

Energy Resources and Energetic Challenges for the United Kingdom in the Shadow of Brexit

L á s z l ó B o k o r

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Abstract

The aim of this article originally was to discuss energy-related challenges in the United Kingdom, reflecting especially on a post-Brexit era. The topic, however, quickly evolved into a thorough energetic overview of the British Isles and it involves the entire analysis of the locally available energy resources including both non-renewables and renewables. Whilst the paper is focusing on the availability, utilisation and energetic importance of all of these local resources written in a school textbook style, it also ventures into understanding the reasons behind their decline or growing usage and how and why these have changed over the last few decades researched academically. It also attempts to compare energetic situations, such as electricity generation, to other European countries and focuses on the importance of global co-operation, and international efforts to tackle, for example, environmental issues including climate change.

Key words

Energy resources; energetic challenges; international co-operation; United Kingdom; Brexit



People hate scientists. There is no use in beating about the bush here. The scientist is in danger of becoming the scapegoat for the helplessness which the public feels. And if an immense revulsion of public feeling does lead to the destruction of the scientific tradition, then the world may again enter a dark age as it did after the Goths destroyed Rome. It is not impossible that the whole mechanical and intellectual society which we know could be abolished by a great wave of fanaticism.

BRONOWSKI, J. (1956)

1. Introduction

On the 23rd June 2016, the people of *Great Britain and Northern Ireland* were invited to a referendum on their country's membership of the *European Union*. The rhetoric and credibility of the campaign on both ends still remains questionable; the results next morning, however, showed 52% to 48% in favour to leave the *Earth's* most successful political, commercial and cultural integration (THE GUARDIAN, 2016a). Despite the non-representative 4% difference, so far it seems that the *United Kingdom's* departure has now become a reality which can build up questions on a high number of challenging issues. Energy economics and environmental concerns are just two of the most important among these.

During this referendum campaign left and right could follow a large number of social media pages and groups, daily papers, and political debates broadcasted on the television or radio, mostly run by experts or actual scientists; and one could also see hundreds of contributors from the public, including fictional experts, dedicated pro or anti-EU journalists, and fake-news generators, some of them claiming the *United Kingdom* to be fully independent producers on frankly everything including, among many other challenging areas, food production, fishing, mining, manufacturing, and approaching this by adapting models similar to *Norway's*, *Iceland's* or *Switzerland's*. In this process, from a geographic point of view, the absence of logic and rationality of information adaptation, analysis, synthesis and evaluation can be identified which scientific seriousness is one of the major factors that inspired the author to prepare this paper in his own research field and to

discuss facts regarding energy economics focusing on the natural givens of the *British Isles*.

The research activity of the author has now been stretching for a decade and mainly focuses on the geography of energy resources and their connection to locality, sustainability and environmental awareness; in the shadow of *Brexit*, and several other European nationalism-filled irrationalities (for example the proposed ban on wind energy projects in *Hungary* (277/2016. [IX. 15.] decree of the government—WOLTERS KLUWER [2016]), these terms need to be put into the focus more than ever before.

2. Aims of study

In this article, a thorough analysis on the *United Kingdom's* energy resources and their availability, utilisation and economics will be presented, and those geographical facts are also highlighted that should be taken into account when discussing these resources' locality & globality, sustainability and integration among countries. International comparisons will also be made to see how some of the other *European* countries (especially *Norway*, *Iceland* and *Switzerland*) are performing in the same area. Two of the author's own models will also be employed (*Need* and *Co-operation*) to help explain certain facts regarding (for example) local and global integration, and international cooperation. The bases of this research set on traditional regional geography which examines the social and economic spheres on the principles of physical geography; therefore, there will cliché explanatory parts be also presented to develop general understanding.

3. Research methods

GAILLE, S. (2016) has published an article on *LinkedIn* on the impacts of the energy industry that could follow *Brexit*. The article published on a social media platform is only mildly thought-provoking, but it can still encourage researchers to deepen their own thinking and analyse the problems related to energy sustainability right from their roots. This current paper is mostly a simple but thorough analytical review of

previously researched primer and secondary sources, but the different energy-related contents are now analysed separately and then synthesised and evaluated in the aim of forming a complex piece of writing from geographic point of view, and by employing two models. According to this, the reader will find:

1. General definitions in both energetics and sustainability which were mostly sourced from specialist books or phrased by the author.
2. Historical overviews of the energy resources and their local uses which were also traced in books, but journal papers and online databases were also searched to collect data.
3. Statistics on how important these resources are or how their utilisation changed over certain periods which were tracked in national statistics websites and other company databases. The data collected are presented in charts and diagrams that were made in Microsoft Excel.
4. Models to help understand the connection among certain factors, for example crude oil–petrol–transportation. These and other images were designed by using CorelDRAW X6 and SmartDraw.

4. Energy resources

A few years ago, a paper by the author of this paper was published in this *GLS* series on what energy is and what energy resources mean (BOKOR, L. 2013). According to the information presented in that article, it is worth sweeping the dust off some definitions and present them again in a compressed, but updated form here in this work too.

Everything that exists in our *Universe* is composed of either *matter* or *energy*. The interaction of these two parts is essential, because energy is what makes matter change through time (physically and/or chemically), which causes the shaping processes of our planet (STRAHLER, A. H. – STRAHLER, A. N. 2002). Energy is nothing more than stored ‘work or force’, which is re-released under certain conditions (GULYÁS, J. *et al.* 1995). This appears in different forms, such as thermal, electric, nuclear, and mechanical (BREUER, H. 2002). The forms of energy may

be divided into three main groups: kinetic energy, potential energy, and chemical energy (STRAHLER, A. H. – STRAHLER, A. N. 2002). The forms of energy can be traced back to one of the four fundamental interactions of physics (fundamental forces/interactive forces): gravitation, electromagnetism, strong nuclear, and weak nuclear (HOLICS, L. 2009).

The energy itself is invisible, rather than a factual, objectified material. This is typically transmitted by the energy source. However, this is already a more evident material that is always a source of energy stored in a characteristic *energy bearer*. This latter principle can be anything, as everything is abundant in stored energy (so-called subatomic energy) that can be handled or seen (EDDINGTON, A. 1935). From the point of view of, and in the earthly dimensions of our geographical approach, the *Earth*, in this sense, is one of the largest energy bearers. It bears different types of *energy sources* that can be objectified in materials (for example hard coal), or in the direct or indirect results of physical processes and phenomenon that cannot be detected with a naked eye (for example wind). Its nature and manifestation vary by geographic dimensions, that is to say, most of the energy bearers can conclude in the existence of more energy bearers (*Figure 1*).

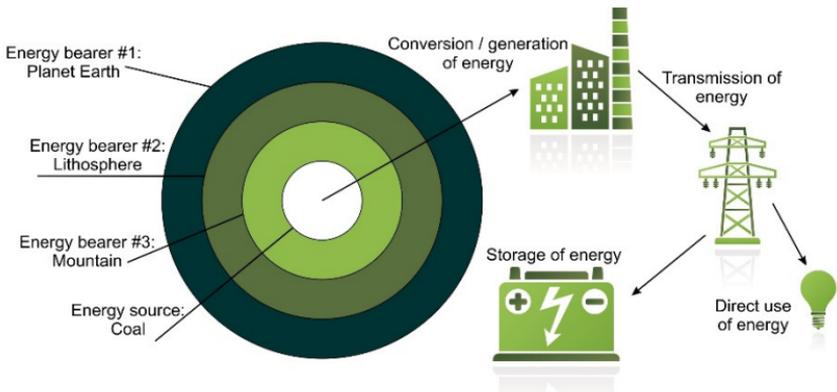


Figure 1 – A Simplified Example of the Spherical Structure of the Energy Resources

Edited by BOKOR, L. (2016)

This *spherical structure* may include the whole lithosphere or a single mountain range that bears various energy sources. There can—for the modern society’s needs and use—be thermal energy or electric energy transformed from. The principal difference between the *energy bearer* and the *energy source* is that the source can be exploited for its electric power and thermal unit, but the energy bearer does not function as a source. The *energy carrier* is, according to ISO 13600, either a substance (energy form) or a phenomenon (energy system) that can be used to produce mechanical work or heat, or to operate physical or chemical processes (ISO, 2007). The energy carrier is a product and can directly be used in demand of energy, for example batteries, petrol.

