspian area through TAP/TANAP, a development that will be a pillar of the future gas security of supply of the EU. As mentioned on previous sections, this pipeline could serve as a route to also supply Leviant Basin and Persian Gulf gas to the EU energy market, even if this means that Turkey's position is further being empowered.

Lastly, another country that is expected to gain many benefits from these pipeline wars is Greece, as will serve as a transit country for the Turkish Stream. This developments is expected to both empower Greece's position on EU level, enhance the overall energy security of the area, promote better relations with Turkey, as well as provide much needed financial benefits, as Greece is severely affected by the economic crisis.

4 EU Energy Policy

Energy policy is undoubtedly one the most significant political issues today. It is fundamentally connected to climate change, making it not only one of the most complicated issues, but also one the topics with the greatest priority within the EU. In the past, energy policies were chiefly made at the nation state level, and even today a number of actors oppose more competencies for the EU. Areas of debate entail the energy mix of countries and how to finance future energy investment. Generally, though, the signs for a mutual energy policy appear to be improving.

4.1 Policy making and associated parties

4.1.1 EU Commission, Council, Parliament

The EU Commission is entitled the right to introduce legislation and has, as a result, significant influence as it settles the agenda. Occasionally the Commission gets an order from the Council to prepare specific energy legislation. In the legislative procedure though, the Commission has very limited authority, for it may revoke a legislative draft, but it has no decisive word on it. The Commission is the executive body of the EU government and each individual policy area is headed by a Commissioner, who is suggested by his country's government. Similarly to the operation of national governments, the Commissioner's stance may affect significantly the final decision of the Commission [23].

During the legislative procedure the EU Council and the EU Parliament are decisive actors. The Council is comprised of the respective ministers (ministers for energy) from Member States and consequently is the EU actor with the strongest concentration on Member States interests [24]. In the past, the Council would make decisions concerning all energy legislation consensually, this brought numerous initiatives to an unexpected end. Following changes brought in under the Lisbon Treat, nowadays the majority of issues can be decided with qualified majority. The EU Parliament is the second legislative body in the EU and has obtained more authority over the last years, particularly under changes established by the Lisbon Treaty. Under the Lisbon Treaty co-decision, that is based upon the principle of parity among the Council and the European Parliament, was renamed the "ordinary legislative procedure", with the Council concluding with qualified majority and the Parliament concluding with simple majority. Since the new ordinary legislative procedure has been implemented, the Parliament has participated in all critical energy policy decisions.

The EU Parliament is arranged in political factions [25], yet decisions of Members of parliament are occasionally also greatly affected by their country of origin. Decision making in the EU parliament consequently seeks a different logic than in national parliaments. Coalitions may be developed across faction lines; however, energy policy is strongly affected by political preferences.

4.1.2 Member States, National Energy Companies, Corporations

The Member States are the most significant actors besides the institutional EU bodies. They affect energy policy through their energy ministers in the EU Council and thus decide the “general direction” of energy policies in the European Council. Furthermore, the EU can merely act in areas for which the EU was entitled the competence to act by the Member States. Member states may not be interested in the short term to give particular competencies to the EU. For instance, the energy mix remains a Member State jurisdiction. National preferences, accessible energy resources, industrial issues and of course energy foreign policy all affect the kind of mix a country has. While Germany, for example, has concluded on terminating nuclear energy, France possesses a share of 42% of nuclear energy in its mix. Similarly, while the majority of countries attempt to replace coal with other fuels, so as to reach climate goals, Poland’s coal share is higher than 50% in its energy mix, for it has considerably large coal reserves. Notable energy-mix differences indicate differing interests. For Poland, for instance, high CO2 depletion goals pose a fairly bigger challenge than for the majority of other countries in the EU. This frequently led to its “brakeman” position in negotiations. On the contrary, some countries are solely reliant on one supplier (Russia) and particularly in the gas sector have become more anxious about their energy security than countries that are more diversified supplier wise. So, these countries request for more energy solidarity. This request was incorporated in the Lisbon Treat, bolstering energy security in the EU.

The (inter-)national energy companies in the EU also have a significant role to play. Through associations they participate in the Economic and Social Committee, as well as in numerous European forums. Besides these activities they lobby also in other ways as, for instance, through direct contacts with EU MEPs or Members of the Commission. The “national champions”, like Germany's RWE and EON, France's EDF or ENEL in Italy, also exercise influence through national channels. As the liberalization procedure in the energy sector is lagging, a number of national champions made a financial profit out of it, also improving their leverage.

For sure, companies are, naturally, motivated by profit, leading to positions that may be far of what is best for EU citizens. These negative inclinations are somewhat covered by the action of civil society actors like environmental protection corporations. Those have acquired significant influence, for they provide science and data concerning climate change and energy issues and thus considered credible. They lobby almost the same way the energy companies do.

4.2 History of European Energy Policy

4.2.1 First steps towards collective action

In 1951 the “Treaty establishing the European Coal and Steel Community (ECSC)” was signed, indicating the start of the integration of Europe [26]. With the installment of the ECSC, a shared customs union was formed. The goal was to control collectively the two commodities that were necessary for warfare and reconstruction alike, resulting in the formation of a common political interest and enhancing cooperation. Another early collective action was the establishment of the European Atomic Energy Community (EURATOM) [27], which occured six years later. In spite of these beginnings, European integration of energy policy did not advance too smoothly. The cooperation did become progressively closer- yet the speed of this progression highly varied.

The 1960s were defined by a concentration on the nation state level. A push towards energy collaboration was initiated by the oil crises in 1973 and 1974. Consequently, in 1974 the “Council Resolution concerning a new energy policy strategy for the Community” was passed, which was shortly after improved with energy goals for 1985. With this the Council not only highlighted the added value of close collaboration among Member States to tackle energy problems, but also adopted guidelines regarding energy supply (promotion of nuclear energy, hydrocarbon and solid fuels in the Community; diversification) and energy request (utilizing energy in a more logical way).

Over the few years that followed the issue of environmental protection became more popular in Europe, but this did not yet reflect in European legislation, particularly as climate change was not yet high on the agenda.. Progression of common energy policies frequently came through financial routes, yet this somewhat changed with the incorporation of environmental protection into the Single European Act in 1987. The focus, though, still lay on financial objectives, like the completion of the Internal Energy Market. This inclination was highlighted when the Commission was unsuccessful in their effort to include a separate energy chapter into the "Treaty of Maastricht" in 1992 [28]. Numerous Member States, particularly those that had moderately high own reserves, vetoed this suggestion as they did not desire to give away autonomy in that area. Neither the "Treaty of Amsterdam" (1999) nor the "Treaty of Nice" (2003) brought notable developments for a common energy policy. For that reason, the critical energy regulation in the following years, such as the Renewables Directives (2001 and 2003) and the establishment of emissions trading in 2005 were based upon environmental regulation.

Following the adoption of the Kyoto protocol in 1997, climate change and consequently energy issues came strong on the international agenda resulting in a more favorable atmosphere for aspiring goals. More and more policy makers concluded that energy and climate challenges were of such proportions that solutions were not to be found on the nation state level, and it also made for a good common aim for the European Union, that aspired to take the lead in the fight against climate change.

4.2.2 An integrated European energy policy

It wasn't until March 2006 that EU heads of state and governments supported the first EU "energy action plan" The Commission's "An energy policy for Europe" strategy signifies the start of a more incorporated European energy policy, that gained respectable incentive since then [29]. The action plan pointed out the three biggest challenges for European energy policy, that create the core of the common energy policy till today: sustainability, security of supply, and competitiveness.

In order to fulfill those goals the Commission also pointed out quantifiable aims. Merely two months later the response came in form of the Council Conclusions. In its "action plan 2007-2009" the Council adopted numerous of the Commission's suggestions, among them the famous 20/20/20 targets. These targets refer to three 20% goals, to be achieved by 2020:

- A decrease in EU greenhouse gas emissions of at least 20% below 1990 levels.
- 20% of EU energy consumption from renewable resources and
- 20% decline in primary energy utilization by enhancing energy efficiency.

The plan entailed a spectrum of other functioning areas, most evidently the completion of the internal market for gas and electricity, issues regarding security of supply, internal energy policies and energy technologies. The article initially states the "functioning of the internal market" remaining loyal to its roots, yet then presents numerous innovations as:

- guarantee function of the energy market
- guarantee security of energy supply in the EU
- promote energy efficiency, saving of saving and advances of new and renewable forms of energy;
- promote energy networks interconnection

The most ingenious point, (b) refers to guaranteeing energy security in the EU, which until that times was a duty of each Member State. Energy mix, energy foreign policy as well as the circumstances for taking advantage of its energy resources, yet, remain in the hand of the nation state. Following the clear demands of the Council for an action plan the Commission set to operate and drafted a list of suggestions, among them the third "Internal Energy Market Package" (2007). Propositions had already formed directives in 2009 regarding emissions trading, Carbon Capture and Storage (CCS) as well as the promotion of renewable energies.

