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Which economic aspects would have the greatest impact in the European Union for switching from traditional to renewable energy?

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1 Introduction

Climate change is the most crucial challenge the humankind currently faces and the transition from traditional to renewable energy is seen as the solution. This thesis aims to bring attention to what the author believes to be the most important economic aspects to consider in the European Union regarding the shift towards a renewable energy future.

Firstly, the methodology of the thesis will be discussed, allowing the reader to understand the technique for testing the points brought forward by the author. The hypothesis proposed by the author is that renewable energy price competitiveness, stranded assets and carbon leakage are ultimate aspects to consider when switching to a fully renewable energy system in the European Union.

Following the methodology will be the literature review, where the first topic of climate change will be investigated. Interesting data and facts will be uncovered and the importance of the need for a low carbon economy will be brought forward. Ensuing thorough description of the current traditional sources of fossil fuel-based energy will be introduced and dissected, providing the reader an overview of the pros and cons of our current coal, oil and natural gas resources. Renewable energy and its various forms will be next, allowing a glimpse of our future energy system and bringing up valuable background knowledge about the advantages and limitations of each. Controversial Peak Oil theory will be examined, presenting the reader with a rift in current understanding of the full availability of petroleum resources. Rather niche and upcoming topic of the origin and potential renewability of fossil fuels will be quickly brought to light, followed by a more popular and recent topic of electric vehicles and the pressure they bring on the current transportation and energy sector. Finally, the Europe 2020 strategy will tie up the previous topics and concentrate the reader's attention back on our own member states and their progress in adapting to the change.

Analysis of the three proposed economic aspects is left in the end of the thesis, validating the previous review of literature, challenging the hypothesis and bringing the topic to a resolve. Customarily, outcome and findings are presented in the conclusion, guiding the reader once more through the discussion and presenting any possible discoveries.

2 Methodology

Based on qualitative research, this thesis aims to answer the research question proposed by the author: Which economic aspects would have the greatest impact in the European Union for switching from traditional to renewable energy?

Consists primarily of secondary data collected from a range of studies, books, research papers, online sources and academic journals to grant a complete outlook on the subject. Various relevant resources were found that support the topic and provide an unbiased and complete view of the literature review. Slight risk of choosing mainly secondary data for conducting the analysis is obvious, however, the author has considerably reduced it by providing a broad collection of reference material from different sources and backgrounds, therefore diminishing any possible error.

3 Climate Change

Since climate change has been the main underlying cause for switching from traditional energy sources to renewable energy, the author has decided it to be a crucial component of this thesis.

Scientific consensus holds that manmade climate change, also known as global warming, is affecting all of us at an alarming rate (NASA, 2018). Global warming, as the name implies, is the gradual increase of temperature of the globe and is caused by an occurrence called the greenhouse effect. Gases such as carbon dioxide (CO_2) methane (CH_4), ozone and nitrous oxide (N_2O) are the primary greenhouse gases (GHGs). Solar radiation emitted from the sun hits the earth’s surface, causing heat and radiation to bounce back towards space. Fortunately for life on earth, just enough of this heat gets trapped by the atmosphere and provides us with the climate and living conditions we have today. However, greenhouse gases obstruct the so-called escape of radiation, trapping the heat close to earth and increasing the overall temperature of the planet. To put the increase of GHGs in perspective, from 800 thousand years ago till the beginning of the industrial revolution, the amount of CO_2 particles in the atmosphere was around 280 parts per million (ppm). Nowadays, the amount is around 400 ppm. Such an increase is clearly not natural and can be attributed to the rising temperatures of our oceans and the environment in general (Pappas, 2017). Second prevalent GHG is methane, which is over 20 time more potent than carbon dioxide. Although, methane is a naturally occurring greenhouse gas such as CO_2 and N20, human activity has influenced its concentration in the atmosphere considerably (EPA, 2014).

The effects of global warming are not limited to the rise in temperatures, which is why scientists and researchers nowadays find it more suitable to call it climate change. Though temperatures are rising around the planet, the change causes adverse effects such as massive snow storms and hurricanes. Climate change is continuing to melt ice caps, increasing the size of already enormous dry and barren areas such as the Sahara Desert and acidifying the oceans. Most noticeable result is the decrease in polar ice caps and glaciers which have already been in slow decline since the last Ice Age, yet another natural process artificially accelerated by humans (Pappas, 2017).

Additionally, further indications of man made climate change is presented by the Copernicus Climate Change Service, showing how 2017 was the second year, after

2016, to break global temperature records (Doyle, 2018). One major contributor to the massive increase in carbon dioxide levels that are agreed to be the main culprit, is the way we produce electricity (NRDC, 2016).

4 Traditional Energy "Fossil Fuels"

Traditional energy sources, also referred to as fossil fuels, are sources of energy that have been most commonly used throughout the human history. These sources of energy are non-renewable, meaning that the amount available is finite and the replenishment of said fuels extremely slow. As the name implies, fossil fuels are made up of ancient fossilised animal and plant matter decomposed and collected over millions of years. These organisms used a process called photosynthesis, through which they stored energy collected from the sun. Once dead, the organic matter retained some energy captured and fell to the ground or sunk to the bottom of swamps and peat bogs, causing them to pile up and get covered over time. Decomposed and constantly covered over millions of years, the matter was subject to various heat and pressure, over time, causing it to develop into different types and forms of fossil fuels; coal, petroleum (oil) and natural gas. Despite the growing support for renewables, supporters of fossil fuels argue that it is neither reasonable nor intelligent to expect an immediate retreat from current traditional energy sources, stating the unreliability, cost and inefficiency of renewable. Defendants of fossil energy point to growing energy demands that according to the *International Energy Outlook 2017* report by the United States Energy Information Administration will rise 28% by 2030 (EIA, 2017a). Additional information regarding population growth demonstrates that with the global total population predicted to increase from the current 7.6 billion in 2017 to 9.5 billion by 2050 (UN, 2017) is a clear indication of the necessity of fossils and our short to medium term dependence on tradition energy sources.

Recent predictions by BP, the sixth largest oil and gas producer in the world, state that traditional energy sources such as coal, oil and natural gas will provide 75% of the total energy consumption in 2035, despite the surge in renewable energy. Total yearly increase in CO2 emissions is projected to slow to 0.6% compared to the 2.1% currently, which still results in a 13% increase by 2035 compared to present levels (IER, 2017).

Fossil fuels have been the staple, inexpensive, accessible and preferred way of energy production for the past half century, mined and extracted from vast reserves found throughout the globe. Value of the fuel has been generally affordable because of abundance, low cost of extraction, transportation and government subsidies, therefore, providing humanity with an inexpensive way to generate energy and provide services. Producing energy from fossil fuels is achieved by burning the fuel and causing heat, which is either utilised directly with furnaces or pushed through a turbine to produce electricity. Heat energy of fuels is often measured in British thermal units (Btu) with one Btu regarded as the heat needed for the temperature for one pound of water to increase one-degree Fahrenheit (AGA, 2018).

4.1 Coal

Coal is a widely established type of fossil fuel, generally made up of carbon and hydrogen, with a small amount of sulphur and heavy metals present. Coal is most often used in electricity generation through combustion. Abundance and energy density has promoted coal to become the most commonly used fossil fuel in the world. Due to the nature of its components, it is considered the largest contributor of carbon dioxide emissions in the world.