It may be difficult to distinguish among the bearer, the source, and the carrier; therefore, to make their terms clearly understandable, the approach taken has to be simplified: in this sense, the bearer is, for example, a mountain, where the source (for example black coal) can be found; and the carrier is, for example, the electricity itself that is transformed (produced or generated) from the source and is either directly used (for lighting homes) or stored for further use in a particular device (for example a battery).

Energy resources can be anywhere on the planet, but the type, quality, and availability of the source specific to one locality of the planet is limited to the area and its natural givens, and which clearly defines what people can do in that region where they live. This is known as potential. On a larger scale, instead of people, one can also refer to cities, regions or countries and see with what they are naturally provided, as this is the core thing to understand how their economies are based on those resources and also, how they can be linked to other activities. This will also make us understand how some of the economies that are lacking in certain resources need a wider international integration (co-operation) to be successful. First of all, let us discuss primary energy sources, and some information of their production and consumption in regards to the *United Kingdom*.

The primary energy resources (or primary energy or PE) are the major types of sources from where energy derives. They can either

belong to non-renewables (non-constants) or renewables (constants). The purpose of the energy resources is to provide an input to a system which in a more understandable way means, for example, filling up our car with fuel (1/ transportation) placing wood in a log burner to generate heat and warm interior spaces (2/ heating), or burn black coal in a conventional power station to generate electricity (3/ electricity generation). It is now easy to see that without trees one cannot place wood in the log burner or without coal one cannot generate electricity in a power station. And, after all, one can also see that if one were unable to generate electricity, it would not be able to run an extensive industry which would have a significant effect on the economy. But, once again, there are other solutions in an area other than just wood and coal. These resources, their availabilities and conditions in the *United Kingdom* are presented in this paper.

5. Production and consumption of primary fuels in the United Kingdom

Primary fuels mean fuels without energy conversion and transformation processes (for example into heat, electricity or mechanical work). When one talks about primary energy, it normally refers to domestic (indigenous) production, so what a country can produce by itself. The *Total Primary Energy Supply* (or TPES) includes the balance on imported and exported energy resources (and some other data related to trade and waste of energy too). The TPES is important as it highlights the balanced amount of imported fuels in a country's energy mix which also links to the country's dependency on non-domestic resources (DONEV, J. n.a.).

According to the *UK Energy in Brief 2015* (NATIONAL STATISTICS, 2015), the domestic production of primary fuels changed significantly between 1980 and 2014 (*Figure 2*). The information that is presented in this chart clearly shows that the *United Kingdom's* primary energy production is still dominantly composed of fossil energy resources (especially crude oil and natural gas, the coal's importance is becoming more and more insignificant) whilst the share of the renewable energy

resources carries on being relatively small², but their importance is certainly growing and in electricity generation, in some cases, have already outcropped the coal (VAUGHAN, A. 2016). In the total production, the primary fuels have been in decline since the early 2000s whilst the renewables are increasing (NATIONAL STATISTICS, 2015).

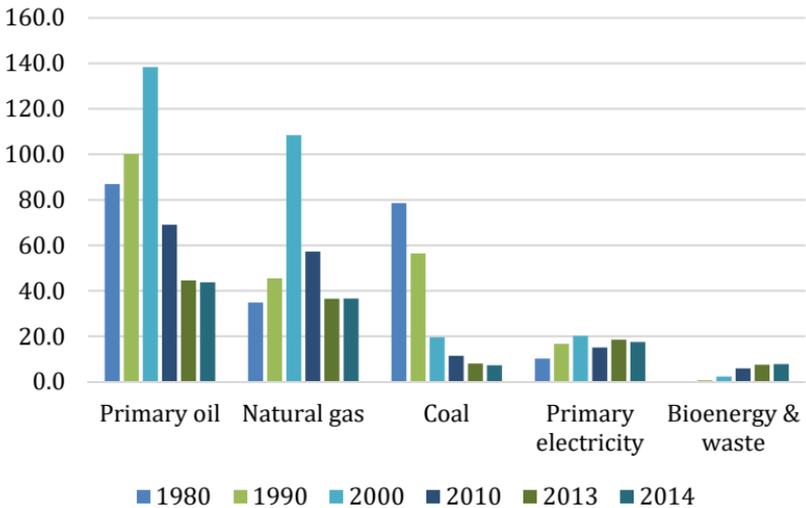


Figure 2 – Domestic production of primary fuels in the United Kingdom between 1980 and 2014 in Million tonnes of oil equivalent

Source: NATIONAL STATISTICS (2015)

Figure 3 shows the correlation between the primary energy production and consumption. It can clearly be seen that in the period between 1980 and 1990, the Britain’s production was synchronised with the consumption which means that it was used as much as the country actually needed and all the domestic production equalised the domestic consumption whilst there was sufficient amount for export too. Between 1990 and 2005, the country was still able to compete with the

² In Figure 2, renewables are merged into the last two categories of which primary electricity (more about it in Chapter 6) is consisting of wind, solar and natural flow hydro, plus includes nuclear too.

cheaper imported resources which resulted in higher production than the country was required. The peak value, that is shown in the chart around 2000, marks a period when the production was the highest and increased rapidly mainly due to the growth of oil and gas (NATIONAL STATISTICS, 2015). Since the early years of the 21st century, the domestic production has declined dramatically which mainly affected the fossil resources (coal and hydrocarbons) and in the last 5–6 years, it has been importing more than producing domestically (locally). To understand the decline in the overall production–consumption relationship, a closer look at the different types of energy resources and an insight in their decline will be required.

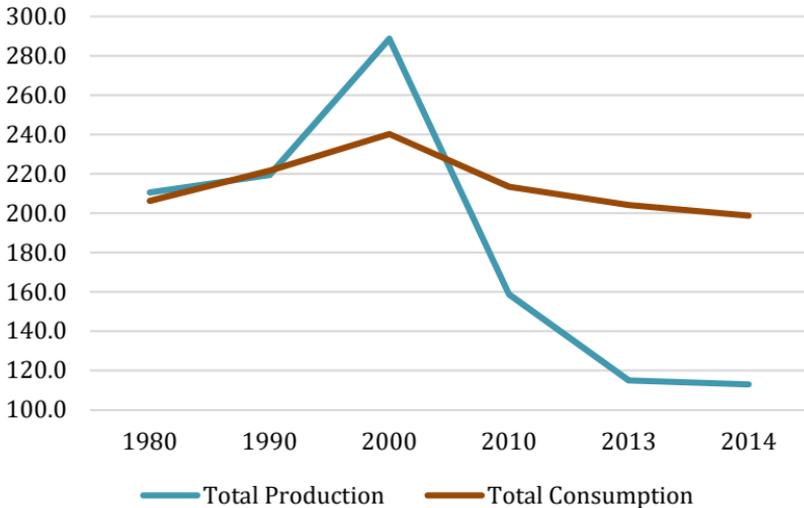


Figure 3 – Primary energy production and consumption in the United Kingdom between 1980 and 2014 in Million tonnes of oil equivalent

Source: NATIONAL STATISTICS (2015)

The task now is to see with what energy resources the *United Kingdom* is provided by nature (this is the primary energy source) which can be converted to be a secondary energy source, which is also known as an energy carrier. One will also see how their roles and importance

changed throughout history and will receive explanation on their present decline or success. The research will concentrate on the major primary energy resources beginning the journey with the non-renewables (coal, crude oil & natural gas, and nuclear), renewables (solar, wind, hydro, tidal, and wave, biomass, and geothermal). These categories may consist smaller sub-sources too.

The TPES which defined by IEA (n.a.) is majorly made up of domestic production + imports – exports; therefore, when it comes to the total primary energy supply of one certain area, the indigenous production that is based on the resources found in the area and the export/import balance, has to be addressed; it will also be pointed out how the import/export effect the economy, but will not discuss at an overall level. After the primer sources have been discussed, an overview of the electricity production will be carried out, because that is deliberately the most important product of energy resources which has a major impact on the whole economy and in generally on the everyday lives of people.