Following some intense legislative progressions since 2007, currently numerous strategy papers are delineating energy developments on EU level, the most significant ones being: "Energy 2020. A strategy for competitive, sustainable and secure energy" and "Energy Roadmap 2050", the latter published at the end of 2011. "Energy 2020" is an extended energy strategy published by the Commission in November of 2010. It is based on the "energy action plan" of 2007, though notes that this strategy is not very possible to reach the 2020 goals, let alone the challenges on the long run, specifically the emission cuts of up to 95% by 2050. Consequently it focuses at providing new tools to meet the 2020 goals. The Commission longs for creating the way for energy legislation by indicating the direction with its strategy papers.

4.2.2.1 "Energy 2020. A strategy for competitive, sustainable and safe energy"

"Energy 2020" [30] highlights the imperative need to act so as not only reorganize the energy market in the EU and achieve the climate targets, but also to remain competitive in the future. In order for the challenges to be carried out, the Commission evaluates investments needs of 1 trillion Euro, particularly for (re-)constructing infrastructure. The Commission recognizes five areas of priority, specifically for reaching the 20/20/20 goals:

1) *Achieving an energy-efficient Europe*. Energy efficiency possesses great potential for more energy safety and a green economy. Simultaneously it remains a considerable goal that the EU is still has a long way to go in order to accomplish it. The problem started with an unfortunate goal designation in the first action plan (“20% decline compared to projected levels”) and yet the advancement in the fields continues to remain limited. Along other actions, the Commission wants to accomplish a breakthrough by further focusing on buildings and transportation, the two areas that utilize most energy next to energy. While success has been achieved in the industry thanks to the EU-ETS, the building and transport sector continues to be difficult to convert to “green” and the previous Directives haven't accomplished the wanted results. Thus, in June 2011 the Commission suggested a new proposal for a directive to challenge energy inefficiency in the EU.

2) *Completing the internal energy market.* The Commission continues to work in order to complete the integral energy market, for the present situation leads to higher expenses for energy and less energy security in their analysis. A significant concentration is on the infrastructure projects of “European interest” that would be essential for the completion of the internal market, for instance for constructing grids that transport renewable energies within Europe from the places where it is sourced to the areas where the majority of energy is utilized or constructing modern smart grids that can integrate the decentralized generation of renewable energies and lead to energy savings.
3) *Empowering consumers and accomplishing the highest levels of safety and security*.
4) *Expanding Europe's leadership in energy technology and innovation*.
5) *Empowering the external dimension of the EU energy market*.

4.2.2.2 “Energy Roadmap 2050”

The “Energy Roadmap 2050” [31] is also a paper on EU stratery, though as the name implies, with a longer time-frame, as “the pattern of energy production and utilization in 2050 is already being established”. The Roadmap 2050 is a solution to the lasting investment cycles of energy infrastructure, and aspires at giving a direction for after 2020. Its Roadmap aims to provide planning assurance for investments, particularly as in the decade to come, a lot of infrastructure will have to be replaced. By 2050 the EU is engaged to deplete greenhouse gas emissions to 80-95% below 1990 levels. The Roadmap 2050 shall show the way to accomplish these decarbonisation goals and guaranteeing the fundamental targets of energy security and competitiveness. In Europe, numerous stakeholders elaborated decarbonization scenarios up to 2050. As a starting point, the Commission evaluated these scenarios, compared to a set of own scenarios and a current trend plus a business-as-usual scenario. The main observation of this analysis is that "a secure, competitive and decarbonized energy system in 2050 is plausible", even if the scenarios have different focus. Generally, the Commission forecasts rising domestic expenditures for energy. Moreover, in all scenarios renewable energies increase considerably, energy savings are essential and decentralized and centralized elements of the power system must be interlinked.

The decarbonization scenarios are described down below:

- High energy effectiveness. Political engagement to very high energy savings to reduce energy request to 41% by 2050 compared to the peaks in 2005 and 2006.
- Diversified supply technologies. No technology is favored; all energy sources may compete on a market basis with no particular supports efforts, considering public acceptance of both nuclear and carbon capture and storage (CCS).
- High renewable energy sources (RES). Powerful support efforts for RES proceeding to a very high share of RES in gross terminal energy consumption (75% in 2050) and a share of RES concerning electricity consumption going up to 97%.
- Delaying CCS. Similar to the diversified supply technologies scenario yet presuming that CCS is delayed, leading to higher shares for nuclear energy.
- Low nuclear. Similar to the diversified supply technologies scenario though hypothesizing that no new nuclear in being constructed, thus leading to a higher penetration of CCS.

Based on the scenarios mentioned above the commission recognized five important working areas:

1. *Transformation of the energy system*, particularly by managing the demand side (high energy effectiveness, specifically in building and transport; intelligent energy technology), advancing renewable energies and cultivating renewable heating and cooling in a decentralised system; and by creating conventional sources like coal and gas, "greener". A substantial hope lies with the marketability of CCS, while nuclear energy is too a fundamental pillar in the Roadmap energy system.

2. *Reconsidering energy markets*. This aims primarily the incorporation of the internal energy market. Local and long-distance networks shall be incorporated as long as the infrastructure for high renewable usage and intelligent technology should be promoted.

3. *Motivating investors.* The biggest part of the reorganizing of the EU energy system has to be completed by private investors, particularly energy companies. Only in particularly noteworthy cases do investments have a public good character and shall gain support. For the normal process the EU still has to provide incentives, such as ETS, for low-carbon investments. A move towards more remarkable and more tailored financing via public economic institutions like the European Investment Bank (EIB) or the European Bank for Reconstruction and Development (EBRD) as well as the mobilization of the commercial banking sector in Member States might also aid in making the transition function.

4.*Promote public acceptance.* The transition shall influence employment and jobs, demanding education and training as well as a more dynamic social dialogue. Mechanisms that aid workers challenged with job transitions to develop their employability are required and actions should be taken to guarantee pricing schemes remain transparent and comprehensible to final consumers. Furthermore, citizens must be informed and participate in the decision-making procedure, while technological choices have to take into consideration the local environment.

5. *Driving change at the global level*. In the transition to 2050, Europe must secure and diversify its supply of fossil fuels, while simultaneously establishing cooperation to build international partnerships on a wider basis. As Europe's request progresses away from fossil fuels, and energy producers develop more diversified economies, incorporated strategies with present suppliers must address benefits of cooperation in different areas such as renewable energies, energy effectiveness and other low-carbon technologies. The EU should utilize this opportunity to consolidate its cooperation with its global partners.

After arranging the working areas for its energy system the Commission recognizes ten conditions to accomplish the new system. The long term vision shall be supported by progressing strategies until 2030 and by putting into action the “Energy 2020” strategy first. The conditions as such are not new and entail present policies such as more energy effectiveness; more renewable energies and a totally incorporated energy market are essential.

The “Roadmap 2050” is merely a strategy and its scenarios offer various opinions as such. The legislation, that is, the directives that will outline the energy markets for the decades to follow, is still unknown. The benefit of the Roadmap is, though, that the Commission makes a clear declaration analyzing what it wishes to accomplish by 2050. It stresses that it can be achieved and that it will be considerably more affordable than the current strategy. A decarbonized energy system shall lead to high energy security, lower import reliance, lower energy prices and CO2 decline. Moreover, it shall provide cobenefits, such as better health conditions and quality of the air.

4.3 Energy Security Strategy

Following the legislation mentioned above, the EU also requires a hard-headed strategy for energy security that cultivates flexibility to shocks and disruptions to energy supplies in the short term and decreased reliance on specific fuels, energy suppliers and routes in the long-term. For many years to come, the Union's energy security is inseparable to its need to move to a competitive, low-carbon economy, consequently this strategy has to be an indispensable part of the overall policy for climate and energy.

The key to enhanced energy security lies first in a more collective appeal through an operating internal market and greater cooperation at regional and European levels, especially for coordinating network progress and opening up markets, and second, in a more comprehensible external action. Tackling energy security in a fast-changing environment shall demand flexibility, capacity to adjust and change. For that reason, this strategy may possibly require to evolve because of changing conditions.

In response to all these concerns, the European Commission released its Energy Security Strategy [31] in May 2014, which demonstrates areas in which decisions must be taken or actual actions applied in the short, medium and longer term to answer to energy security worries. Eight strategic pillars promote tighter cooperation for all Member States while being flexible on national energy choices, further enhancing solidarity.

4.3.1 Instant actions to tackle a significant disruption during the winter of 2014/2015

For the winter of 2014/2015, the Commission acted together with Member States (the most reliant on single gas suppliers), regulators, Transmission Systems Operators and operators to enhance the Union's instant preparedness with regard to possible disruptions, by increasing storage capacity, developing reverse flows, advancing security of supply plans at regional level and to taking advantage of the potential of Liquefied Natural Gas.

4.3.2 Strengthening emergency/solidarity mechanisms

The EU has an overriding priority: to guarantee that the best potential preparation and planning enhance resilience to unexpected disruptions in energy supplies, that strategic infrastructures are protected and that the majority of the of vulnerable Member States are altogether supported.