Not all coal is created equal. The different types of coal include; peat, lignite, sub-bituminous, bituminous, anthracite and graphite. Such distinctive categories are due to the energy density of each material and carry various benefits and attributes to its use. Lowest energy density is seen in peat, the source material of coal, and is used as low-grade fuel in district heating and home furnaces. Generally, the deeper coal is found, the more pressure, time and temperature it has endured, resulting in better combustion capability. Peat being mostly decomposed plant matter found in wet environments close to the surface, with minimum 30% of deceased organic matter and withheld from oxygen, is not very energy dense. Since it requires temperatures high enough to decompose, yet low enough to do it over a long-time span, it is most often found in the Nordic hemisphere (IPS, 2018). Second lowest by quality is lignite, sometimes referred to as brown coal, which is soft and crumbly material situated closer to the surface as the higher quality coal. Due to its low quality and extremely polluting properties, lignite is most often used in generating electricity close to its extraction points and rarely transported further (Lyons, 2017). Better quality source of energy such as sub-bituminous coal is more often used in energy production, specifically to produce steam for various steam powered engines and turbines. Sub-bituminous coal is also referred to as black lignite, since it has similar characteristics with slightly older formation and higher energy density. Although less polluting due to its lower levels of sulphur, sub-bituminous is of less energy dense and available than bituminous coal, which accounts over 50% of reserves worldwide. (Kay, 2017). Bituminous coal derives its name from the presence of a high level of bitumen contained within the rock and provides two specific applications for its use; thermal coal which is used for energy production through steam engines and metallurgical coal, also known as coking coal, that is used in iron and steel production. Besides graphite which is mostly used in pencils and difficult to ignite, anthracite has the most optimal energy density and low emission value when it comes to coal (EIA, 2018a). Coal is extracted either thorough mining the surface layer by layer till the coal seam or going underground and excavating it through deep mines.

4.2 Oil

Petroleum, also known as oil or crude oil, is a fossil fuel that is found deep underground in vast reservoirs, located both under the ocean and below ground. Colour and density of petroleum can range from thick to thin, transparent to pitch black all depending on the conditions it encountered over the millions of years (Micu, 2017). Crude oil can be refined into various petroleum products such as gasoline, diesel fuel, heating oil, jet fuel, lubricating oils and asphalt to name a few. Historically, humans have utilised oil for thousands of years and a multitude of purposes (NOIA, 2018). Although, it was the ancient Chinese, back in 600 BCE that were first recorded using oil for lighting purposes and transporting it through pipes made from bamboo, the big breakthrough on a global scale happened in 1859 when an American by the name of Edwin Drake successfully extracted it in Titusville, Pennsylvania (EKT, 2018). In the past, lamps ran on whale oil which was highly dependent on the whale population that was being over consumed and alternatives such as coal oil were quite expensive. Therefore, the popularity and adaptability of oil was greatly welcomed as kerosene refined from crude oil was much cheaper and more convenient compared to whale oil that had to be hunted and gathered through a laborious process and in limited quantities. Kerosene was used and available before the discovery in 1859, although, it was found mostly from tiny leaks that caused oil to seep to the ground or rise on top of bodies of water in meagre quantities. By-products from the drilled crude were initially discarded as there was little known use for them at the time. With the popularisation of automobiles and increasing appetite for electricity, oil has become a staple in the worldwide energy mix. Nowadays, petroleum and its derivatives are extremely common and are used for a number of purposes around the world. Oil remains the most used fuel in the world and providing 32.9% of global energy consumption (WEC, 2016).

4.3 Natural Gas

Natural gas according to biogenic theory, along with coal and petroleum, developed hundreds of millions of years ago from buried organic matter. As the name implies, natural gas was formed in the form of gas instead of solid or liquid such as coal and petroleum. Contrary to popular belief, the gas itself is transparent and odourless, however, mixed with chemicals that give it a rotten egg smell to warn and detect of any leaks in the pipeline (EIA, 2018b). Natural gas flowing out of the drill sites is primarily made up of methane, a highly potent greenhouse gas, as well as small amounts of liquids and other gases that are later separated into valuable products such as propane, butane, ethane and pentane (C2ES, 2018).

Discovery of natural gas dates to ancient times when people encountered flames gushing out of the ground, often using these as sites of worship due to its mystical grandeur. Practical use for the gas was first recorded in ancient oriental cultures, where people used pipes to transport and burn the gas in salt production. Natura gas is gaining popularity in energy production, emitting half as much CO2 as burning coal and one third of that from petroleum. Natural gas use is gaining traction as emission standards and climate change worries pressure industries to seek low emitting sources of energy. Replacing gasoline and diesel in heavy transport vehicles and making use of combined heat and power (CHP) technology or cogeneration are just some of the many effective uses of natural gas (EERE, 2018). Common ways to transport natural gas include pipelines and liquification where the gas is cooled to form liquid Natural Gas (LNG), which can then be easily shipped around the world (AGA, 2018).

5 Renewable energy

Renewables are considered a clean and “green” source of sustainable energy that can be harnessed from natural sources such as wind, sun, water, plants and the earths own heat. Nowadays, viewed as the answer to climbing rates of greenhouse gases and pollution, renewable energy is gaining immense popularity and political support. Offering a wide range of harnessing methods, it is suitable and useful technically everywhere in the world. With costs of renewable technologies falling year after year, the renewable counted for nearly two-thirds of net new power capacity installed in 2016 (IEA, 2018). With global energy needs rising by 30% by 2040, renewable energy is seen as the biggest push for a solution. Political support for renewables was cemented in 2015 at the World Climate Summit in Paris, where the Paris Agreement was signed by 194 countries. The agreement is planned to begin 2020 and organises an unprecedented worldwide effort to combat rising emission and global temperature levels, work towards a low carbon economy and encourage vital innovation in finance, energy and technology sectors.

According to the new report published by the International Renewable Energy Agency (IRENA), titled *Global Energy Transformation: A Roadmap to 2050*, for the 195 members of the Paris Agreement to reach their climate goals of keeping the global increase in temperature below 2 degrees Celsius by 2100 compared to 1990 levels, a 600% boost in renewable energy adoption needs to be achieved. The report states an increase of investment towards better energy systems from the current $93 trillion to a whopping $120 trillion is required, with additional $18 trillion suggested for power grid and energy flexibility projects. Such investments, according to the report, would not only serve to fulfil the requirements of the Paris Agreement but generate a further 11 million new job opportunities in the energy sector, a net positive when considered the losses of fossil fuel related employment. Another aspect of the IRENE report to recognise is the case for stranded assets, already invested money in fossil fuel related energy generation, that are predicted to amount to $11 trillion of losses by 2050, with possibility of doubling should the transformation of the energy mix be prolonged (Hill, 2018).

Besides the clear environmental benefits of renewables and the geopolitical advantages of domestic energy production, renewable energy is also economically attractive (Acciona, 2018). Estimations predict that should the share of renewables in the global energy supply double by 2030, it would result in $1.3 trillion or 1.1% increase in global gross domestic product. Additionally, the total amount of people employed by the renewable energy industry would be close to 24.4 million by 2030 (IRENA, 2016).