5.1. Non-renewables

5.1.1. Coal

One of the most traditionally and widely used energy resources that has been respected and had a high significance throughout the history of mankind, for over thousands of years. One of the major type of energy sources that has also had a definite impact on the development of societies and economies (FREESE, B. 2006).

The coal is a type of a sedimentary rock with combustible properties. Its quality and heat content (normally presented in kJ/kg) are defined by the conditions that have formed them and according to this, there are several types of coals from lignite (brown coal) to anthracite (the hardest and most metamorphic coal beside graphite) (WOODCOCK, N. 1994). The coal has organic origin (mostly died vegetation) and takes thousands to millions of years to form. During its formation it conserves the energy and other physical materials; when it burns, it releases a high amount of chemicals and substances which makes this

energy resource one of the most CO₂ intense and least environmentally friendly (ADB, 2009).

Nearly all of the coal reserves of the *British Isles* occur in carboniferous rock (formed about 358.9 to 298.9 million years ago) deposits, with 86–88% average carbon content which makes this type a high quality natural fuel (MCLEAN, A. C. – GRIBBLE, C. D. 1985). According to the statistics of UK COAL (2011), the country is abundant in coal, the reserves are estimated to 3,196 million tonnes of which 2,344 is accessible underground and 856 on surface. No surprise then why the *UK* has had the potential to build an extensive industry and economy based on coal. However, this type of energy resource is primarily used to produce electricity (nationwide) and heat (domestic) which, due mainly to environmental reasons, has been in decline for decades since renewable energy sources enjoy more widespread use due to their more environmentally friendly properties (BIAN, Z. *et al.* 2010).

Until the 1950–60s, coal was the main energy source in the *British Isles* which fits into an international trend at that time. Ever since its downfall began, it has resulted in closures of coal mines and the domestic production decreased rapidly. Currently, there are a small number (26) of surface coal mines operating across the country and extracting coal for energetic purposes—the last deep mine, *Kellingley*, was closed down in 2015 (BBC NEWS, 2015). The closure of coal mines, therefore, are direct effects of the decreasing economically accessible fossil and the increasing use of renewable resources, and also a change of lifestyle and standards of people in the early 21st century.

Locally thinking, the huge coal reserves are important for *Britain*, but the mines are inevitable due to current international market forces. The most easily accessible deposits are used up; therefore, mining and machinery has become expensive and less environmentally friendly (WAUGH, D. 2000). Coal mining and consumption have significant effects on directly the local and indirectly the global environment (BIAN, Z. *et al.* 2010); therefore, if other, environmentally more friendly and economically exploitable local sources are available, they need to be put in favour to coal. This so called ‘green type’ of using alternative

energy resources has caused the significant drop of coal usage which in 2016 many times resulted in 12-hour long electricity production without the input of the coal-fired power stations (THE GUARDIAN, 2016b). Moreover, building an energy reliance on coal is not sustainable in a long run, because, on the one hand, it is being a fossil fuel means that reserves can and will run out in a certain period of time; and, on the other hand, it is not worth running an economic sector that is based on coal whilst the other part of the world is changing their economic structures and becoming coal-free, which means coal keeps losing its value and importance in the economies and the energy systems.

The currently extracted coal in the *United Kingdom* is principally addressing domestic electricity production in conventional power stations. The more widely harness of renewable energy resources since the early 1990s, however, decreased the need of coal in electricity production (*Figure 4*) and, according to recent trends, it stagnates at around 30% in the total electricity production (refer to *Chapter 6*).



Figure 4 – The coal’s decreasing share in the electricity mix in the United Kingdom between 1960 and 2014

Source: THE WORLD BANK (2014)

Coal will, however, remain a quasi-important energy resource of the future generation both at nation level in electricity generation and in domestic use to generate heat for homes. Once the power station technology becomes more advanced and environmentally friendly (carbon capture and storage, or one of the newest discovery on how CO₂ can be turned into ethanol [YAHOO, 2016]), the coal might have the chance to be once again a significant type of energy resource, but this chance, in line with the more and more efficient and environmentally friendly emerging technologies and other alternatives, is very small.

5.1.2. Hydrocarbons

Hydrocarbons refer to a group of compounds of organic origin that mainly consist of hydrogen and carbon. They are naturally occurring and majorly found in crude oil. When geography of energy talks about hydrocarbons, it normally refers to a group including crude oil and natural gas. These two are currently the world's most primer energy resources. They have had a dominant role since the second half of the 20th century and their importance is still highly significant in the second decade of the 21st century. Crude oil and natural gas have shaped our society and lifestyle; without them the world would look majorly different as it is now (in both a positive and a negative sense).

Crude oil is the leading resource of our society. The most common (and well known) products of it are fuels, for example petrol, diesel, kerosene, which have a central role in transportation as a 'food for our cars'. However, other petroleum products are widely present in the economy as industrial activities use crude oil and other hydrocarbons to produce a wide range of items that have key roles in our society, for example plastics, lubricants, packages, medicines and plenty more 'ingredients' that are used to produce other items. Our modern society relies on crude oil and will carry on being an important energy resource in the future. This importance will, however, have to decline as burning off fuels (for example carbon dioxide [CO₂] and sulphur dioxide [SO₂] emissions) and environmental contamination related to the petrochemical products (for example plastics) have a significant envi-

ronmental impact which has to be more seriously addressed. Also, the extraction of crude oil (mining) is one of the 'dirtiest' in regards to all the other energy resources that have been involved in a high number of ecological disasters since the beginning of the 20th century that had local or, due to the *Earth's* physical cycles (for example hydrological), even global environmental effects (the most notable oils spills incidents are, among many others, the *Exxon Valdez* in 1989, and the *Deepwater Horizon* in 2010—USCG, 2011).

Natural gas plays a key role as a domestic energy resource in cooking and heating homes; and it is also one of the major energy sources of electricity generation in thermal power stations. In Britain, this latter one currently represents 29.1% in the total share (more information at *Chapter 6*). Natural gas and crude oil have the same origin, but their chemical compositions are different. Whilst the burning of crude oil (and coal) is one of the most carbon dioxide, sulphur dioxide and greenhouse gas producer, the natural gas has more environmentally friendly properties (EIA, 2016) which is why gas-fuelled vehicles (public buses) are considered to be 'greener' than the ones fuelled by petrol or diesel.

Crude oil and natural gas are both formed over millions of years buried deep; therefore, they have to be extracted from underground reservoirs. In the case of their availability, an extensive amount of hydrocarbons is found in the sedimentary rock basement of the *North Sea* (for example in *Dogger Bank*). These reservoirs became economically exploitable in the 1970s, after the Middle east oil crises. Let us, however, bear in mind that hydrocarbons are finite resources which means, according to the amount of extraction, sooner or later the reservoirs will run dry. This means, setting an entire economy's reliance on indefinite resources cannot be sustainable on a long run, but *Britain's* dependence is and will be highly significant on it (CRITCHLOW, A. 2015). This realisation comes along with the modern environmental awareness that puts the renewable energy resources in favour and also that imported oil and oil products are becoming cheaper. One of the key characteristics of the *North Sea* crude oil is, compared to the mid-

dle east oil, being ‘sweeter’³, better quality (PETROLEUM, 2015), but its extraction is more expensive due to the technology that it requires to bring the ‘black gold’ up to the surface. Since the last production peak in 1999, the crude oil and gas production in the UK have been in decline (THE ECONOMIST, 2015)—*Figure 5*.