4.3.2.1 Oil stocks

Member States are required to build up and manage minimum reserves of crude oil and petroleum products and this should diminish the risks of supply disruptions. Current stocks portray approximately 120 days of consumption which is well above minimum demand of 90 days supply. Furthermore, the EU stockholding obligation is constant and connected to the oil stockholding obligation established under the International Energy Agency (IEA). The assurance that no physical lack of supply is possible to happen and is an essential element to temper market price fluctuations, should a crisis occur. The EU should accordingly promote further international cooperation and transparency regarding oil stocks and oil markets, noticeable involving important new consumers, such as China and India.

4.3.2.2 Preventing and mitigating gas supply disruption risks

After 2006/2009 gas supply crisis, the EU has enhanced its coordination capabilities so as to avert and reduce possible gas supply disruptions [32]. Investments in back-up infrastructure are now compulsory: by 3 December 2014 Member States have to be capable off satisfying peak request even in the case of a disruption of the single biggest infrastructure asset. Additionally, reverse flows have to operate on all cross border interconnections among Member States. There are European regulations to secure supplies to protected customers (for instance customers that utilize gas for heating) in severe circumstances, and Member States need to design Emergency Preparedness Plans and Emergency Response Plans. There regulations provide a European groundwork that creates trust and guarantees solidarity as it ensures that Member States operate on their national responsibilities and together improve security of supply.

4.3.2.3 Protection of critical infrastructure

The EU has begun to develop a policy in order to tackle the physical protection of critical infrastructure which entails energy infrastructures [33]. More attention should be addressed to IT security. Moreover, it is essential to establish a broader debate on the protection of strategic energy infrastructure like gas and electricity transmission systems that are providing a major service for all consumers.

4.3.2.4 Solidarity mechanisms among Member States

The consensus that is the trademark of the EU demand for practical assistance for those Member States that are most vulnerable to intense energy supply disruptions. Appropriate contingency planning, based on stress tests of the energy systems and discussions with national authorities and industry, should thus be arranged and frequently inspected, with the aim of ensuring minimum levels of intra-EU deliveries of alternative fuel supplies to complement emergency stocks.

4.3.3 Moderating Energy Demand

Moderating energy request is one of the most effective tools to decrease the EU's external energy reliance and exposure to price hikes. The present situation adds urgency to the formerly agreed EU energy effectiveness target of 20% that will have as a result, 371mtoe primary energy savings in 2020 in comparison with forecasts.

These savings can be accomplished considering the measures that have been foreseen in the relative legislation are applied precisely and without delays. Particularly, this regards the Energy Efficiency Directive [34] as well as the Energy Performance of Buildings Directive [35].

Accomplishing respectable energy savings is merely possible if there is a clear recognition of priority sectors as well as motivation of investment capital that can be easily accessed. Energy request in the building sector, accountable for approximately 40% of energy consumption in the EU and a third of natural gas utilized could be reduced by up to three quarters considering the pace of the renovation of building is sped up. Enhancements in district heating and cooling can too make a significant contribution. Similarly, industry consumes about 1/4 of gas utilized in the EU and there is considerable possibility for energy effectiveness gains driven by a bolstered Emissions Trading System.

In order to bring about further investment from the private sector, which has a major role to play, the European Structural and Innovation (ESI) Funds have ring-fenced a minimum of €27 billion particularly for low carbon economy investments, including energy effectiveness, which is forecast to rise to over €36 billion[36].

4.3.4 Building a well-operating and fully integral internal market

A European internal market for energy is a crucial factor concerning energy security and is the delivery mechanism to accomplish it in a cost-effective way. Government interferences that influence this market framework, such as national decisions on renewable energy or efficiency targets or acts to assist investment in or decommissioning of nuclear generation, or actions to assist major infrastructure projects, for gas for example(pipelines: TAP, SouthStream and NordStream and LNG Terminal in the Baltic Area) must be analyzed at European as well as in regional level to guarantee that decisions of one Member State do not sabotage security of supply in another Member State.

4.3.4.1 Making the electricity and gas internal market function better

The 3rd internal energy market package [37] establishes the framework within which the European internal market must develop. Positive steps have been accomplished in regional market integration. Competitive and liquid markets provide an efficient hedge against exploitations of market or political power by individual suppliers. Well-advanced trading mechanisms and liquid spot markets may offer efficient short term results in the event of disruptions, for it is already the case for oil and coal. The same security can be accomplished for gas as well as for electricity, considering that pipeline capacity and grids are available to transmit supplies from one place to another.

4.3.4.2 Accelerating construction of significant interconnectors

A genuinely integrated and competitive internal energy market requires considerable development of energy transport infrastructure and specifically cross-border interconnections among Member States. The Commission evaluates that approximately €200 billion are requested up to 2020 with regard to these developments.

The Regulation on the Guidelines for trans-European energy networks together with the Connecting Europe Facility (CEF) were created to guarantee the on-time implementation of the major projects Europe needs [38] along 12 priority corridors and areas. The first Union list of projects of common interest (PCI) was adopted in 2013. Six(6) projects in electricity and twenty seven (27) in gas sector have been labeled as crucial for EU's energy security in the short and medium terms [39]. Approximately half of these projects should be ready by 2017 while the rest are planned for 2020, with most located in South Western and Eastern Europe. The cost of these projects is evaluated at approximately €17 billion. Critical PCIs are mostly large scale projects, with the exception of a few LNG terminals and storage projects.

Taking into consideration the significance of interconnectors for enhancing security of supply and the necessity to facilitate cross border trade, the European Commission suggests to expand the current 10% interconnection goal to 15% by 2030 [40] and is willing to intensify its support to critical project to speed up their implementation.

4.3.4.3 The European oil market

The interdependence between the EU, US, and Russia regarding oil, the availability of oil stocks, as well as the ability of trading and transporting oil internationally, means that there is no instant threat for the EU concerning its oil supplies. As Russia is EU's biggest supplier of crude though, a significant number of EU’s refineries are designed for this specific oil, which increases reliance on Russian oil. Moreover, the refining sector in the EU gradually decreases its capacity and is vulnerable to investments from Russian companies [41] becoming less independent and competitive. Both these issues have to be analyzed, so as to form a relevant strategic policy for the EU oil market.

4.3.5 Boosting energy production in the European Union

The EU can decrease its reliance on specific suppliers and fuels by promoting utilization of its own indigenous energy resources. During the last decades, indigenous production has gradually decreased, with the renewables being the only exception. Using renewables, sustainable fossil fuels and nuclear energy could however mitigate this trend in the years to come.

Renewable energy

Increasing utilization of renewable energy saves approximately €30 billion a year, according to Eurostat [42]. There is a promising cost-effective potential for renewable heating and electricity to further decrease natural gas utilization in numerous sectors by the end of the decade. Worries however exist regarding its cost and the way it could affect the operation of the internal market.

Hydrocarbons and clean coal

Exploiting conventional oil and gas in Europe should comply ato energy and environmental legislation, as the new Offshore Safety Directive [43]. Exploiting oil and gas from unconventional sources in Europe, and particularly shale gas, could to some extent mitigate diminishing conventional gas production, considering issues of environments impact and public acceptance are sufficiently addressed and a thorough analysis of EU's unconventional reserves is implemented. In the case of coal, its high CO2 emissions mean that they can only survive in the long-term EU mix if Carbon Capture and Storage (CCS) technology is used. CCS can also be utilized for enhanced gas and oil recovery, that cannot be extracted via traditional methods.

4.3.6 Developing new energy technologies

The current strategy to decrease EU energy reliance demands significant alterations to the energy system, which on their turn require significant advances of new technologies. Both diversification of supply, optimized energy networks operation, mitigating energy demand, lowering costs, storage issues and much more partially rely on technological advances. A detailed analysis of the topic is addressed at Chapter 5.

4.3.7 Diversifying external supplies and related infrastructure

4.3.7.1 Gas

Gaining access to more diversified natural gas resource base is a priority for the EU, while preserving at the same time considerable import volumes from trustworthy partners. LNG has to be further used as an important diversification tool over the following years. New LNG capacity from Qatar, Northern America, Eastern Africa and Australia is expected to enlarge global LNG market liquidity [44], something that should be analyzed and affect EU's energy policy priorities. These developments should be facilitated by efficiently mirroring priorities in EU external policies. Moreover, the adequate operation of internal interconnections and gas network has to be secured by the EU, so that gas can flow to all regional markets.

Building up better relationships with current import partners is essential, however a versatile policy has to aim to new sources of supply too. The pipelines that form the Southern Corridor, which was analyzed in Chapter 3, and the corresponding projects of common interest are a prime example.

4.3.7.2 Uranium and nuclear fuel

Nuclear safety is an unquestionable priority for the EU. The EU should continue to be the global leader for nuclear safety. It is accordingly essential to speed up the adoption of the improved nuclear safety directive [45], strengthening nuclear regulators' independency and informing the public.