Worthy mention; China is leading the charge in renewable energy growth, accounting for over 40% of capacity installed annually and firmly defending its place as the market leader in hydro and bioenergy. Due to the immense influence on renewables, China is viewed as the biggest player on the market, deserving of special attention and encouragement as they navigate their way from a production to a service-based economy all while leading the world through another energy revolution (IEA, 2017a)

5.1 Solar

Main types of renewable energy being harnessed nowadays include; solar, wind, hydroelectric, geothermal and various biofuels. All renewable technology is either directly or indirectly influenced by the sun, specifically by its rays. The sun has been around long before we as humans set foot on this planet, warming, nurturing and lighting all life on earth. Knowledge of solar energy has been known since ancient civilisations, where people positioned their houses and camps according to the path of the sun, as a result, gaining valuable warmth during the cold winter months and shelter from the rays during hot summers. Solar can be used either through passive means such as taking advantage of energy efficiency gains from the position of the sun and the material it reaches, or by photovoltaic (PV) technology such as the solar panel to generate electricity and heat water. Photovoltaic technology has been used in space exploration vehicles for its virtually endless supply of energy and relatively low-cost maintenance. Collection of solar energy is generally achieved through a three-step process, starting with a module that collects and transfers the sun rays into electricity, an inverter that converts it into an alternating current suitable for domestic use and possibly a battery to store excess energy. Solar technology has improved so considerably that it is now possible to integrate solar panels inside windows, walls and even roof tiles of the house (NRAL, 2001). Currently solar is the fastest and most promising form of renewable energy, representing the greatest share of new renewable energy capacity to be installed for the coming half a decade.

5.2 Wind

Another classical representation of renewable energy is wind power, especially the image of gracious white pack of turbines calmly rotating on vast fields and grasslands. The basic technology behind wind power is rather old, dating back to the first sail boats close to 5000 BCE and the elementary wind mill designs used in ancient China and Middle East (WEF, 2018). Using a rather straightforward system, power is generated by wind rotating long blades connected a generator and monitored by a computer. As the wind direction changes, necessary adjustments to the turbine are made to maintain maximum efficiency. Wind turbines come in different shapes and sizes, together with various purposes ranging from grinding grain and pumping water for the livestock to supplying electricity for whole households. Main wind turbine designs include the horizontal axis and vertical axis variety, built both on- and offshore. Bigger turbines are also more efficient, usually clustered together in assembles called wind farms. Albeit the symbol of renewable energy, wind power carries certain surprising, yet obvious limitations. Reliability of wind currents means that turbines commonly run below peak efficiency rates and leave the turbine operator fully exposed to weather risk (EREE, 2018). Installation costs can be expensive, considering that the turbine needs to be transported often to remote wind plenty locations, possibly connected to the general electricity grid and granted various safety and municipal permits (Rinkesh, 2018). Typically mentioned drawback of specifically larger sized turbines is the threat to local bird population, as birds have died by being struck by the high-speed blades. Regardless of these disadvantages, wind power is considered net positive for the environment and thus continues to gain momentum both in technological advancement and popularity (Bratley, 2017).

5.3 Hydroelectricity

Most productive renewable energy source currently available is hydroelectricity, or simply hydro, which accounts for 18.4% of global electricity production (CIA, 2018). Typical hydropower plants require dams and large water reservoirs to be collected, which means flooding sizable amount of land to store the water. Captured water is then directed through the dam and past turbines that use such kinetic energy to run a generator (Robinson, 2018). Applying a dam is considered damaging to the rivers ecosystem and biodiversity (UCS, 2018) by restricting the natural movement of fish and minerals, which is why run-of-river, commonly referred to as damless hydropower plants, are gaining popularity all over the world. This system works by redirecting, rather than storing, part of the river and using the force of gravity to power turbines (Turbulent, 2018). With over 3700 new hydropower dams planned to open in the next 10-20 years, over 700 gigawatts of capacity is predicted to hit the market, ensuring a considerable effort towards renewable energy (MIT, 2016).

5.4 Geothermal

Geothermal is perhaps the most promising type of renewable energy, converting heat deep below the earths surface into steam that runs generators or simply directing hot water to nearby households.

> “The amount of heat within 10,000m of Earth’s surface contains 50,000 times more energy than all the oil and natural gas resources in the world (UCS, 2018).

Such a natural resource is extremely lucrative for satisfying future energy demand and divesting from our current fossil fuel backed economy. Geothermal energy does not necessarily need to be harnessed close to volcanoes or cracks in the tectonic plates, milder heat can also be accessed by heat pumps three meters below ground virtually anywhere in the world. Such milder heat is useful for regulating the temperature at homes or offices and general direct heating purposes (UCS, 2018). Geothermal energy also provides great supplementary baseload energy source to other renewables such as wind and solar that rarely run at 100% capacity. For example, Iceland gets 66% of their primary energy needs from geothermal and 19% from other renewables (NEA, 2018).

5.5 Biomass

Biomass, accounting for 15% of global energy supply (Altenergy, 2018), is dedicated to utilising various organic material that is otherwise simply discarded or left to rot. Food, plant and agricultural waste as well as algae and a wide range of organic waste products can be reused after their life has come to an end (EIA, 2018c). For example, leftover sticks, branches and pulp from the forestry industry can be used as fuel and transferred into energy. Methane, or biogas, collected as the by-product of anaerobic digestion at landfills can be refined and used as fertiliser, vehicle fuel or fed straight into the natural gas pipeline. Major downside to biomass is the area it takes to grow energy crops such as corn and wheat, and as such should not be used as the main source of energy but to complement and diversify other renewables and “recycle” waste (Gasum, 2018).

6 Peak Oil theory

Peak Oil is a theory proposing the concept of peak, or max, supply of oil and the ensuing irrevocable decline in production. First proposed in 1956 by an American geologist and geophysicist called Marion King Hubbert, the theory predicted that the United States oil production would reach a tipping point in 1970, after which it would start its slow decline till the resource was fully depleted. Hubbert also predicted that the global oil supply would reach its peak close to 2010, which due to advances in oil exploration and extraction technology, such as fracking, never materialised (Towler, 2014).

Conventional drilling techniques took advantage of huge collected reservoirs of oil and gas captured by dense and nonporous rock formations, drilling vertically to reach the core. Unconventional drilling, also known as hydraulic fracturing or simply fracking, allows access to deposits of much denser oil that is contained within shales and tight rock pores (MNGD, 2018). Fracking is exercised by pumping various chemicals and lubricants accompanied by water into these tight deposits and increasing the pressure, which as a result breaks open the tight pores and cracks allowing the mixture to be pumped back on land and refined. Since early 2000s, fracking has been exceptionally effective at allowing access to previously inaccessible oil and gas reserves, although, the environmental hazards such as chemical leakage, contamination of ground water purifiers and escaping potent greenhouse gases such as methane cause it to be a very controversial mode of drilling (Conca, 2017).