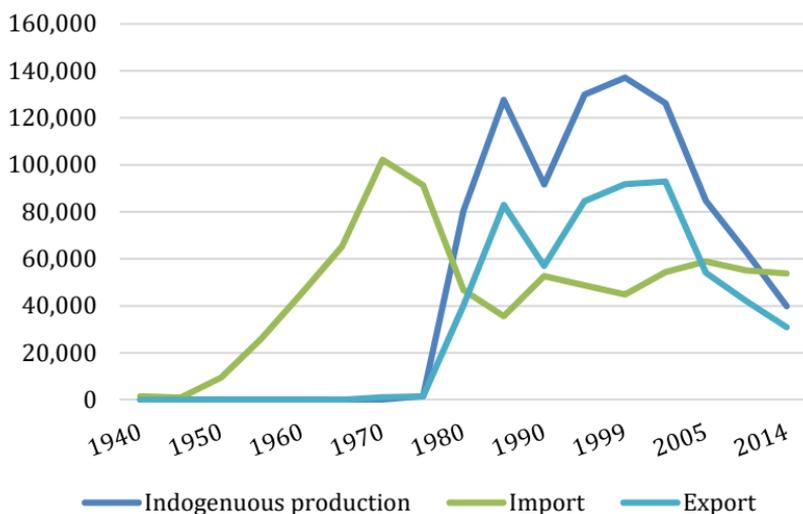


Figure 5 – Crude oil production in the United Kingdom (excludes oil products) between 1940 and 2014 (in thousand tonnes)

Source: DEPARTMENT OF ENERGY & CLIMATE CHANGE (2016a)

5.1.3. Nuclear energy

Atomic power, through the process of nuclear fission to generate electricity, is without doubt the most and the least supported type of electricity generation method at present times. On the one hand, it provides a low carbon power production in which case makes this option one of the greenest amongst all; but, on the other hand, it poses many threats and, in case of an accident, the contamination of the environ-

³ Sweet crude oil means its sulphur content is below 0.5%. Sour crude oil has sulphur content greater than 0.5%.

ment and living systems may be highly significant. A nuclear power station accident is a potential hazard, if we understand that the planet is one integrated organic entity which is connected via several geographical spheres: for example, the atmosphere or the hydrosphere are global systems which means that an accident in *Japan* can affect the world oceans just as well the global air systems (as it happened in *Fukushima* in 2011).

It is not the aim of this research to decide whether nuclear energy is a good or a bad choice of energy generation method, but it has to be seen that a nuclear power station has affects not only during its operating time, about 30 years, but over millions of years even after the power plant has ceased. The aim now is to highlight facts according to its utilisation in the *UK*. In the *European Union*, according to *Figure 6*, 14 out of 28 countries generate electricity with nuclear power stations which makes the *EU* moderately dependent on it, approximately one-quarter of its electricity to be precise (WNA, 2016d).

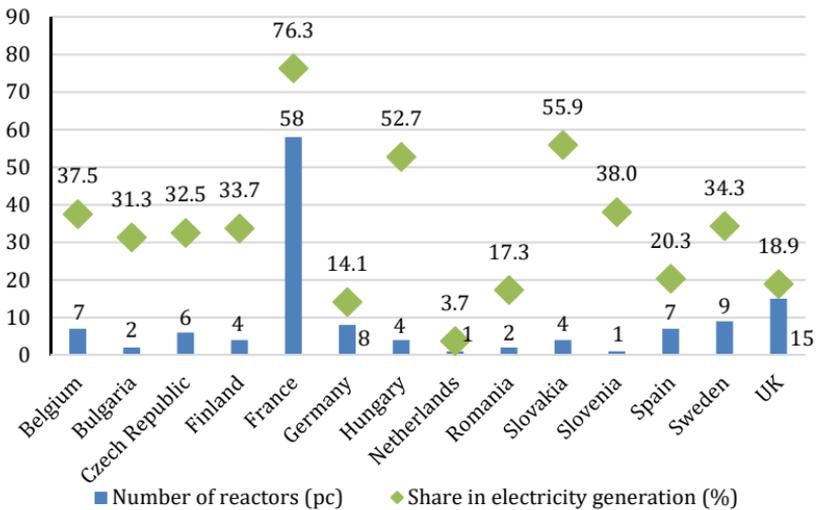


Figure 6 – Number of nuclear reactors in the European Union and their shares in the electricity generation (2016)

Source: WNA (2016d)

Within the *EU*, after *France* (58 reactors and 76.3% share), the *UK* has the largest number of operating reactors (15) which in 2015 provided about 21% (WNA, 2016a) of the country's total generated electricity. Smaller countries by size and population, such as *Hungary* and *Slovakia* with 4 reactors each produce a sizeable amount of electricity with nuclear power stations (WNA, 2016b; 2016c) (*Figure 6*).

According to some sources, the *United Kingdom's* nuclear power stations are planned to be gradually shut down in the next few decades (ENERGY-UK, n.a.; ALDRED, J. – STARKEY, N. 2013), however, in regards to some other sources, there is no sign the *UK* would abandon this method of electricity generation as there are new power plants planned (4) and proposed (7) to be in line by 2025 and 2045 – the most recent is the controversial *Hinkley Point* (MASON, R. 2016). At present, a full closure of the country's nuclear power stations would raise questions how or from what sources the 'missing' amount of electricity would be generated (which is currently $\frac{1}{5}$ of the total electricity mix).

One of the major difficulties with nuclear energy is the fact that it is not a resource. Nuclear energy is a result of methods when, through nuclear reactions, energy is released from a certain type of energy source. In the case of nuclear power stations, the resource is normally uranium, sometimes plutonium—highly radioactive elements (BGS, 2010). The other difficulty is, therefore, how to supply the power stations with uranium, which is the major energy resource to generate the electricity from? Also, what happens with the exhausted, but highly radioactive parts? Earlier *Hungary* and *Slovakia* were mentioned where both countries have a significant dependency on imported uranium, mainly from *Russia* (WNA, 2016b; 2016c). This fact makes both of these countries strongly dependent on imported fuel and also makes their electricity generation majorly reliant on one source in the mix which does not provide these countries with sufficient energy security (KRAEV, K. 2016).

Focusing on the *United Kingdom*, although there are some minor occurrences mainly in different locations across *Scotland*, in the *Penine* area, and in *Cornwall*, uranium is not currently mined (BGS, 2010;

WNA, 2016a). The uranium is imported from a range of countries, but the country's other nuclear facilities (conversion, enrichment, fuel fabrication, reprocessing and waste treatment) are self-sufficient (WNA, 2016a). The energy mix in the *UK* still shows a diverse range of resources that are used in electricity generation. In this regards, about 20% share in electricity generation may easily be replaced by other alternatives (mostly renewables), but viewing this from the aspects of politics, it is certainly a challenging energy endeavour.

5.2. Renewables

Nowadays, it is very common to discuss the role of renewable energy resources when environmental awareness and energy security come into focus. These terms are certainly inseparable. As seen in the previous chapters, the conventional energy resources, in a way or another, are in a decline in the *European Union* and so as in the *United Kingdom*, but a global trend in favour to the 'green' energy resources can also be observed. Global climate change, global warming, CO₂ issues, SMOG, air pollution, and other similar issues, are examples that are mostly related to mining and burning of non-renewable energy resources. Coal, crude oil and natural gas are commonly known as fossil fuels. They, however, are of organic origin, but their solid matter takes millions of years to form; the release of their stored energy through emission mean a direct impact on the environment which can reach global scales. Also, since they are finite resources, the modern economy cannot have the time and 'patience' to wait millions of years for them to renew; therefore, in contrast to them, renewable energy resources can be powerful alternatives. In fact, one of the major triggering factors of the wider use of renewables and the more and more spreading green philosophy is the unavoidable decline of conventional energy resources.

Most of the *Earth's* physical forces provide access to the energy that they 'store': solar (sunshine), atmospheric (wind) and hydrospheric (water) phenomenon (hydro power in general, wave & tidal energy),

bioenergy and geothermal have significant energy potential. In the following, only these major resources are discussed.

Regarding (a) *solar energy*, the potential in the *British Isles* compared to the Mediterranean is significantly less. However, solar radiation is available even in the polar regions, therefore as being a local source, it is worth investing in the harness of this type of energy resource. Other countries in the *European Union*, such as *Germany*, *Denmark*, *Sweden* and *Austria*, have developed the solar technology (including photovoltaic and active solar heating) to high standards which guarantees efficiency and stability at high degrees—and generation even in cloudy weather. The solar energy's international success has certainly encouraged its utilisation in the *UK* too, as from 4,040 GWh in 2014, the electricity generation of solar photovoltaics increased to 7,561 GWh in 2015 which is an 87% change (GOV, 2016). Solar energy is an alternative to fossil resources and its greatest importance could be achieved locally as a domestic generator of electricity and heat which could potentially contribute in lessening the household energy expenses which could even lead to domestic energy independence. Their installation on the rooftops of houses could also help save the impact on other greenfield areas as one of the biggest issues with solar power stations is the large land area they require. The extra electricity generated could be feed into the national grid which would also bring extra money into both the local government's budget and the household.