Russia's role as a major nuclear fuel producer and the fact that it provides investment nuclear packages has to be carefully considered, so as to avoid utilizing non-EU technology to construct EU nuclear plants. The latter could end up increasing EU's dependence in Russian supply. The diversification of supply has to be ensured by the Euratom Supply Agency [46] for any new nuclear project. Of course, this also applies to all plant operators.

4.3.8 Enhancing coordination of national energy policies and speaking with one voice in external energy policy

Several of the aforementioned measures require the exact same prerequisite, a productive and efficient coordination of Member States when addressing energy issues. In order to meet this need, the Energy Union initiative was adopted [47] which serves as the medium through which the Member States can communicate energy related issues before adopting them and therefore avoid potential threats on energy security of other Member States. A good example would be decisions on energy mix. The EU has to communicate coherent messages in global fora and organizations and use foreign policy instruments in a constant basis, such as summits with strategic partners and permanent involvement of energy topics in political dialogues.

5 Technology and EU Energy Security

Action concerning innovation and research already made a significant contribution to EU energy security. This is notably the goal of the SET-Plan Integrated Roadmap recently in preparation, that shall recognize the changes needed for the transformation of the energy system in the medium to long run, the essential research and innovation actions, as well as the major drivers for innovation. As far as supply is concerned, the progression of new and innovative energy technologies that are simultaneously, more effective, more reliable, more cost-effective, and cleaner, will be supported by the Roadmap. As regards network infrastructure, the goal will be to guarantee energy system incorporation by advancing the tools to manage variability regarding the energy supply, distribution and storage, in order to accommodate rising renewable production and to allow more decentralized power generation from various sources. Finally, another important fact is, that considerable enhancement concerning energy efficiency, particularly in the building sector, for industrial application and for cities, shall be supported by the Roadmap.

Indicative agreed strategic targets

European Commission services, representatives of the EU Member States, representatives from industry and research, Norway, Iceland, Switzerland and Turkey, (for instance the SET Plan Steering Group) have agreed upon a list of target concerning different technologies in order to enhance energy security. Indicative targets are presented for each technology, while the full reports on strategic targets are included in each section in the form of references. All relative data is extracted from SETIS [48].

5.1 Photovoltaic Solar Electricity

Taking into consideration the entire value chain, from raw material processing, cell and module manufacturing to power electronics, local storage choices and system integration, there seems to be an urgent demand for enhancing the cost structure and cost competitiveness of the European PV industry. Much potential exist for further development in photovoltaic devices, despite the notable developments in efficiency, reproducibility and reliability over the last year. Critical to those developments are fabrication procedures and material properties, while on the same time, developments in the system architecture and operation shall promote cell efficiency. Generally, innovations regarding PV is mostly refers to:

- Printed Solar Cells, as Europe's know-how on PV technology, nanotechnology and manufacturing can help towards reducing both capital costs for manufacturing plants and energy payback time
- PV modules, as constructing materials: Multi-lateral research with the cooperation of the PV manufacturing, the certification bodies as well as the building materials industry is needed.

Moreover, European PV research, should aid industry remain at the highest level of a broad range of technologies in order to achieve:

- Efficiency, stability, lifetime and energy yield. Energy yield (kWh/Wp) should also be considered and not only initial capital expenditures(€/Wp) over the financial or technical lifetime.
- Environmental sustainability: Manufacturing and the materials used needs to be environmentally friendly. Recyclability of materials is an indicative example.
- High productivity fabrication and constant monitoring, to lower down costs
- Applicability, by standardizing PV modules characteristic, which shall also help reduce installation costs.

Indicative agreed strategic targets

– Boost PV module efficiency by at least 20% and 35% by 2020 and 2030 correspondingly in comparison to 2015 levels.

– Decrease costs by at least 20% and 50% by 2020 and 2030 correspondingly in comparison to 2015 levels.

– Boost module lifetime to 30 and 35 years by 2020 and 2025, having a assured output of 80% of its initial level.

– Promote commercialization of near zero-energy buildings through integrated PV. Decrease their cost by 50% and 75% by 2020 and 2030 correspondingly in comparison to 2015 levels.

Full report – SET-Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics (PV).[49]

5.2 Concentrated Solar Power

CSP technology continues to be under development, demonstrating high potential for technical enhancements, the main of which are:

- Boost generation efficiency, based on increasing operating temperature, resulting in higher turbine efficiency. Active parabolic plants utilize a synthetic aromatic fluid as heat transfer fluid, which limits the cycle's efficiency, as it cannot go higher than 400 degrees Celsius. As a result, research is concentrated on finding alternative fluids as nanotechnology enhanced fluids, molten salt, alternative inorganic fluids, as well as direct steam generation.
- Decrease solar field expenses, through new approaches on support structures, mirrors and receivers. Structure's cost could decrease by reducing the materials and labor used to achieve optimal reaction to wind loads. Thinner, lighter glass mirrors could be used and heavy silver-backed glass mirror reflectors may be replaced by lighter, more affordable, efficient front-surface advanced reflectors.
- Decrease internal consumption of auxiliary resources, as water and electricity.

Agreed strategic targets

- Short term: >40% cost decline by 2020 (from 2013) reflecting on a supply price of <10 ct€/kWh concerning a radiation of 2050 kWh/m2/year
- Longer term: advance the next generation of CSP/STE technology. New cycles (including supercritical ones) with a first demonstrator by 2020, with the goal of accomplishing further cost declines and opening new business opportunities.

Full report – SET-Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Solar Thermal Electricity (CSP/STE) [50].

5.3 Wind Energy

In order to reduce costs, wind turbines are advancing towards taller towers, lighter nacelles, larger motors, and more reliable components. Their capacity factors imply the need to enhance their efficiency concerning energy capture. Advances are required in several fields, as in materials, in new components and model, as well as in processes.

Superconducting materials are required to be developed to use in electricity generators. New stiffer, lighter yet affordable and recyclable blade materials can help to better resist fatigue. Moreover, new blade coatings with self-cleaning potential and ice shedding characteristics could reduce sand and water droplet erosion and boost UV light resistance. New surface treatments like PVD coatings, laser treatment and nitriding treatments could be utilized to enhance gear teeth properties. High loads in towers and foundations could be sustained through new high strength steel materials, new, very liquid yet of quick hardening pre-stressed concrete and enhanced mortars durable in a wide spectrum of temperatures. Magnets operating better at higher temperatures, high-temperature superconducting (HTS) wire and related cryogenic materials are also technologies that could be utilized to improve wind power efficiency. New components to monitor wind turbines operation is required, as well as components to achieve a reliable connection to the grid, like cables, circuit breakers, transformers, switchgear, etc., for DC substations as well as for 66 kV AC inter-array cabling. As regards modeling, better knowledge of loads, electrical effects in the electrical and mechanical parts of the turbine, as well as load effects is of major importance. Last but not least, new procedures are needed for several issues, as recycling blade materials inexpensively and plan of manufacture, turbine assembly, transport, and establishment.

Agreed strategic targets

- Decrease the levelized cost of energy (LcoE) to (a) less than 10 ct€/kWh by 2020, and to (b) less than 7 ct€/kWh by 2030.

By 2025, evolve wind energy systems that can be utilized in water >50m at a maximum distance of 50 km from shore with a LcoE of less than 12 ct€/kWh and by 2030, to less than 9 ct€/kWh.

Full report – SET-Plan – Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Offshore Wind. [51]

5.4 Marine Energy (Wave and Tidal)

Europe is the world leader in the field of marine energy conversion technologies having state of the art facilities as the European Marine Energy Center (EMEC), the Biscay Marine Energy Platform (BiMEP) the Wave Hub and the Danish Wave Energy Center (DanWEC). Various marine energy technologies have been developed through research , however, many need to be done as this technology is in its early steps. Numerous concepts are yet to be tested, being the first priority of the sector. Tests have to simulate real conditions, while they should also upscale to array level.

Capacity factors of marine energy technologies are at the time merely about 2000 full operation hours a year. It is evaluated that this figure may be boosted to 3000 annual functioning hours in 2020, reaching 3500-4000 h/y in the long term, making marine energy competitive among other low carbon technologies. As off-shore operation and conservation is quite expensive, system viability also appears to be highly relevant.

Agreed strategic targets

- Decrease the LcoE for tidal stream energy to at least 15 ct€/kWh in 2025 and 10ct€/kWh in 2030.
- Tidal stream goals should be followed by wave energy technology at least 5 years late: in 2025 20 ct€/kWh, in 2030 15 ct€/kWh and in 2035 10 ct€/kWh.

Full report - SET Plan – Declaration of Intent on Strategic Targets in the context of an Initiative for Global Leadership in Ocean Energy[52].

5.5 Biomass and Waste Power Generation

Based upon thermo-chemical (gasification, combustion and pyrolysis), as well as biochemical/biological (digestion and fermentation) procedures, numerous conversion technologies exist, in different stages of development.