According to BP, growth of electric vehicle popularity, lowering of emissions in transportation sector, increased energy efficiency, rising demand for increase in air quality and reduction in greenhouse gas emissions are all reducing the demand for oil faster than the supply can deplete and thus, current focus should be directed towards peak oil demand and diversification of the market rather than peak oil supply and its eventual conclusion. BP also acknowledges that slight disparity in GDP growth expectations and effectiveness in energy consumption in the transportation sector can cause significant deviation of the predicted timing of a peak in oil demand (BP, 2018).

Demonstrated by Figure 1 below, different predictions of peak oil demand can vary considerably and thus, must be viewed critically.

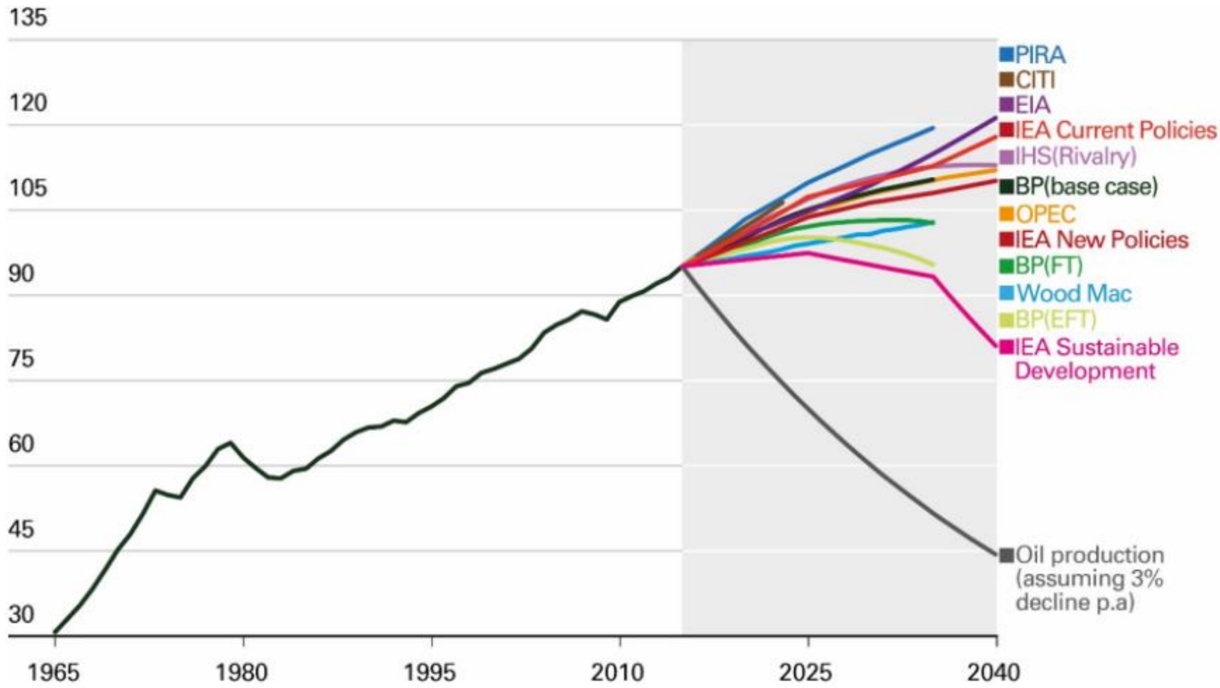

Figure 1. World oil demand estimation comparison (BP, 2018)

Although the supply has recently broken predictions of Hubbert's theory of peak oil (Cooper, 2018), prices of oil currently do not follow traditional supply and demand principles and are artificially manipulated by the Organization of Petroleum Exporting Countries (OPEC), which tighten or loosen supply in their favour. Controlling the price of oil is exercised with caution, as too low of a price results in diminished profits for exporters while too high of a price forces people to seek alternatives, further weakening potential gains from exports (DiLallo, 2016).

The fact that oil supplies are finite and will eventually run out is for the most part agreed upon, predictions of the date at which such an event happens, due to undiscovered reserves and technology, is however highly speculative and vulnerable to miscalculation.

7 Biogenic vs Abiogenic Petroleum

Consensus on the creation and origin of petroleum currently held by western science points to ancient microorganisms, plant matter and their subsequent burial over millions of years after which immense pressure and temperature caused by the material collecting on top of them resulted in transformation of solid, liquid and gas formations known as coal, oil and natural gas. This type of theory is referred to as biogenic or Western theory on the creation and origin of oil (Summers, 2015).

However, there is a growing number of scientists and researchers challenging such a theory, indicating that organic compounds are extremely common in space rock and atmospheres of other planets in our solar system (Bansal, 2015), suggesting that these compounds must be abiogenic in origin rather than biogenic. The opposing group of abiogenic theory supporters, also called Russian-Ukrainian group explain inorganic origin of oil because of chemical reactions of minerals rather than by decay of organic matter, further deducting that oil is a renewable resource found in immense quantities in presently unreachable depths (Ragheb, 2018). Hydrocarbons are a chemical compound consisting of a combination of hydrogen and carbon atoms, together in great quantities making up the composition of oil (EIA, 2017b).

Popularity of biogenic theory can be attributed to the 17^{th} and 18^{th} century scientific understanding of carbon-based compounds and importance of life in their creation (Summers, 2015). Additionally, different types of organic matter and residue was found in various depths and layers of rock formations deep underground, which combined with extreme pressure, temperature and other factors could have resulted in huge concentrated stores of oil, as extraction of oil from fossilised organic matter is proved true (Heinberg, 2018).

Although it is widely supported fact that oil can be retrieved from fossilised organisms (Penner, 2018) and is conjointly backed by decades of data and technological development, some newer research has proven that part of the chemistry suggested by the abiogenic theory supporters to be surprisingly valid and worth investigating.

However, majority of evidence supports the biogenic explanation, the one true cause for the origin of oil might be difficult to conclude, while a more beneficial approach to tackle the question could be a balance of valuable data from both sides of the debate.

8 Electric Vehicles

Popularity of electric vehicles (EV) has grown tremendously, however, widespread application has not been accomplished, as of 2015, almost 1 out of roughly 700 cars in Europe was electric (EEA, 2016a). Sale of electric vehicles is growing year by year as shown on Figure 2 below, with record 750 thousand cars sold globally in 2016. Percentage of EV in total car sales is still relatively low with member states such as Norway and the Netherlands leading the union in 2013 with 6.2% and 4%, respectively.

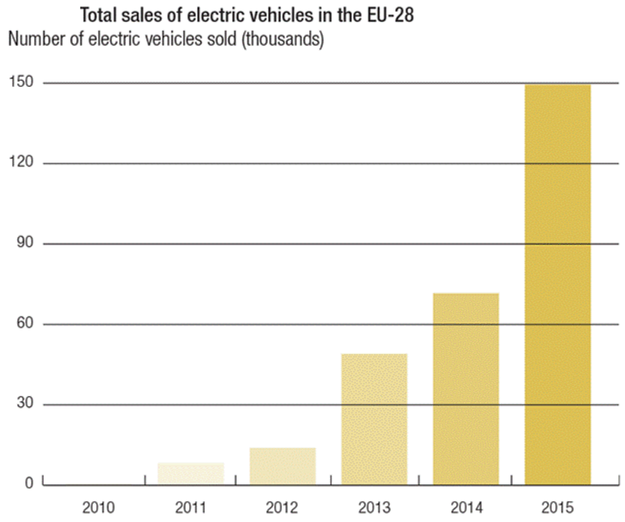

Figure 2. Global EV Outlook 2017, International Energy Agency, 2017. (IEA, 2017)

Predictions indicate a quick rise in EV in the upcoming years, with some research showing a range of 7-32% share of the total vehicles in the EU market (Asmelash & Cerdan, 2017).