The utilisation of (b) *wind energy* is one of the most successful throughout *Europe* (apart from some areas such as *Hungary*—GREENFO [2016]). There are countries already in the *EU* where wind represents the highest share in the electricity production (for example in *Denmark* where the composition of electricity generation from wind is 74.5% including the production of on and off shore farms which represents 42.1% in the total electricity generation—ENERGINET [2016]). One of the most important factors in efficiently harnessing the energy of wind is the access to the constant wind resources. Geographically talking, the more western a country in *Europe* is situated, the more and better

quality wind potential it has. This means, the closer it lies to the *Atlantic Ocean*, the easier it can access the western winds that dominates in *Europe*, especially its western part of it. The *British Isles* are at the gates of this corridor which means the *UK* has one of the greatest potential of wind energy to harness everywhere on *Earth* and considered to be the best in *Europe*. However, whilst in *Denmark*, wind represents almost half of the electricity production, in the *UK*'s mix it is approximately 15%. Its appreciation has, however, become rapidly increasing in the recent years and it is now one of the most successfully developing sector. By the end of 2015, 14,291 MW worth of installed capacity of wind turbines had been harnessing wind across the *UK* on and off-shore generating 17,423 GWh electricity (GOV, 2016)—*Figure 7*.

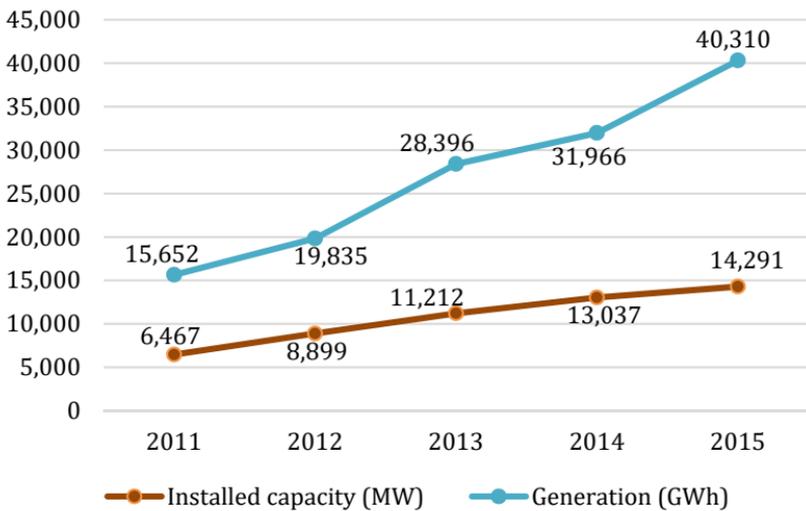


Figure 7 – The development of wind energy in the UK

Source: GOV (2016)

One of the main issues with wind energy as a variable resource (the same as with solar power) means the electricity generation is timely dependent and also largely defined by its properties in a given time (for example speed). Wind energy is, therefore, only an alternative to

fossil resources but an efficient addition to the mix of diverse range of energy resources.

As it is going to be presented in the next chapter, (c) *hydro power* is the renewable energy resource that has been utilised in electricity production for the longest time in history and has major importance in many of the European countries and in their economies. It does not have much impact on the *UK's* electricity production as its total share in the mix was 3.2% in the end of 2015 which also includes the shore-line tidal and wave systems (GOV, 2016). The total installed capacity has not changed much in the past decades and it is consistently holds around 1,759 MW that produced 6,289 GWh electricity in 2015. Compared to solar and wind, hydroelectric power stations are able to provide electricity in a continuous manner, but they require certain geomorphologic conditions to operate efficiently. According to BHA (2016), the *UK's* hydro potential would allow to double the current capacity, but installation of new plants at new sites onshore raises potential environmental concerns (BOKOR, L. 2012). In this regards, the role of new and emerging technologies that concentrate on harnessing the energy of seas has increased rapidly in the recent years. Electricity generation by wave and tidal streams are more predictable than wind or solar, and according to the *UK* government's sources, they could represent up to 20% of the *UK's* current electricity demand (GOV, 2013).

Overall, geographically the *UK's* renewable energy resources (solar, wind and hydro) are excellent alternatives to fossil resources, because the *British Isles* geographical situation makes this possible. Even though the solar energy potential is much less than in southern *Europe*, the *UK* lies in the gateway of the *Earth's* most powerful wind resources and hydropower from the seas, which have immense local importance due to an island situation.

According to *Figure 8*, the overall energy generation from renewable sources in the *UK* is currently based on the increasing utilisation of all locally available solar, wind, and in a small scale, hydro (including wave and tidal) resources. Based on the GOV (2016) statistics, the total

generated electricity in 2015 was 83.6 TWh which is an increase of 29% compared to 64.6 TWh in 2014. The overall share in the country's electricity generation has increased from 19.1% (2014) to 24.7% (2015). Since the UK government introduced the *Renewable Obligation scheme* (RO) in 2002 (*England & Wales*) and 2005 (*Northern Ireland*), and also the support system through *Feed in Tariff* (FiT), the electricity generation from renewable sources have *increased rapidly* (GOV, 2016). The pie charts, however, shows that, despite the *British Isles* excellent potential of all three major renewable resources, the UK still relies and increases the share of bioenergy (70.7%).

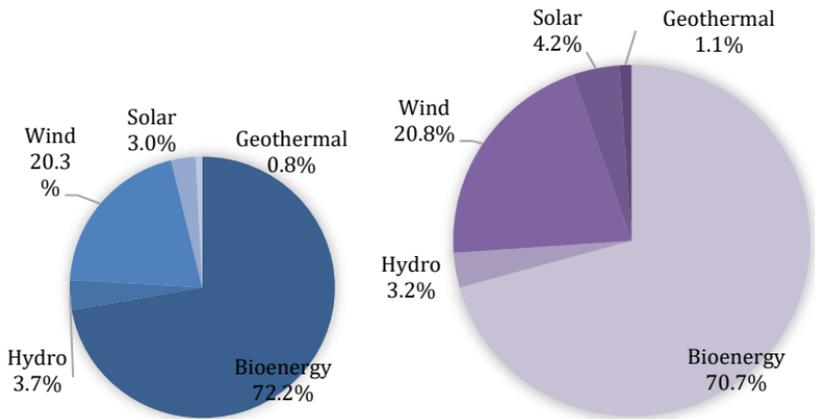


Figure 8 - The mixture of renewable energy sources within the electricity production in the UK in 2014 (left) and 2015 (right)

Source: DEPARTMENT OF ENERGY AND CLIMATE CHANGE, 2016b; GOV (2016)

Bioenergy (biomass) (d) has the highest share in renewable energy fuel use (*Figure 8*), but that 72.2% (2014) and 70.7 (2015) share do not correspond with one resource only. In fact, when it comes to bioenergy, it is common to refer to plant biomass (24.2%/25.3%), landfill gas (12.3%/9.7%), domestic wood (11.5%/11.4%), transport biofuels (9.2%/6.00%), waste combustion (4.2%/6.2%), industrial wood (3.4%/4.7%), anaerobic digestion (2.8%/3.4%), sewage gas

(2.5%/2.2%), animal biomass (1.9%/1.6%) and co-firing (0.2%/0.2%). Bioenergy, therefore, refers to a diverse range of, mostly, organic matters. The more variety it comes from, the more diverse options there are to utilise them as bioenergy can be used to produce heat (burn wood), fuel (rapeseed oil for bio-diesel), and generate electricity (burning gas).

According to the *British Geological Society* (BGS, n.a), despite the *UK* is not volcanically active (like *Iceland* or *Japan*), there is still a substantial *geothermal (e)* resource. *Shallow geothermal source* means access to the top 10–15 m of the ground by heat pumps (aerothermal heating), but this is technically still solar energy as sunshine heats up the top layers of the ground which means constant temperature throughout most of the year. *Deep geothermal energy* (geothermal gradient in the *UK* is 26°C/1 km) has been tried at numerous sites (for example *Eden Project* in *Cornwall*), but their importance has not been addressed successfully yet, even though, according to the *Renewable Energy Association*, the *UK* has a high potential of geothermal energy which could provide approximately 20% of the electricity. At the moment, the importance of geothermal is only 1.1% in the total primary energy mix (GOV, 2016).