Biomass combustion. Further progress towards low emission stoves and boiler systems is needed when biomass is utilized in small and medium-scale. Future research should concentrate on the progression of advanced control systems and better design. Stirling Engine technology is at demonstration phase. Technical and financial benefits for small plant capacities and low operating costs can be utilized moving to an Organic Rankine Cycle (ORC) engine, even though it presents low electric efficiency and high costs for particular investments.

Biomass co-firing. Technical issues arise in fouling, feeding and ash disposal which diminish reliable and long-term operation of coal plants. Biomass co-firing with coal presents the lowest costs and highest efficiencies among other bioenergy production. Advances needed include enhanced boiler design, process control and fuel handling.

Biomass gasification. Gasification is a process to convert biomass to fuel gas (syngas), which faces several challenges, both technical and economic. Many gasification concepts are available, depending on the operating pressure and the gasification medium. Syngas can either be used for synthesis of biofuels, chemicals and biomethane and for production of heat and/or electricity. Integrated Gasification Fuel Cell (IGFC) systems with the use of biomass gasification-hydrogen route has high potential for energy production use. Most significant issues are the cost of supply of biomass and the reliability of the gasifier. Improving efficiency and processes for integration, as well as reducing costs and complexity are the next steps to be addressed.

Waste. Numerous technologies are available for waste conversion, such as biological or thermal treatment. Steps required for energy recovery from waste are pretreatment, energy conversion and waste conversion. Efficient energy generation is possible through waste gasification with gas cleaning in syngas reforming or combined cycle applications. Boost of electrical efficiencies and increased heat use can boost energy recovery. The heterogeneous nature of waste, the high risk for corrosion in boilers and low heating values consists the main issues of this technology.

Anaerobic digestion. Anaerobic digestion suits a wide range of biomass feedstocks, but plants are limited due to feedstock availability. Biogas can be used to supply the grid or for final use in gas motors, if upgraded in natural gas quality. The main issues are gas purity requirements and quality standardization and infrastructure. Next steps required to enhance efficiency and costs are to increase feedstock basis, improve biodegradability, conversion, design and process integration.

Pyrolysis. Fast pyrolysis is biomass conversion into a liquid bio-oil, gaseous and soil components. In order to enhance bio oil quality and use it as a fuel, pretreatment is required to get it to higher values. Research is required in numerous aspects, as on the conversion procedure, on the process reliability and control of bio-oil composition, as well as on the quality and the utilization of bio-oil and its thermal stability.

Hydrogen from biomass. Numerous routes exist for the conversion of biomass to hydrogen, including chemical, biological, and thermo-chemical, at different level of progression and not still financially reasonable. Procedures for hydrogen production include: photolytic biological hydrogen; biomass conversion to hydrogen; gasification; pyrolysis. Photo-biological procedures are at a very early stage of advancement and have low efficiency in conversion. New genes of hydrogen producing bacteria and enzymes tolerant in oxygen have to be found, while improving conversion process and efficiency.

The creation of the relevant hydrogen infrastructure and safety issues that comes along this technology pose significant obstacles that need to be addressed.

Torrefaction. Torrefaction creates solid feedstock (bio-char) of higher quality, a more homogeneous composition and high energy density. Demonstration projects are being deployed, yet no commercial torrefaction plant exists today. Fuel characteristics, as resistance on biodegradation and degree of torrefaation, have to be standardized. Existing commercial and technical issues require a further development of this technology to be tackled.

Biorefineries. Biorefineries is a concept for the co-production of both products (feed, materials, chemicals, food) and energy (heat, biofuels, electricity and biogas). This technology is barely a concept, with its evolution depending on the technical maturity of different procedures in order to produce bio-based material, energy and bio-chemicals.

Indicative Agreed strategic targets

- Efficiency of at least 75% for conversion of biomass to intermediate bioenergy carriers by 2030.
- Efficiency of 70% for electrolysis based renewable hydrogen production by 2030
- Achieve a total production of 25Twh of advanced biofuels by 2020.
- Reduce cost of liquid /gaseous advanced biofuels by biochemical or thermochemical processing: <50 €/Mwh and <35 €/Mwh in 2020 and 2030 correspondingly
- Reduce the cost of renewable hydrogen: <7 €/kg and <4 €/kg by 2020 and 2030 correspondingly
- Reduce conversion expenses for efficient large scale cogeneration of heat and power by biomass by 20% and 60% by 2020 and 2030 correspondingly compared to current state

Full report - SET-Plan – Declaration of Intent on "Strategic Targets for bioenergy and renewable fuels needed for sustainable transport solutions in the context of an Initiative for Global Leadership in Bioenergy [53].

5.6 Carbon Capture and Storage

CCS technology is considered to be the most prominent technologies towards moving away from solid fuels, especially for power generation and the need to lower emissions.

Despite Europe is among the leaders in CSS technology advancement, it lags as regards demonstration projects, with only 2 large scale CCS project located in Europe out of 16 existing in total globally. Commercial deployment of CCS until 2030 requires assurance of the financial and technical feasibility of current existing technologies in integrated value chains. Some examples would be, CO2 transportation through pipelines and/or ships, its guaranteed long-term storage underground in relevant geological formations and of course CO2 capture from large-scale industrial facilities.

A fruitful demonstration program will encourage the construction of innovative plants during 2020's, that in its turn will pave the way for a large-scale deployment of CCS in the 2030's. The EU has, through the European Energy Programme for Recovery (EEPR), already financed €1 billion for six(6) demonstration projects. Besides the ongoing demonstration program, focused research will be needed in order for CCS to become as competitive as required to achieve the penetration described in Energy Roadmap 2050.

The advancement of innovative capture concepts shall lead the way for the next, second and third, generations of CO2 capture technologies with enhanced performance, that shall lead to further declines of electricity expenses. Advancement of more effective solvent systems, as well as procedures for post-combustion capture, for instance improved carbonate systems and phase change and new CO2/H2 separation systems for integrated pre-combustion capture, moving towards next generation systems with high efficiency circulating fluidized bed reactors and chemical looping are some of the directions to which research needs to move to. Second and third generation technologies, that shall further diminish the investment and functioning costs, as well as the associated energy penalty, will be developed by pilots that will have the lead. They will concentrate on the testing of new/optimized solvents, membrane, sobrents, new power plant integration methods for all three capture ways, pre-combustion, post-combustion and oxy-fuel.

Other research needs include, utilize biomass as feedstock and analyze the feasibility of bio-CCS. Moreover, safety and therefore public acceptance has to be improved with the development of concepts concerning CO2 transportation. These entail the design of materials appropriate for pipelines handling CO2 at different compositions, averting longitudinal cracking and pipeline fractures. In order to boost the safety of operations and contribute to the optimization of infrastructure, better assessment of storage potential and site characterization in required. Activities shall entail large scale storage demonstrators as well as pilots and development of models regarding the behavior of injected CO2 at various timeframes. The advancement of more refined and cost-effective overseeing and modeling techniques will contribute to the evaluation of CO2 migration, fluid-rock interactions, cap rock integrity so that storage security can be validated. This will result in improved leakage detection and measurement, both in-site and by remote distant sensing. Lastly progression of financially reasonable technologies that can utilize captured CO2 as feedstock (CCUS) for chemicals and synthetic fuels production will further enhance the economic side of CCS.

Indicative Agreed strategic targets

- One or more large-scale CCS project in the power sector by 2020
- One or more large-scale CCS projects supplied by an industrial CO2 source with a full FEED study by 2002
- Feasibility studies on CCS deployment by SET Plan Countries by 2025-2030
- One or more functioning Project of Common European Interest regarding the transportation of CO2 by 2020
- Detailed geological storage capacity studies by 2020
- Three or more pilot projects on new CSS technologies, one of which has to be on Bio-CSS.
- Construction of one Important Project of Common European Interest (IPCEI) to analyze industrial CCU from various angles.

Full report - SET-Plan Declaration of Intent on strategic targets in the context of Action 9 'Renewing efforts to demonstrate carbon capture and storage (CCS) in the EU and developing sustainable solutions for carbon capture and use (CCU)' [54].

5.7 Nuclear Fission Energy

Depending on their evolutionary enhancements or developments, nuclear reactors designs are frequently categorized in Generation II, III and IV. The majority of the reactors functioning internationally are of Generation II type. In the EU-27, two Generation III reactors are under construction, while Generation IV plants are to be commercially set up around 2040. Following Fukushima, it became clear that more focus is required on extreme and scarce external safety hazards, therefore means to recognize these hazards have become a priority for research along with models that simulate such incidents.