According to the optimistic Bloomberg's *Electric Vehicle Outlook 2017* report, EV could amount to 54% of new car sales by 2040 and become cheaper than common combustion engine vehicles due to reduced battery prices which is currently the single most expensive component inside them (Bloomberg, 2017). Serious shift in the transportation sector results in the direct increase of demand in electricity as vehicles switch from internal combustion engines to electric equivalents, further highlighting the importance of lowering emissions in the energy sector in the future (Stockton, 2018).
Transportation sector is the second largest global GHG emitters, preceded only by power generation, continuing to be greatly dependant on fossil fuels, although with the

rise in electric vehicles that is slowly starting to change (C2ES, 2017). Transport sector is culpable of close to 25% of the total GHG emissions of the European Union, additionally, while other sectors have achieved to substantially lower their GHG emissions compared to 1990 levels, transportation as of 2016 is a whole 25% higher (European Commission, 2018).

Higher concentration of electric vehicles means a greater need for innovation and development of the power grid systems currently in place, requiring important investments and certain restructuring (Stockton, 2018). Batteries inside electric vehicles could potentially be used to conserve and deliver energy; known as “vehicle-to-grid” system, owners of stationary EV would be compensated for allowing the energy grid to use the batteries of their plugged-in vehicle in adjusting electricity flow across the grid (Cenex, 2018). Due to the variable nature of renewables such as wind and solar (IRENA, 2018), vehicle-to-grid systems could balance the supply and demand of electricity and store electricity during off time and release it during peak hours to manage a sort of baseload power supply (Douris, 2017).

9 Europe 2020

Europe 2020 is a ten-year strategic plan set forth by the European Union with the goal of promoting and advancing employment and the overall economy. Europe 2020 was first proposed by the European Commission in 3rd of March 2010 and intends to provide a general unified direction for the 28-member states. The initiative was meant to fix the flaws and shortcomings of the previous plan, the Lisbon strategy active from 2000 – 2010 (EFESME, 2018).

> It emphasises smart, sustainable and inclusive growth as a way to overcome the structural weaknesses in Europe’s economy, improve its competitiveness and productivity and underpin a sustainable social market economy. (European Commission, 2018b)

This objective is solidified by eight targets in areas such as employment, research and development (R&D), climate change and energy, education, poverty and social exclusion. Each target is given measurable and quantifiable specifications that define a clear direction for national governments. Goal for employment was identified as 75% of people ages 20-64 in active employment, while 3% of the EU’s gross domestic product was to be invested in research and development to cover the R&D target. Previously mentioned climate change and energy objectives included reducing greenhouse gas (GHG) emissions by at least 20% compared with 1990 levels, increasing the share of renewable energy in final energy consumption to 20% and finally, moving towards a 20% increase in energy efficiency. Education targets were defined as rates of early school withdrawal below 10% and minimum 40% of people 30-34 years of age to have acquired higher education. Last, but not least, minimum 20mln less people at risk of poverty and/or social exclusion (European Commission, 2018b).

Purpose of the targets is to provide a clear outlook of acceptable results that the European Union should achieve by the year 2020. Overall targets are set EU wide, while the details of completion are left to national governments to allow freedom to decide the best course of action by each individual member state. Burden is not shared between members of the union as every state is responsible for their own progress and contribution to the 2020 strategy. Europe 2020 targets are complementary, for example, increasing the share of renewable energy will positively affect the employment targets and an increase in employment will in turn improve poverty and competitiveness of the whole EU (European Commission, 2018b).

9.1 Progress

Responsibility of reporting on the progress of targets is left to individual member states, which publish annual progress reports. Monitoring of said progress reports is conducted by Eurostat, European Union's statistics agency. Latest review of the strategy was conducted in 2015 when the European Commission, based on the positive progress reports, decided to continue the Europe 2020 strategy for the remaining five years. The Commission also stated that the European Union has made great progress in certain targets, while clearly lagging in others. The global financial crisis of 2008 has hindered some of the results significantly, especially in the areas of research and development, employment and poverty reduction. The greatest improvement has been made in the climate and energy targets, especially regarding share of renewable energy and reduction of problematic greenhouse gas emissions (EEA, 2016b).

According to the Europe 2020 headline indicators, employment targets took a major hit after the financial crisis, which dragged down the total employment rate of 20-64-year olds from 70.3% in 2008 to 68.6% in 2011, respectively. In the years following, the percentage of employed gradually increased and sits currently at a solid 71.7% as of 2016 (Eurostat, 2018).

10 Economic aspects

Various aspects need to be considered when discussing the future of renewable energy production in Europe and the switch from fossil fuel to a renewable future in the energy sector. Economic aspects to be focused on include analysis of renewable energy price competitiveness, stranded assets and carbon leakage.

10.1 Renewable Energy Price Competitiveness

Switch from traditional to renewable energy in Europe and its consequence on the price of electricity is a hot topic. Therefore, electricity price competitiveness was chosen to be discussed, to provide a clear view of the current situation and benchmark pricing.

Eurostat (2017), the agency in charge of official EU statistics, data presented on Figure 4 below shows that 48.1% of net electricity generated in 2015 derived from fossil fuels and 26.4% from nuclear energy, while 25.3% of the total mix was renewable. According to Eurostat, the share of renewable energy in the EU grew from 13.4% in 2005 to 25.3% in 2015, signifying a considerable growth trend hopefully matched and exceeded in the future.

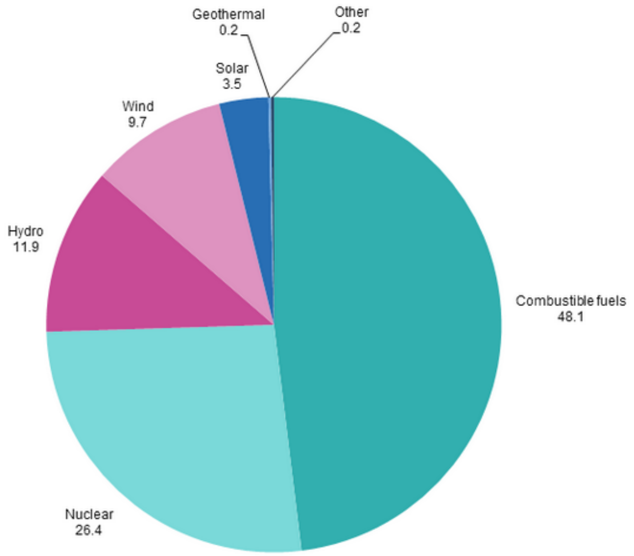

Figure 4. Net electricity generation, EU28, 2015. (Eurostat, 2017)

Such renewable growth was supplemented with the decline in fossil fuel and nuclear share, from 56.4% to 48.1% and 30% to 26.4% respectively.