6. Electricity: a wider view

So far, the primary energy resources of the *United Kingdom*, their origin, and the impact they have on the local (domestic) economy have been discussed. It has also been shown that the energy resources are important for the industry and to run the country's economy. There are many energy resources that are primarily used in certain sectors, for example, crude oil is majorly used to produce petrol and other petrochemical products. But the majority of energy resources are used to generate only electricity which, as an energy carrier, is then used to produce other things. For example, currently the entire economy and life fundamentally rely on electricity: in factories everything is based on precise machinery, car manufactory, IT industry would not even exist without it: internet, services, online banks, stock exchange, Face-

book, Twitter, etc.; everything is electronic and digital. Public services, for example, hospitals need a lot of electricity and energy safety. And the diversity of its use make us more dependent on it day after day (televisions, smart phones, electric cigarettes, electric cars, and the world is becoming more ‘electrified’) (LEKSHMI, S. 2010). Electricity has extended the economy and its sectors and nowadays relies on one another: from primary production (crude oil extraction) → secondary production (manufacture, assembly) → tertiary production (transport, advertising, warehousing, selling). And besides these there are the intellectual (quaternary) and educational levels (quinary) which has gained more and more significance in the past few decades (BIS, 2012). Without electricity, the lives known cannot be imagined anymore. This can also be seen in how the UK’s economic sectors have redistributed in a half century (*Figure 9*).

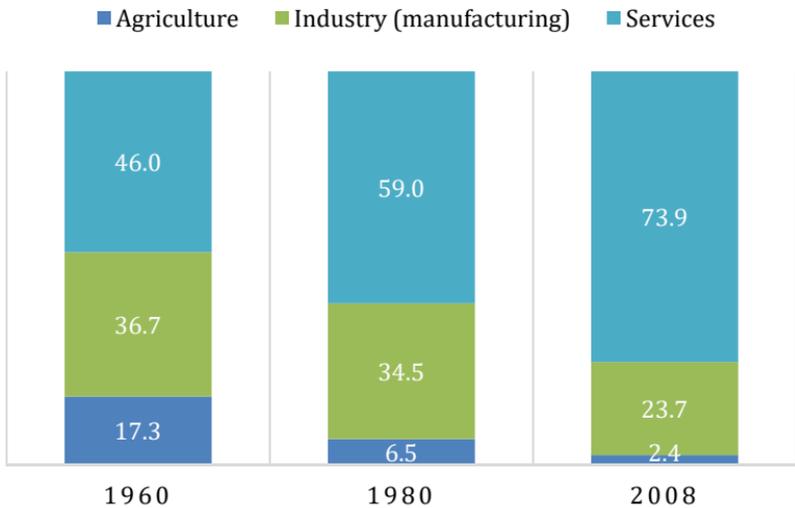


Figure 9 – The United Kingdom’s industrial market economies, distribution of labour force (percentage)

Source: GRIFFITHS, A. – WALL, S. (2011)

This is a global trend which also means that the integration among the planet's continents have got a strong bond which is increasingly recognised in the countries that are situated in a certain region. These are mostly economic integrations as multilateral free trade areas, such as the EFTA in *Europe* or the NAFTA in *North America*, but there are already more developed integrations that go much beyond economy, such as the MERCOSUR in *South America*, or the *European Union* which is one of these regional integrations and the most successful of them on the planet. In this system electricity also has a key role as production and consumption are strongly connected among the European countries and the future's idea is the establishment of a common *European super grid* (JEFFERIES, D. 2014). Moreover, electricity is the cleanest and most environmentally friendly energy carrier which can be produced directly from 'clean' energy resources; therefore, one of the most important aims of the human civilisation should be to reduce the fossil resources and to establish energy systems mostly on electricity provided by the *Earth's* infinite resources. Its generation, therefore, needs to be continuously secured and they have to be done along with certain environmental requirements which means the electricity generation has to provide us with a sufficient amount whilst keeping the environment clean and healthy. For this latter reason, the electricity has to be transmitted from resources that are widely available in the country. This is when the energy resources for electricity generation is provided locally. Nowadays, however, the resources for electricity production may travel thousands of miles (see the availability of primary energy) which might be tolerable as long as it is based on equal trading deals and conditions, and not results in dependency and the extensive use of fossil resources. This responsible co-operation is shown in the *Co-operation Model* (BOKOR, L. 2013). This idea (responsible co-operation) makes globalisation a 'domesticated pet' of locality which is a useful interaction among other locations with different conditions and properties. The interaction by making a global network is the only option that can make a locus work quasi independently with other local hot spots which can also help tackle global problems at

larger scales (*Figure 10*). The co-operation is stronger and more efficient when each individual locus situated near to each other.

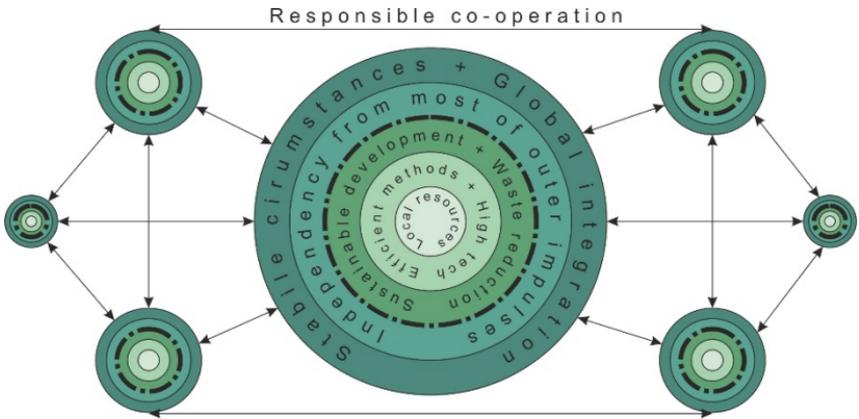


Figure 10 - The Co-operation Model

Based on BOKOR, L. (2013)

According to BOKOR, L. (2013), the term of ‘producing electricity’ is not fully accurate when one understands that energy itself is stored in a certain material (for example in coal) which only has to be released from that given energy resource by transforming it into a different form. The conversion of energy can be performed in many different ways depending on what one wishes to use that energy for and what type of energy is particularly needed. When it comes to electricity, electrical power is normally generated with a turbine of some type, but the type of energy resource can place electricity generation into two main categories in regards to how naturally it becomes electricity. According to ØVERGAARD, S. (2008): “*In the UN manual electricity from nuclear, hydro, wind and geothermal sources is labelled primary. The OECD/IEA/Eurostat manual states that; »Electricity is produced as primary as well as secondary energy. Primary electricity is obtained from natural sources, such as hydro, wind, solar and tide and wave power. Secondary electricity is produced from heat of nuclear fission of nuclear fuels, from the geothermal heat and solar thermal heat and by burning*

primary combustible fuels such as coal, natural gas, oil and renewables and wastes».

Now let us have a look at how the UK produces electricity. Based on NATIONAL STATISTICS (2016b), *Figure 11* shows the dominance of fossil fuels (coal, gas, and oil) which in 2015 was as high as 53% in the whole mixture. According to the previous observed years, their overall share, however, is in decline.