The majority of Generation II Light Water Reactors (LWR) stated their operation during the 1980's and if they're not guaranteed life time extensions they shall be decommissioned during the 2020's. It is anticipated that the majority of nuclear power plants will expand their life time in operation to 50-60 years, so the reliable operation of those reactors during 2010-2030 shall require significant R&D action towards:

- Increased awareness of ageing materials and mechanisms
- Advancement of best practice guidelines concerning ageing mitigation and prevention
- Further evolution and verification of modern computer codes for loading estimation

Generation III LWR reactors are the most advanced nuclear reactors available. Based upon feedback from operating experience and enhancements through R&D, the designs shall be further refined. Generation III reactors are currently being deployed. Three fast reactor concepts (Generation IV) are being developed within the European Sustainable Nuclear Industrial Initiative (ESNII). The French project called ASTRID is a sodium-cooled fast reactor (SFR) and a prototype is planned after 2020 and commercial set up after 2040. By 2020, a pilot of the MYRPHA project of Belgium on a lead-bismuth cooled accelerator driven system (lead-cooled fast reactor concept – LFR) is planned and it is anticipated to be commercially set up approximately by 2050. Under investigation is also a gas-cooled fast reactor (GFR), but it needs more R&D on fuel and materials, and as a result its commercial deployment would be farther in the future. In order for SFR and LFR to be commercially available by 2040 and 2050 correspondingly, various advances have to be achieved, such as:

- Innovative fuels and structural materials, so as to support high fast neutron fluxes, high temperatures, and grant a plant lifetime of 60 years.
- Enhanced safety, and endurance against sever damage, for instance core designs with moderate void effect and other favorable reactivity feedback effects.
- Concerning future construction of Gen IV reactors, advancement of European codes and standards to be utilized.
- In order to accomplish more precise and detailed modeling benefiting from the rise of computational power, more developed physical models and computational appeals.
- Enhanced sustainability through a better utilization of fissile materials, diminishing of long live radioactive waste, and decrease of proliferation risks.

Lastly, it must me noted that another possible area in which nuclear power may play a role in both the heat and electricity markets, is nuclear cogeneration utilizing (Very) High Temperature Reactors.

Indicative Agreed strategic targets

- Clear timeframe of implementing the new Nuclear Safety Objective my 2017 from all Member States
- Research on aging of structures and materials, as well as on design resistant to accidents, as enhanced fuels and containment new designs by 2025
- Radioactive waste decommissioning and handling
- Operation of the world's first deep geological repositories for used nuclear fuel and/or heat-generating high-level radioactive waste in Europe by 2025
- Build on EU's culture and knowledge on nuclear waste handling and the developments of the decommissioning sector by 2030.
- Promote competitiveness and efficiency in nuclear sector
- At least one Gen IV pilot in Europe by 2030

Full report - SET-Plan Declaration of Intent on Strategic Targets in the context of Action 10: 'Maintaining a high level of safety of nuclear reactors and associated fuel cycles during operation and decommissioning, while improving their efficiency' [55].

5.8 Advanced Fossil Fuel Technologies

Gas and coal power stations will remain a major part of EU's portfolio even if high RES scenario is considered, when they can act as backup in times with no supply and tackle sudden changes in demand. Various technologies are currently being operational, while new are on their way on research. Both categories are being analyzed below.

Steam turbines for coal plants

Nowadays, most of the European coal power stations utilize subcritical steam turbines that have thermal efficiencies lower than 40% (LHV). The next evolutionary step in the progression of steam turbines regarding coal power stations is to increase the steam temperature to 700 degrees Celsius, thus accomplishing a thermal efficiency of up to 50%. The switch from iron-based to nickel-based alloys is essential to the 700 ºC technology, for only the latter are capable of tolerating the higher temperatures. Some pilot projects to try components under real life circumstances have begun within projects financed by the EU and Member States like for instance the COORETEC program. The complete commercialization is not anticipated before 2020-2030.

Integrated Gasification Combined Cycle (IGCC)

Initially, IGCC was developed for the treatment of refinery residues and not with a focus on power generation. Globally, merely 17 of the currently functioning 137 IGCC plants are utilized for power generation and barely 6 of these utilize coal as their basic feedstock, with relatively higher costs than coal stream turbine plants. The main objective of research is to display the commercial significance of this technology for power generation from coal. Next steps basically include the improvement of the gas turbines used, which at the time are not as advanced as the ones used in combined cycle natural gas plants. The European Turbine Network currently works at this direction, aiming to integrate the latest H-class gas turbines into a IGCC to achieve efficiencies up to 50%.

Gas turbines and combined cycle gas turbine plants (CCGT)

In combination with combined heat and power systems, and principally for peak power generation, gas turbines have been utilized for more than 50 years. CCGT efficiency back in 1990's were about 55%, as the gas turbines deployed at that time were commonly about 35%. Currently, the most advanced gas turbines have a power rating of 375 MW and thermal efficiencies of 46%, enabling CCGT efficiencies reach figures above 60%. The majority of investment projects nowadays though, utilize enhanced F-class gas turbines leading to slightly lessened CCGT efficiencies (58%). Research goal on CCGT is to achieve a combined thermal efficiency of 63% by the end of 2020.

5.9 Electricity Networks Technology

Electricity network is generally divided into the transmission network, which is characterized by high voltage and long distances, and the distribution network of lower voltages and distances. Moving towards Smart Grids will require significant research in several areas, while most important goals are to achieve reliable supply through the transmission network and efficient integration of distributed generation from renewable energy to the grid. As regards technology research, the following are some of the priorities that need to be addressed.

- Long-distance connection technologies, with High Voltage Direct Current (HVDC) being one of them, HVDC, bears advantages over high voltage alternating current in underwater and long distance transmission.

- Enhanced network control technologies, as Flexible AC Transmission Systems (FACTS) that provide better efficiency in many levels. FACTS are enhanced power electronics devices that are currently being deployed in the transmission grid.
- Technologies to promote new grid and consumer-drive services, entailing:

Smart metering, which both help distribution and producers-consumers, who can gain a clearer picture of their generation and consumption. Utilization of smart meters in combination with Demand Side Management (DSM) can help having more rationalized consumption

ICT/telecom networks which are necessary for the advancement of smart grids, can possibly empower the capacity for fault aversion, generation control, demand side participation and asset management.

- New approaches in operation, maintenance, as well as forthcoming planning.

Innovative architectures for smart grids like active distribution networks, virtual power plants and microgrids is one part. Active distribution networks, entailing microgrids, include ICT, DG technologies, proper protection infrastructure, distributed energy storage, demand side management and power electronics. Black start capability and/or intentional islanding are features demonstrated by microgrids. Virtual Power Plants (VPP), on the other hand, can be separated in the technical virtual power plant (TVPP), and the commercial virtual power plant (CVPP). The first one utilizes resources either located in the same geographical region or physically linked by the local distribution network, while the latter incorporates resources that may be more dispersed by being connected for example to different distribution networks.

Technology and procedures towards the integration of various technologies, as renewables and generally distributed generation, demand response, electric transportation, distributed generation (DG) are needed. Other tools, for forecasting, management of assets and emergency response development are also required. Lastly, multi-lateral energy grids that interconnect gas, heat and electricity are also important.

5.10 Smart Cities and Communities

Smart Cities is not referred to an individual technology, but more to the promotion of a combination of more efficient current technologies, like ICT, transportation and energy.

Typical examples are nZEB (near zero energy buildings), improved heating and cooling systems, enhanced electrical appliances, as well as the transformation of the electricity distribution grids to smart grids and the establishment of electrical-based transport. A vast number of sensors, as well as technologies for communication and monitoring shall be used, which will increase the demand for data centers, data analysis systems, servers, cloud computing facilities etc. Enhancing energy efficiency of ICT technology has to be addressed at the short term, as it is anticipated to play a pivotal role in smart cities deployment and development.

Smart Cities, being rather complicated systems, are expected to provide numerous technological challenges during their development. One of the most critical issues is adopting standards in order to guarantee connectivity and operability among systems and to encourage competition. Fruitful pilot projects that scale up through time to city scale pilots are also crucial for the development of this multidimensional technology.

Agreed strategic target

- The goal by 2025 is to have at least 100 fruitful examples of net zero-energy/emission districts (ZEED) with positive blocks (PEB), synergistically-linked to the European energy system, and to be able to export relevant technology that was developed in a large-scale.

Full report - SET Plan – Declaration of Intent on Strategic Targets in the context of an Initiative for Smart Cities and Communities [56].

5.11 Buildings and Energy

Buildings shall be acknowledged as a cornerstone of the future energy system in our society. A broad variety of technological solutions that can be utilized to substantially lessen their energy consumption currently exist. Numerous factors affect buildings' energy consumption, such as their orientation and geometry, their establishments efficiency, as well as occupancy behavior, usage patterns and general energy management. While it is broadly accepted that current technologies can achieve considerable reduction of energy use, there are obstacles, as the vast variety of technology and numerous actors involved, that decelerate the deployment of such solutions. Overall, the energy consumption reduction in buildings consists of three actions.

First step is to implement energy saving measures, as the building shell has a pivotal role on minimizing the energy needs of a building. Key technique examples on this direction are designing in a way to achieve optimal orientation and low ratio of compactness, use passive cooling and heating, utilize daylight to lower needs for lighting, use the required insulation and avoid thermal bridges. Upcoming technologies, as new materials for insulation or ventilated windows, promise even better results.