European Union data compared to the global total primary energy supply in 2015 shown below in Figure 5, indicates a relatively positive situation regarding renewable energy share in EU compare to the rest of the world.

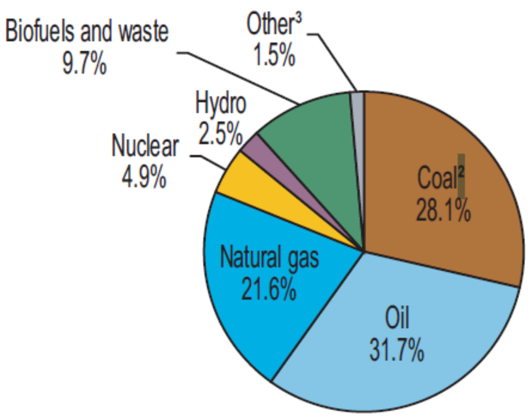

Figure 5. World total primary energy supply (TPES) by fuel, 2015 (IEA, 2017b)

As evident, fossil fuels represented 81.4% share of the total energy supply in 2015 compared to the nearly half 48.1% in the EU. Meanwhile, global renewables brought a total 13.7% of electricity compared to 25.4% in the union. Clearly the difference is mostly made up of nuclear energy and less of renewable supply (IEA, 2017c).

Power prices are determined by supply and demand of electricity. Supply is defined by the output of various power generation methods such as fossil fuels and renewable energy, which in turn can have specific factors affecting them such as availability renewable power due to weather or various fossil fuel prices. The wellbeing and status of power stations and the overall electrical grid can also be a factor determining the end price of electricity, as power outages and maintenance can disturb the system and cause delays. Demand is mostly affected by time of day, public holidays and general consumer behaviour due to weather or preference (RWE, 2018).

Size of power plants is usually measured by the amount of electricity they can generate, unit of measurement is in Megawatts (MW) (Enrlich 2017: 6), however, price of electricity for consumers is often measured in the local currency per kilo Watt hour e.g.

€/kWh, Watt being named after Scottish inventor of the steam engine called James Watt (Energy Lens, 2018).

Findings from the latest International Renewable Energy Agency (IRENE) report, *Renewable Power Generation Costs in 2017* state that renewable energy prices have been decreasing steadily over the years, as shown in Figure 3 below, and will continue to become increasingly cost competitive against traditional fossil fuels in countries all over the world. Fall of electricity price from solar photovoltaic generated projects is particularly impressive, driven mainly by their 81% drop in module prices since 2009. Clearly, Figure 3 shows solar power in general to have dropped the most in price/kWh compared to other renewable energy sources. Electric vehicle batteries have also become 73% cheaper between the years 2010 – 2016, further improving storage capability of intermittent renewables.

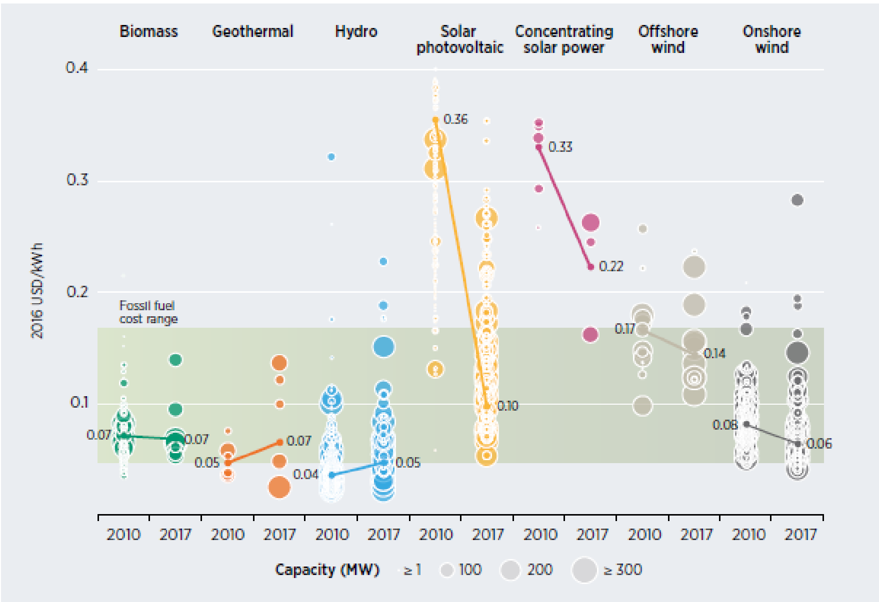

Figure 3. Global levelized cost of electricity from utility-scale renewable power generation technologies, 2010-2017 (IRENA, 2017)

Current prices of fossil fuel generated power in G20 countries ranges from $0.05 - $0.17 per kWh with slight decrease expected over the years as technology improves extraction efficiency and supply. The report highlights important economic aspects to consider for Europe when switching to renewable energy, as the remarkable fall in solar and wind prices shows a clear trend of renewables setting new benchmarks in cheap energy. During 2017 the global weighted average price for solar and onshore wind ranged between \$0.06 - \$0.10/kWh, which proves that the renewable energy is already an economical alternative to traditional fossil fuels and should be fully utilised as such. Solar photovoltaic prices have reached an astonishing \$0.03 per kWh in countries with abundant sun such as Mexico, Chile and Dubai to name a few. Main drivers for the decrease in renewable energy costs are identified as technology, competition among governments regarding bidding for contracts and abundance of experienced project developers (Dudley, 2018).

Cost of CO2 through systems such as the European Union Emissions Trading Scheme (EU ETS), largest emissions trading scheme in the world, has certain effects on the price of electricity. Such cap-and-trade programmes are put in place to set a cost to CO2 emissions created from generating electricity or other high emitting activities. The purpose is to incentivise the lowering of emissions by making emitting an expense. Participants are required to compensate for each ton of CO2 with one EU allowance (EUA), that must be purchased from government auctions (primary market) or through environmental commodity exchanges or traders (secondary market). Free allowances are also distributed to each participant and the number given is reduced annually. Naturally, such a system grants extra expenses to electricity producers as they need to now pay for each ton of CO2 emitted, thus, putting a strain on their revenue and the price of electricity they can sell for. Renewable energy producers gain an edge since they have the added benefit of not having to pay extra for generating CO2 free electricity. By design, the system is set to make sure that low emitters would be incentivised not to raise their emissions and in turn, large emitters would find ways to reduce their emissions to cut costs (Parmesano & Kury 2010: 27-36). EU ETS is currently in phase three, after testing the scheme in phase one where EUA prices hit zero due to oversupply of free allowances and phase two where they learned from the mistakes and lowered the cap, increased extent and penalties (Carbontrust, 2018).

Europe, along with the global power sector, is witnessing a shift towards a sustainable future in energy production, however, looking at the final electricity market report analysis of the European Commission (2017) we can notice that although the decrease in profitability of fossil fuel as electricity generation in the majority of European energy markets was solid, it had less of an impact in Southern European member states where profitability was healthy because of high wholesale prices. Another important and often mentioned aspect of the transformation to a complete renewable energy system is the current requirement for baseload electricity that would support the system regardless of the intermittent renewable production. Therefore, the Commission states that although the prices for fossil fuels might not be optimal at times, the system requires the use of traditional sources to safeguard the general structure. Such a fact clearly restricts the impact of falling renewable energy prices until a sufficient supply of baseload power or considerable advancement in energy storage capability is figured out.