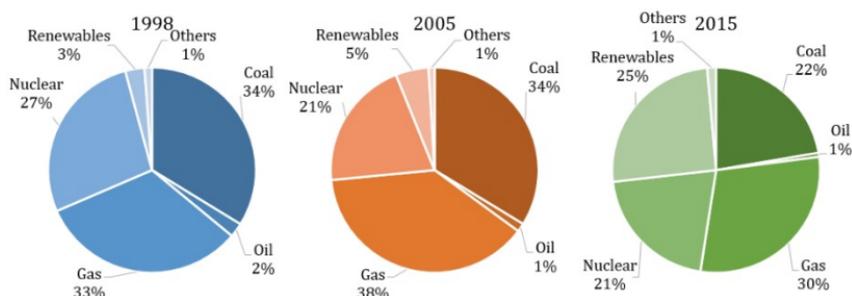


Figure 11 – Electricity generation in the United Kingdom in 1998, 2005 and 2015 (%)

Source: NATIONAL STATISTICS (2016b); Edited by BOKOR, L. (2016)

The coal at the end of 2015 represented 22% which has dropped significantly within the last 10 years (from 34%) and will very likely carry on falling out as an energy resource in the future for electricity generation. Nuclear has its share at 21% which has not changed much in the recent decade. It is promising to see the increase of renewables in the share which dominantly consists of wind and bioenergy, but there is an increase in the use of solar energy. The presence of other renewables, including hydro, is very little. It is worth having noted here that THE GUARDIAN (2016c) article headlines “Record 46% of UK’s electricity generated by clean energy sources in 2015” is misleading as they merged renewables with nuclear energy and classed the second one as ‘clean’ whilst forgetting about the significant environmental hazards that atomic energy poses.

Figure 12 shows how the electricity generation and supply and the significant downhill from 1998 to 2015; *Figure 13* presents how the

generated electricity is consumed among the British sectors at national level.

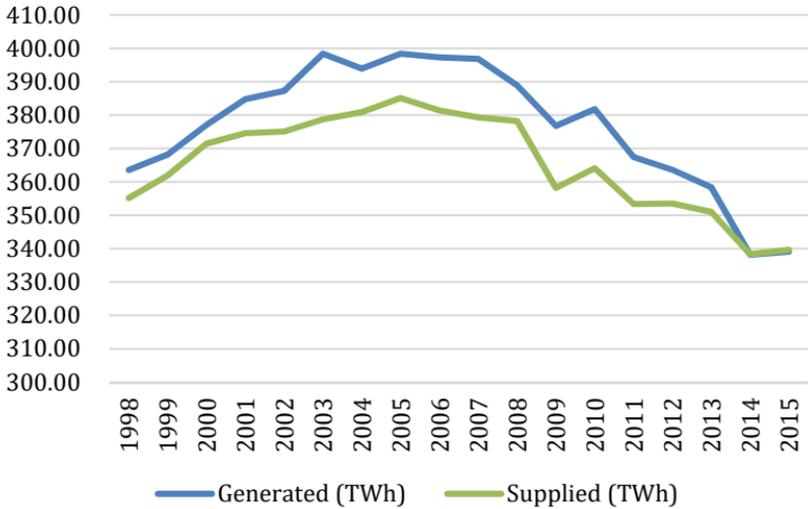


Figure 12 - Electricity generation and supply in the United Kingdom between 1998 and 2015 (in TWh)

Source: NATIONAL STATISTICS (2016b)

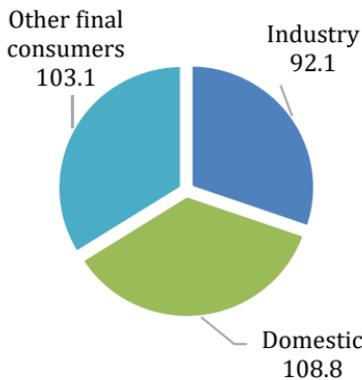


Figure 13 - Electricity consumption in the United Kingdom by sectors in 2015 (in TWh)

Source: NATIONAL STATISTICS (2016a)

In the following, it is worth comparing the above with some of the other European countries. Also, when this comparison is carried out, let us stick with the electricity production only, because these parameters tell us sufficient information about how a country is provided with energy resources and, therefore, other economic situations can be linked. It is not the aim to analyse consumption thoroughly, and the reason that this chapter only discusses and makes comparisons to electricity generation is enough to show links to local energy dependency or independency. For example, if a country's electricity is dominantly generated from hydro, that links to the dominance and sufficiency of local energy resources, while a largely mixed structure with fossil fuel dominance links to insufficiency and higher dependency of import fuels.

Throughout the *Brexit* campaign, the leavers frequently used *Norway* as a possible way for the *UK* to follow, so here it is (*Figure 14*) *Norway's* electricity pie chart:

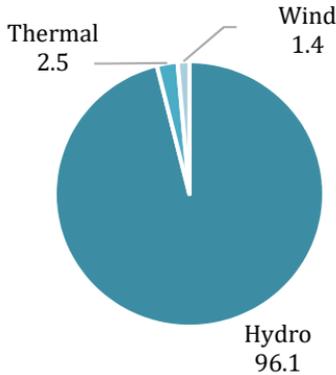


Figure 14 - Electricity generation in Norway (2013)

Source: SSB (2015)

Figure 14 shows information on what methods *Norway* uses to generate electricity. The data is as of 2013 (SSB, 2015), but if a similar chart is analysed now or ten years earlier, it would, without doubt, have looked the same with an overwhelming dominance (96.1%) of

hydroelectric power. And, it is very likely that this mixture will not change any soon in the future. The answer behind the predominant share of hydro power based on at least two, but very important, factors and both are geographic: 1) *Norway* is situated in the oceanic climate region and 2) it is a largely mountainous country with high peaks, steep hillsides, deep valleys and fjords. The first information tells us that the country receives an immense amount of precipitation every year (above 1,000 mm), the second tells us that the country's natural givens are fully suitable for harnessing the power of the rivers. Basically, the *UK* and *Norway* are very similar in their physical features, but whilst the first one's mountain municipalities share 25.21%, the second one's 91.84% (EUROPEAN COMMISSION, 2004). As of today, *Norway* has access to over 4,000 river systems, and has over 900 fully operational hydro power plants with the installed capacity around 30,000 MW (produces about 125 TWh electricity) which makes *Norway* the 6th largest hydroelectricity producer on *Earth* (GONZALES, D. *et al.* 2011; WIKIPEDIA, 2016).

It is also an important fact that *Norway*, since the discovery of the *North Sea* and *Barents Sea* hydrocarbon fields, the country's economy has been dominantly set on the trade of crude oil and natural gas. Their domestic use is very little and both are mainly used in transportation (fuels) and household supplies (cooking and heating). According to CIA (2016), whilst the production in 2015 was estimated 1.568 million barrels per day⁴, the refined petroleum products consumption was only 225,200 bbl/day (the production in the *UK* in 2013 was 771,800 bbl/day, the refined petroleum products consumption in 2014 estimated to 1.505 million bbl/day). According to INDEXMUNDI (2016), the domestic use has been constant since 1980 whilst the production peak period was in 2000 when, on a daily basis, 3,222 thousand barrels of crude oil was produced, principally for export purposes. That is where *Norway's* richness comes from which is the overall result of the naturally available energy resources, the size of the country's consumption basis and excellent trade policies in place (such as fishing).

⁴ An oil barrel (USA) which is abbreviated bbl.

The situation regarding electricity generation and the reliance of energy resources in *Iceland* is very similar to that of *Norway's* (Figure 15).

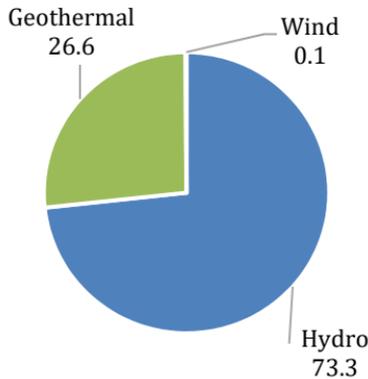


Figure 15 – Electricity generation in Iceland (2015)

Source: OS (2015)

The harness of hydroelectric power has been the most traditional since the main island, according to its terrain and climatic conditions (also oceanic), has a vast amount of water to utilise. The share in mix has just recently dropped down to 73.3% which is due to the more diverse and logical use of geothermal energy. *Iceland* is an active volcanic island where the energy of *Earth* can easily and sufficiently be accessed without any modification. All the energy production then is consumed by only a small number of people which is about the same as a middle-size city in the *UK*. *Iceland*, according to its natural resources, is able to supply its electricity production from 100% domestic resources. One would now raise the fact that *Iceland* does not require international co-operation, but in 2016, exclusion from global happenings would not make *Iceland* one of the richest (by GDP) and most developed countries on the planet. This country still has to be part of international trade and research networks.