Second step is to boost energy efficiency of the establishments of the building and cover remaining needs with the use of renewable energy. Measures like heat pumps, heat recovery systems and biomass boilers can help decrease the energy consumption of HVAC. Furthermore, the use of renewable energy, such as solar, biomass and geothermal could also play a significant role in buildings. Active solar thermal systems and solar energy electrical systems are a good example.

Last step is to optimize occupancy behavior and usage patterns. Several applications for buildings utilizing smart management ICT technologies provide potential to decrease energy consumption and better control the balance of supply and demand and enhance the communication of end-used and utilities.

Indicative agreed strategic targets

- Develop holistic, standardized packages for building renovation to achieve reductions of primary energy use of buildings by 60%. Those packages need to be replicable, reduce ownership costs and lower payback time to 10years by 2025.
- Construction and conservation expenses of near zero-energy or positive energy buildings have to be reduced by 10-15% compared to 2015 by 2025, through developing new market-ready practices
- Average construction duration of new buildings has to be reduced by 20% compared to 2015 levels by 2025, through developing new market-ready practices
- Developing new market-ready practices to lead in more precise energy performance anticipations both for refurbished and new buildings by 2025.

Full report – SET-Plan – Declaration of Intent on Strategic Targets in the context of Action 5 “Develop new materials and technologies for energy efficiency solutions for buildings” [57].

5.12 Electricity Storage Technologies

This technology can be generally divided in large scale storage, used in transmission level, and decentralized storage, used in distribution level. The first one can be considered partially mature with pumped hydro dominating, while the latter is less developed.

Decentralized storage technologies development could be triggered by upcoming developments in consumption and distribution, as well as in the transportation sector moving towards electrification. Research targets regarding the major electricity storage technologies are analyzed below.

Batteries

Batteries are frequently deployed in electricity grids for frequency control and immediate actions needed. Batteries are an electrochemical based storage technology, the most distinguished of them being:

- Li-ion batteries which are the most advanced rechargeable batteries. Consumer electronic devices broadly utilize this technology. On a larger scale, Endessa [58] has installed a Li-ion scheme of up to 1 MW in order to control the frequency in the Canary Islands. [59]
- Lead-acid batteries, that are mostly found as car starter batteries, is a mature technology, that also finds its way in power grid applications. The principal aim of research is to enhance their lifetime and more specifically their discharge cycles.
- NaS batteries utilized in stationary grids. The goal of research is to develop solutions that can provide frequency control to schemes of high PV and wind power generation.
- Flow batteries (Vanadium Redox, Zn-Br) divide the electrolyte from the cell stack and as a result separate the power system from the energy capacity, meaning that they could be used for time shifting services. Research should aim in the addition of more electrolytes, boosting storage capacity and thus enabling up to 10 hours of discharge rates.

Hydrogen

Fundamental goals of research include feasibility demonstration and cost optimization of potential concepts. The research aims on the complete value chain of hydrogen.

Compressed Air Energy Storage (CAES)

This technology is used to power gas turbines and is based on the use of electric energy to compress air, store it in an underground formation and expand it while mixed with gas in the turbine’s combustion chamber. The aim of research is to demonstrate large scale projects of CAES, as the ADELE project in Germany which goal is the development of a generation plant of 60MW with a storage of 3 hours [60].

Flywheels

Flywheels are used in electricity grids, storing mechanical energy through rotating masses. Their capacities are normally 15 minutes and they present almost instant response making them appropriate for frequency control in remote or small power systems with not intermittent renewables' supply. Endesa [59] have used a flywheel of 18MWs in the Canary Islands in combination to the aforementioned Li-ion storage scheme. [59]

Other technologies

Super capacitors, storing energy in electric fields, and superconducting magnetic storage, storing energy in magnetic fields, are further storage technologies. Very fast response times are plausible with both technologies, as they both store electricity directly, which is their main advantage compared to other technologies. Both are currently in early demonstration phase.

Agreed strategic target

- Research focus is on high resource and energy efficiency, re-configurability, modularity and recyclability of systems, cells and materials.

Full report - SET-Plan ACTION n°7 –Declaration of Intent "Become competitive in the global battery sector to drive e-mobility forward" [61].

6 Conclusions

6.1 Brief overview

This dissertation outlines the multilateral nature of security of energy supply in the case of the EU.

Initially, the concept of the term is being investigated, leading to the interpretation most widely accepted, stating that "Security of energy supply is the uninterapted availability of energy resources at an affordable price". What is important to stress is that all three facts need to to be met in order to have a secured energy supply, both availability, continuity and affordability.

In order to assess the security of energy supply in the EU, its current state needed to be analyzed, both in terms of consumption, production and imports. Fossil fuels account for 3/4 of its energy mix, while the rest 1/4 account to nuclear energy and renewables. Solid fuels had been gradually declining through the years, while gas was inclining. The most significant alteration of the energy mix was renewables, which almost tripled their share during the last decade. As regards import dependency, the data depicts that the EU imports more than half of its energy needs, being the world largest energy importer and spending more than €1billion/day on energy imports. Even if the figures of import dependency of different energy sources are substantial, a closer look on their market and EU's import partners is required to get to a safe conclusion. In this respect, total petroleum products and solid fuels, which import dependence is 90% and 55% correspondingly, are relatively well diversified energy sources, as their markets are global and considered to be relatively liquid. However, the EU portfolio of import partners is not well diversified, basically relying on Russia for more than 1/3 of its total energy needs. Almost the same applies for uranium used in nuclear reactors, which despite being almost totally imported, its market is relatively well operating. Gas, however, as an energy source mainly transported through fixed pipelines, is sensitive to supply disruptions, as it is essentially traded in regional markets rather than global ones.

This exact feature, along with the fact that it is heavily promoted in the EU energy mix, makes gas an ideal energy source to be analyzed in terms of geopolitics. To begin with, it had been stressed that energy has been nationalizing during the recent years, as most energy reserves have been passed to national energy companies. Therefore, energy markets are vulnerable to ideological or political ambition of each respective politician in charge. This implies major issues in the energy markets, since political leverage influences market driven operation. As regards gas in the EU, several actors have their role to play in this scheme. While the EU is trying to diversify import partners and routes, Russia pushes stronger and tries to be involved in every forthcoming area of gas reserves favored by the EU, as the Caspian Area, Iraq, Cyprus etc. There are examples of Russia even exercising significant control over the energy sector of ex-Soviet EU Member States, depicting the dynamic of Russia towards maintaining its shares and further expanding its influence. The US are trying to closely monitor this Russian influence from a distant, with the aim of getting into the EU market with their shale oil production, in order to deteriorate Russian power and gain more influence on European soil. On the direction of diversifying suppliers and routes, some interesting cases emerged, such as the case of Cyprus, with the massive Aphrodite field that was discovered in 2011, the corresponding Israeli reserves in the same region and the case of Iran, which sanctions are lifting gradually. Especially Cyprus is a major evolution on the EU security scheme, as these reserves account to EU capacity, which supports the initiative on boosting indigenous production. Several issues need to be addressed though, mainly with Turkey, which does not recognize the Republic of Cyprus while also tries to find ways to exploit those reserves on its interest. Israeli gas is also facing challenges regarding the pathway that will lead to the European market, with a pipeline passing through Turkey with the aid of Cyprus being the most economically prominent option. Qatar is another partner with which the EU is further trying to diversify, both supplier-wise and energy product-wise, as Qatar is the world leader in LNG, which eradicates the dependency of gas in fixed infrastructure and transit countries, even though it requires major investments in the form of LNG terminals. Lastly, Turkey is probably the most interesting actor involved in EU energy security scheme on gas, as it has gained a major role by becoming the basic transit country of TAP-TANAP and Turkish Stream pipelines, while there is a good possibility to further accommodate gas infrastructure that will connect the Levant Basic to the EU market. All these facts are expected to further empower the dynamic external policy and relations of Turkey, which is something that needs to be closely monitored by the EU. The fact that a country not supplying energy to the EU has gained such a key role on the EU energy supply, solely due to its geographic location, is one the best examples on how geopolitics relate to security of energy supply.

Having analyzed the EU dependency on imports and the geopolitical aspect of energy, the relevant actions need to be taken are being presented. Tackling energy security in the EU level requires collective actions and therefore solid policy. In this respect, approaches such as 2006's "An energy policy for Europe", "Energy 2020", "Roadmap 2050" and finally the "Energy Security Strategy" were formed and agreed on by the EU Commission and Member States, further tackling environmental challenges as well. Historically, the European energy policy passed through several stages until becoming integrated, as most Member States were approaching and acting towards their own interest, rather than the Union's collective benefit. As the energy and environmental challenges matured, it was made obvious than they can be addressed solely in a collective level, which led to the adoption of the aforementioned policy. Energy Security Strategy, which is the most significant policy of the EU regarding energy security of supply, is based on strengthening solidarity mechanisms, moderating demand, promote indigenous production, developing new technologies, diversifying import partners and routes, build an integrated electricity and gas market end promote common EU external energy policy. As regards policy making, the EU Commission is the party introducing legislation and the EU Council and EU Parliament are the ones deciding upon it. Member States promote their interests through their ministers in the EU Council, while other parties influencing energy policy making are national energy companies, as well as civil society actors.