Because of this baseload necessity, the value of wind and solar energy, according to a study by Leon Hirth (2013), would decrease considerably as they gain a greater share of the total electricity supply. Such a finding highlights the importance of discussing electricity prices during the transition to renewables, as they clearly come with certain challenging consequences. The intermittent nature of wind and solar causes EU member states such as Germany and Denmark to reimburse neighbouring countries to take their excess variable renewable energy at times. Such an effect naturally gets written into the price of electricity, causing the gains from renewables to be cannibalised by the extra costs from time to time. Another interesting fact is that the electricity price in the EU is most expensive in Germany and Denmark, showing a correlation between high amounts of renewable wind and solar to increased prices. Latest data shows that 53% of Danish and 26% of German electricity originated from wind and solar (Shellenberger, 2018).

10.2 Stranded Assets

Stranded assets are nowadays commonly understood to be assets that have lost value and faced massive devaluation, caused by various environment related risks. Previous examples of stranded assets included the tobacco industry divestment, where, for example, the World Health Organisation in 1980s concluded that tobacco products contradict their objectives and thus decided to divest from the industry. Another example is the South African apartheid where banks felt increasing pressure from the public, divested and refrained from providing further loans. Nowadays, stranded assets are understood to be referring to the fossil fuel industry and their assets losing value due to global climate change goals and the subsequent divestment. This phenomenon is also referred to as a carbon bubble when the fossil fuel reserves and other assets are overvalued and remain untapped due to the shift towards a low carbon future (Ansar et al. 2013: 9-18).

Research has shown that to avoid global surface temperature rise below two degrees Celsius and commit to the framework set and agreed under the Paris Agreement, the world is required to refrain from tapping into most of the known fossil fuel reserves currently available (Carrington, 2015). There are several reports from different sources suggesting the risk of fossil fuel assets losing value or being “stranded” should the Paris Agreement goals be fully enforced.

According to the *Wasted capital and Stranded Assets* report by Carbon Tracker (2013), an independent financial think tank, together with the London School of Economics found that between 60% - 80% of known fossil fuel reserves of publicly listed companies should remain untapped to limit the rise in temperature below two degrees. The total amount of CO2 represented by the potential fossil fuel reserves adds up to 762 gigatons of CO2, compared to the carbon budget estimates. If the world is to keep warming below the goals set in the Paris Agreement, then only around 125 – 225 gigatons of CO2 can be emitted to have an 80% chance of successfully containing the rise in temperature.

Study with a more European Union focus called *The Price of Doing Too Little Too Late*, by the Greens/EFA group of the European Parliament (2014) has found that the carbon exposure to the 43 top EU banks and pension funds exceeds a massive €1 trillion worth of assets. The breakdown of exposure is the following: €260 – €300 billion for pension funds, €460 – €480 billion for banks and €300 – €400 billion for insurance companies with total asset exposure reaching 5%, 4% and 1.4% respectively. These considerable amounts clearly bring the issue of stranded assets at the forefront of discussion in the EU when undergoing the transition from traditional to renewable energy. Taking into account the data published in the report, the annual capital expenditure (CAPEX) of these massive fossil fuel companies reaches around a considerable €500 billion, which is approximately one sixth of the total market capitalisation of said firms. Three different possible scenarios were proposed in the study: first the “Low carbon breakthrough”, where the shift to renewables is quick, second being the “Uncertain Transition” with a sluggish and unclear effort eventually leading to a low carbon system and third scenario of “Carbon Renaissance” where rise in fossil fuel demand and failed climate policy result in massive negative global consequences in forms of extreme weather. According to the study, the first and best-case scenario would already result in combined €350 - €400 billion worth of losses to banks, pension funds and insurance companies. Second scenario would be even more damaging, as if the firms would continue their yearly €500 billion CAPEX behaviour which would eventually collapse. Ultimately, should the global climate effort be inefficient in reaching its goals, extreme damage will be suffered by economies around the globe and massive losses for insurers would be common. Although, the report does admit that the consequences of a carbon bubble bursting and the resulting aftermath would not pose a critical threat to the discussed EU banking, pension fund and insurance sectors.

What basically becomes evident is two potential scenarios, first being the quick yet painful loss in value of fossil fuel assets with full compliance towards climate goals and second, possibility of overshooting the climate goals while minimising loss in value and facing the broad environmental consequences. Both scenarios demonstrate the importance and impact of stranded assets.

Criticism on the notions that fossil fuels will be stranded assets or that the carbon bubble scenarios are legitimate has been countered with arguments such as the improbability that the world is capable to completely overhaul their dependence on traditional energy sources (McGarrity, 2014). Some critics disagree by stating that although the companies are considered large, the total market capitalisation of fossil fuel companies is relatively low, which in the case of a total loss of value should not impact the global economy much (Tol, 2013). Large oil firm, ConocoPhillips, chief economist Marianne Kah was also of the opinion that the carbon bubble might be a scare tactic used to drive investors away from fossil fuel assets. She points out that oil companies are valued based on their proven reserves and those would run out in six to seven years, making the longer-term bubble uncertain. Further investigation of the International Energy Agency's *World Energy Outlook* (2017c), proves that oil demand despite its slight decline will continue its growth together with natural gas use which will increase 45% by 2040, signalling that the so-called carbon bubble might not be as urgent as predicted.

10.3 Carbon Leakage

Climate policies and environmental legislation incur added costs to emitters, when those costs become too much to bare, the emitter, hypothetically, might relocate their production and escape, thus increasing their total emissions in a looser legislative environment and cause loss of jobs/business in the EU. Such a situation is referred to as carbon leakage and under the European Union Emissions Trading System, companies and installations regarded as sensitive to carbon leakage are under Phase 3 given extra free allowances to incentivise them to remain (European Commission, 2018c). For example, aluminium producers in Europe must compensate the CO2 emitted in the production of their products due to the EU ETS, whereas Chinese aluminium producers do not, thus creating an asymmetric situation and possibility for carbon leakage. Carbon leakage is the result of competitiveness, as it is competition that retains profits and captures market share. In the case of European aluminium producers, the extra costs would cause them to be less competitive price wise than their Chinese counterparts, therefore costing the Europeans in both profit and market share. According to the *Climate Policy and Carbon Leakage* report by Julia Reinaud (2008) on behalf of the IEA, states that the European smelting industry has lost its advantage regardless of the added cost of carbon, mostly due to peaked domestic production capacity, higher electricity prices and differences in labour cost.