Lastly, technology is a major part of our modern society and its role on tackling energy security issues is paramount. Advancements on energy technology is expected to decrease the EU consumption and boost indigenous production in a cost-efficient way, thus boosting energy security. The SET – Plan, which is the relevant roadmap on technology, aims to accelerate the development and deployment of energy technologies, bring down their costs and find ways of financing technology projects. Several technologies are being analyzed, such as photovoltaic solar electricity, wind and marine energy in the case of renewables, smart cities and new electricity network technologies, as well as carbon capture and storage and nuclear technologies, in terms on the next steps need to be taken on research to enhance their efficiency and make them commercially viable by reducing their costs. In order to direct research to specific actions, certain targets have been agreed on for each strategic energy technology on EU Commission and Member States level. Indicative targets have been presented to illustrate the potential that advances in energy technology may unlock, the adoption of which will lead to a more energy secure EU.

6.2 Analytical outline in bullet points

Chapter 1 - Introduction

- Energy is a cornerstone of every country's economy and lifestyle
- Security of energy supply is the uninterapted availability of energy resources at an affordable price

Chapter 2 – EU Energy State

- Consumption has been declining thoughout the last decade.
- Final energy use is 1/3 transport , 1/4 industry and 1/4 to residential use.
- Indigenous production has been steadily decreasing over the last decades
- Nuclear and solid fuels account for half of the production
- Renewables have tripled their share during the last decade
- EU's import dependency is 53%, thus imports more than half of its energy needs
- 90% of petroleum products, 70% of natural gas, 55% of solid fuels used are imported. Diesel and jet fuel is also imported.
- Markets for solid fuels, apart from gas, are relatively international, liquid and diversified.
- Almost all uranuim to operate nuclear reactors is imported.
- Renewables dependency is difficult to be calculated (biofuels and waste)
- Electricity production is more sensitive to gas than solid fuel disruptions.

Chapter 3 - Geopolitics

- Solid fuels are depletable and concentrated in few areas
- Their supply is sensitive to political influence since energy sources are being nationalized
- Gas's features, as being traded in region markets and being infrustructure dependend, make it a fitting case to be studied in term of geopolitics
- Several countries have a role to play in EU's gas scheme, most of them related to Caspian Sea, the Persian Gulf and the Levan Basin areas
- The EU's aim is to decrease its import dependency on Russia, through utilizing reserves on the Caspian Sea, the Persian Gulf and the Levan Basin area between Cyprus and Israel. The EU tries to exploit all these reserves both by constructing pipelines and LNG terminals.

- Russia’s goal is to complete with the above routes through a direct pipeline to Europe, bypassing Ukraine and thus decreasing its risk, and to be involved in the Levant Basin area of Cypriot and Israeli gas.
- The US are acting towards joining the EU energy market, in order firstly to monitor the Russian influence in the EU and secondly to export its shale gas in the foreseable future.
- Cyprus, which has suddenly become a major gas reserve holder through Aphrodite field discovery, is trying to tackle issues regarding the routes that shall be used to reach the European market and addressing the relevant political issues with Turkey in this aspect.
- Israel is a very similar case to Cyprus, trying to decide the optimal route of its newly found gas to the EU market. A cooperation with Cyprus is very possible in that respect.
- Iran, with sanction gradually lifting and huge reserves of gas, has the potential to become a future import partner.
- Qatar as a global leader in LNG is trying to furrher enhance its cooperation with the EU, while the EU is moving towards developing new LNG infrustructure.
- Turkey is a very interesting case regarding EU energy future, as it suddendly becomes a key transit country of EU’s gas supply both from the Caspian Area, through TAP-TANAP, from Russia, through the Turkish Stream, and finally possibly from the Levant Basin area, if the case of connecting to the EU market thourgh Turkey is favored.
- Even though the EU tries to diversify and be less dependent by importing energy for several new partners, it got in a situation of being dependent on a single actor, Turkey, as all supply routes pass though it. This fact also points out the complexity of the geopolitical aspects of energy.

Chapter 4 - EU Energy Policy

- The EU Commisions is the executive body of the EU government which introduces legislation but has no decisive word on it.
- Each policy area is headed by a Commissioner, which has significant influence in decision making.
- The decisive actors are the EU Council and the EU Parliament, with the first comprised by respective ministers of the Member States, and the later by member

states political parties.

- Member States affect decision making through their ministers in the EU Council
- Energy companies and civil society actors also influence policy making by participating in associated committees and agencies and through direct contact with members of the EU Commission and so on.
- EU policy walked several steps until achieving a common perspective.
- “An energy policy for Europe” of 2006 was the first integrated approach, followed by “Energy 2020”, “Roadmap 2050” and finally the “Energy Security Strategy”.
- Energy and the enviroment are closely related in EU policy.
- Energy 2020 set goals to decrease consumption and GHG emission and enhance energy efficiency by 20% by 2020 and describes in detail the steps to do it.
- Roadmap 2050 is a strategic plan to reduce GHG emission by 80-95% by 2050, compared to 1990 levels, based on various scenarios. It sets several goals but without explicitly describing the steps to achieve them.
- Energy Security Strategy describes seven strategic pillars in order to achieve higher energy security
    - Empower emergency/solidarity mechanisms such as oil stocks
    - Moderate energy demand by enhancing efficiency and better use of ETS
    - Promote indigenous production through renewables and clean coal
    - Develop new energy technologies
    - Diversify import partners and routes
    - Promote solidarity among the states and adopt common external energy policy
    - Build an intrergated well operating internal market for gas and electricity

Chapter 5 - Technology and EU Energy Security

- Technology is a vital part of the EU energy security strategy
- The SET-Plan Integrated Roadmap describes all the essential research and innovation required on numerous energy technologies in order to enhance the EU energy security of supply
- In the way of implementing the SET Plan, the members of the SET Plan Steering Group (European Commission services, representatives of the EU Member States, representatives from industry and research, Norway, Iceland, Switzerland and Turkey) have agreed on a list of quantitative and qualitative targets regarding different energy technologies.

- Photovoltaic Solar Electricity innovation is mostly around new fabrication processes and PV modules as constructing materials. Their standardization is also critical to reduce costs and increase productivity, as well as increasing their lifetime and efficiency.
- Concentrated Solar Power Generation technology is focused on boosting efficiency through new fluids for increased operating temperatures. Another issue is minimizing the costs of the solar fields, mainly by new construction materials.
- Wind Energy targets mostly refer on minimizing the levelized cost of energy. Their efficiency factors need to be improved, using new materials, utilizing new models of loads as well as new components for a more reliable grid connection.
- Marine (Wave & Tidal) Energy also focuses on reducing the levelized cost of energy. Europe is considered to be the world leader in this field
- Biomass/Waste Power Generation consists of several technologies, such as biomass combustion, biomass gasification, hydrogen from biomass etc. The targets on this specific field are numerous and mostly relate to increasing of their efficiency as well as production targets for some of those technologies.
- Carbon Capture and Storage is considered one the most promising technologies of the future, especially in power generation. Research is towards next generation CCS plants with enhanced performance. Targets are focusing mainly on the constructions of pilot CSS plants, in order to accelerate this technology's deployment.
- Nuclear Fission Energy research and targets mainly on the development of materials and processes to provide enhanced safety and endurance of the nuclear plants. Moreover, research is being conducted on decommissioning of Gen 1 power plants and the development of Gen 3 nuclear reactors.
- Advanced Fossil Fuel Technologies consist of several technologies, such as steam turbines for coal plants, integrated gasification combined cycle(IGCC), and combined gas turbine plants(CCGT). Research and targets are focusing on increasing efficiency, through the use of new materials that can allow higher temperatures and utilizing the most advanced turbines available.
- Electricity Networks Technologies also includes a handful of technologies, such as long distance connection technologies(HVDC), network monitor and control tech-

nologies, as well as ICT technologies etc. The aim of the research it to develop processes and solution in the direction of integrating all of the aforementioned technologies.

- Smart Cities and Communities refer to a combination of more efficient current technologies like ICT and transportation. Typical examples are nZEB (near zero energy buildings), improved heating and cooling systems, enhanced electrical appliances and electrical based transport. Targets currently focus on the successful demonstration of net zero-energy/emission districts that integrate with the European energy system.
- Buildings and Energy refer to broad variety of technological solutions that can be utilized to substantially lessen the energy consumption of buildings. Such solutions include insulation, passive cooling and heating, renewables, ICT technology etc. Targets are mainly focused on reducing costs on building construction, renovations and final use, as well as better assessing the energy performance of buildings.
- Electricity Storage Technologies include batteries, hydrogen as well as other technologies. Targets are mainly based on improving their efficiency and making them modular and recyclable.

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