Solid criticism of the importance of a carbon leakage problem in the EU can be found in the *Carbon Leakage Myth Buster* policy briefing by the Carbon Market Watch (2015), a non-profit organisation dedicated to ensuring effective and just climate legislation. According to the briefing, during 2013 – 2020, exactly 6.6 billion free allowances will be granted to companies deemed at risk of carbon leakage. That amount of free allowances very roughly translate to nearly 80 billion euros of value that can be gained from selling them to the market. However, this amount is obviously a crude estimate based on an average price of €12/allowance during the period 2013 – 2020 and provided for context, should in no way be considered completely accurate due to the volatility of the carbon market and the uncertainty of the future price. Yet, such a huge free allowance subsidy, according to Carbon Market Watch, is providing industries with windfall profits and hindering the transformation to a low carbon economy.

Study ordered by the European Commission in 2013 came up with no conclusive evidence that the EU ETS caused any carbon leakage between 2005 – 2012, furthermore, the increase or decrease in industries was a result of global demand development rather than climate policies of the EU (Bolscher et al. 2013).

Future risk of carbon leakage was also said to be weak according to a study called *Asymmetric Industrial Energy Prices and International Trade,* published by the London School of Economics in 2015, that found how a hike of carbon price from €7 - €65/ton would equal to a 30% increase in energy prices with only a 0.5% fall in exports and 0.07% increase in imports. According to the paper, risk of carbon leakage has been overstated and should not stand in the way of efforts to curb emissions and tackle climate change (Sato & Dechezleprêtre, 2015).

Latest data on the worldwide ETS situation by the shows that emission trading systems, with the introduction of China, now cover nearly half of the global GDP and 15% of global emissions. Such numbers backup the criticism that the risk of businesses relocating their production to escape climate policy is overstated (ICAP, 2017). Additionally, table presented in Appendix 1 shows multiple studies conducted by various authors and institutions finding weak evidence of carbon leakage.

Finally, the Institutional Investors Group on Climate Change (IIGCC) in Europe, which speaks on behalf of 85 insurance companies, asset managers and pension funds managing a staggering €7.5 trillion in assets, assured to then president of the European Commission José Manuel Barroso, that as shareholders in energy intensive industries they heard of no issues regarding competitiveness arising from the EU ETS (IIGCC, 2014). When the industries considered to be most affected by the price on carbon voice their opinion that it does not negatively affect competition, free allowances and carbon leakage lose its argument in the EU.

11 Conclusion

The goal of this thesis was to understand the crucial economic aspect that the European Union should consider for switching from traditional to renewable energy, subsequently transforming their whole energy system and the surrounding economy. The author in his hypothesis chose to focus on the importance of the three main economic aspects the EU should consider: electricity price competitiveness, stranded assets and carbon leakage.

Literature review revealed important details regarding the urgency behind the switch from fossil fuels to renewable energy and demonstrated it by providing research from various sources and authorities. Current climate change situation was closely observed with important statistics clearly magnifying the need for change. After the underlying challenge was demonstrated, a closer look at fossil fuels ensured the reader is up to date on the current source of global energy production. Important distinction was made between the different types of fossil fuels and both the pros and cons brought to attention. What followed was the introduction to various renewable energy sources, including both advantages and disadvantages of each technology. Peak oil theory and its criticism was pointed out next, showcasing the debate regarding the availability and limit of current reserves, leading to the theory of the origin of fossil fuels. Emergence of data supporting the notion that oil could possibly be a slowly replenishing yet renewable energy source was discussed in the biogenic vs abiogenic section of this thesis. After such specifics were brought up and examined, the author redirected the attention back on renewable energy related topics such as the emergence of electric vehicles and the consequences they have on our current energy system and climate effort. Finally, the Europe 2020 strategy and its current progress allowed the reader to focus precisely on the European Union, which brought a smooth end to the literature review and opened the analysis of the hypothesis.

Electricity price competitiveness was the first aspect, which according to the analysis proved to be quite important. Impressive growth in renewable energy capacity and reduction in instalment and maintenance costs proved the emergence of renewable energy as a serious electricity provider. Report by IRENE demonstrated the already competitive situation of energy prices by solar photovoltaic and wind energy. However, the added costs due to the variable nature of wind and solar proved to be considerable, marking the importance of their spot in the hypothesis.

Stranded assets were an aspect found to be crucial as the report by Carbon Tracker pointed out how 60% - 80% of known fossil fuel reserves of publicly listed companies should remain untapped to keep the maximum two degrees Celsius temperature rise limit agreed under the Paris Agreement. Exposure for the EU, specifically showed in the report by the Greens/EFA group of the European Parliament, stated how over €1 trillion worth of assets in the European Union are at risk of becoming stranded, once again validating the importance of the aspect. However, the urgency of the issue was slightly less than expected as the projections by the International Energy Agency showed oil and natural gas demand grow till 2040.

Carbon leakage and its importance in the transition from traditional to renewable energy in the EU turned out to be insignificant. This was proven by a study ordered by the European Commission in 2013 that came up with no conclusive evidence that the EU ETS caused any carbon leakage between 2005 – 2012. Another study by the London School of Economics concluded that risk of carbon leakage has been overstated and should not stand in the way of efforts to curb emissions and tackle climate change. Additionally, the table presented in Appendix 1 showing multiple studies conducted by various authors and institutions finding weak evidence of carbon leakage, coupled with the IIGCC letter to then president of the European Commission José Manuel Barroso stating that as shareholders in energy intensive industries they heard of no issues regarding competitiveness arising from the EU ETS, concludes that the aspect of carbon leakage is not of crucial importance despite the hypothesis.

In conclusion, the author was correct with two of the three aspects suggested in the hypothesis and provided necessary information regarding all of them in an organised and efficient manner.

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Empirical Studies Provide Limited Evidence of Carbon Leakage

Author(s)	*Policy and period covered*	*Sector and geography*	*Strong evidence of leakage?*
Abrell, Zachmann, & Ndoye (2011)	Phases I and II of the EU ETS; 2005–08	Panel regressions; economy-wide coverage of the EU	No, but some sectors affected more than others
Barker, Mayer, Pollitt, & Lutz (2007)	Environmental (energy) taxes over period 1995–2005	Economy-wide coverage of six EU Member States	No
Chan, Li, & Zhang (2012)	EU ETS before and after implementation; 2001–09	Panel regressions covering power, cement, iron, and steel in the EU	No
Cummins (2012)	Phase I of the EU ETS	Panel regressions; economy-wide coverage of the EU	No
Ellerman, Convery, & Perthuis (2010)	Phase I of the EU ETS	Focuses on oil refining, aluminum, iron and steel, cement	No
Graichen et al. (2008)	Phase III of the EU ETS	Focuses on sectors in the EU ETS with more than three installations in Germany	No
Lacombe (2008)	Phase I EU ETS	Focuses on petroleum	No
Martin, Muûls, de Preux, & Wagner (2012)	Phases I and II of the EU ETS	Economy-wide; EU	No
Martin, Muûls, & Wagner (2011)	Phase I of the EU ETS up to 2009	800 companies in the EU ETS	No
Reinaud (2008)	Phase I of the EU ETS up to 2009	Covers steel, cement, aluminum, and refining in EU-25 Member States	No
Sartor (2012)	First 6.5 years of EU ETS	Focuses on aluminum	No
Sartor & Spencer (2013)	After introduction of EU ETS, anticipating Phase III; 1991–2010	Focuses on energy-intensive industries in Poland	No

Table 1. Studies regarding carbon leakage (Ward et al. 2015)