The third country one could hear about many times through the *Brexit* campaign is *Switzerland* whose energy usage and electricity

generation is significantly different to those in *Norway* and *Iceland* (and also in the *UK*) (*Figure 16*).

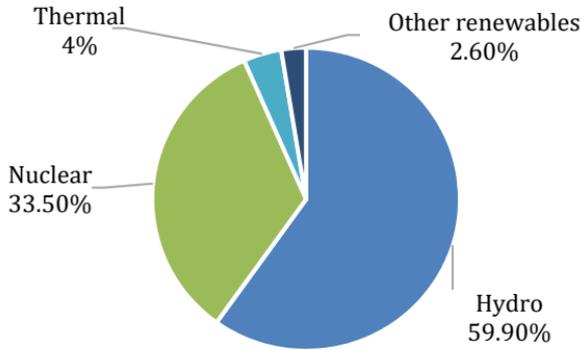


Figure 16 – Electricity generation in Switzerland (2015)

Source: SFOE (2016)

The country is, however, situated in the middle of the *Alps* where a high number of fast and powerful rivers can be utilised for energetic purposes. *Switzerland* has a very strict environmental regulation in place which does not allow the use of conventional power stations, therefore the rest of the electricity is predominantly produced by nuclear power stations.

Several other European countries and their primary energy use or electricity production could be looked at which would show a different reliance according to their natural givens. It is however a good idea to have a look at *Germany*, a country with similar size of economy, land area and population to the *UK*, how and in what ways produces electricity (*Figure 17*).

Having an analytical look at the pie chart, one can see an example of a traditional, strong, continental economy. The coal is still very dominant, but the energy share shows a diverse range of energy resources. The best way to be quasi independent or secured on energy resources when a country has a continental situation if a country develops the energy mix as diverse as possible, which means: the more type of en-

ergy sources is being used, the better and safer the country's electricity production is.

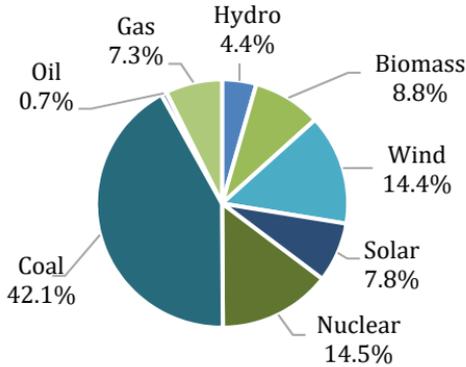


Figure 17 – Electricity generation in Germany (2016)

Source: FRAUNHOFER ISE (2016)

In *Germany*, this means a wider and more efficient reliance on locally available renewable energy resources including dominantly wind, biomass, solar and hydro energy which currently sums up 36.9% in the overall share. Never underestimate the importance of the total share of renewables, *Germany* (and the *UK* too) is still dependent on fossil resources and they need a wider integration with other energy suppliers to run their country and economy effectively.

As an extra addition, *Japan* is one of the non-European examples that has a very dependant energy economy which, according to 2013 statistics, includes 32.42% coal, 14.43% oil, 38.68% gas, 0.9% nuclear⁵, 7.52% hydroelectric, and 6.04% other renewables in its energy mix whilst the country's production, according to its naturally available fossil resources, are very limited (FEPC-DP, 2016). Also, the country is isolated from mainland grid integration and, despite its rich renewable resources, *Japan* only uses 2% of these for electricity generation (BER-

⁵ Note that after the *Fukushima accident* (2011) caused by a series of earthquake and tsunami, *Japan* shut down all of its nuclear reactors (54) and only 2 have been approved to restart since 2012 (BERRAHO, D. 2012). Before the great shut down, nuclear energy represented about 30% in *Japan's* electricity generation.

RAHO, D. 2012). After the *Fukushima accident*, as a result of nuclear phase-out, the Japanese government has started moving towards the renewables and by 2030, it aims to achieve about 22–24% of its share in the energy mix (FEPC-DP, 2016).

7. Summary and conclusion

It is important to rule out the principal differences among these charts, shown in *Chapter 6*, based only on electricity generation of the *United Kingdom, Norway, Iceland, Switzerland, Germany*, and additionally of *Japan*; and even more important to understand the ‘whys’ and ‘hows’ in the overall energy economics. It is understandable that an area without suitable terrain will not be able to provide a country with the possibility to build efficient hydroelectric power stations. But, *Europe* is a large continent where a significant number of locally accessible renewable resources is available. If the charts are analysed at national levels, the *Need Model* (BOKOR, L. – NEMES, V. 2014) helps show what this dependence means if the *UK* is compared, for example, to *Norway* (*Figure 18*).

The *Need model* shows how a local entity should rely on its local resources to be independent, but if this is not possible, and in most countries’ cases it is not, then a wider co-operation is required between or among those places who have the same or similar energetic conditions. In this case, being part of a larger economic body with a significantly larger land mass is the only rational answer. If this model is set against electricity generation (*Figure 18*), *Norway* produces 100% of its demand from domestic resources (SSB, 2015) which indicates positive sustainability, energy use and efficiency, whilst the *UK*’s dependency on imported fuels is predicted to increase in the next decade (in 2015, the import dependency was 38.6%—DEPARTMENT OF ENERGY AND CLIMATE CHANGE, 2016b) means negative local sustainability. This growing reliance is unavoidable even if the demand is set to shrink (MORISON, R. 2016); therefore, the *UK* needs international co-operation to provide its economy with the necessary resources. In the event of *Brexit*, *Britain* would, however, face higher energy import prices which would

potentially drive up domestic energy prices (KAHYA, D. 2016). This is why the *UK's Need Model* is negative, but the *Co-operation Model* indicates that this could still be shifted towards positive sustainability. The answer is a wider international integration and not separation. Most of the energetic challenges that affect a certain locus (a country for instance) are eventually political negotiations too which means, naturally provided and locally available resources and their domestic utilisation is always a subject of current political decisions. These decisions are not always rational and not always focus on those that would make a country's energy systems independent.

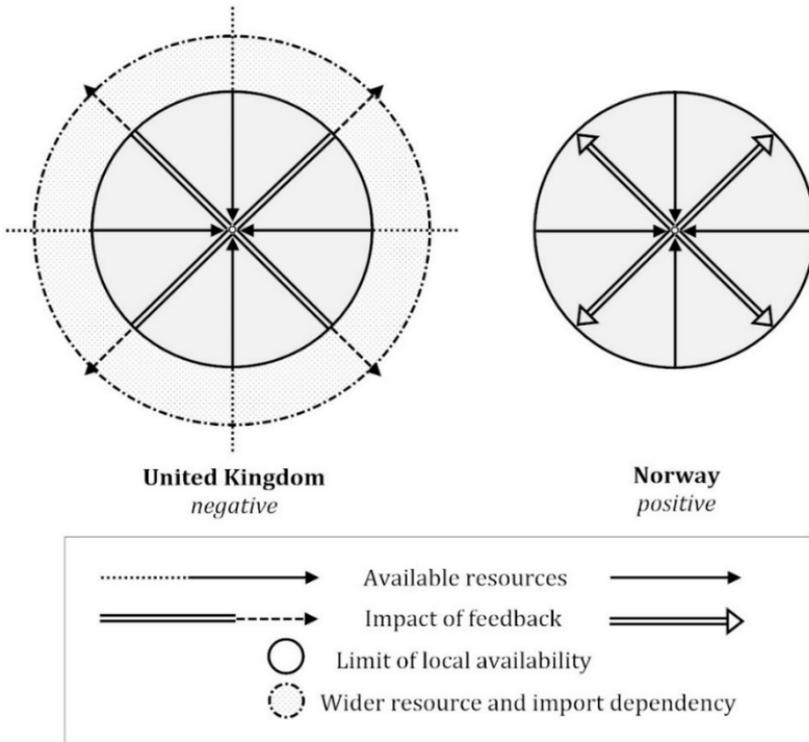


Figure 18 – The Need Model adapted to the UK and Norway according to their electricity generation reliance

Based on BOKOR, L. – NEMES, V. (2014), edited by BOKOR, L. (2016)

The energy economics of the *Earth* (including all the economies) has been increasingly shifting towards the use of renewable energy resources. The answers may be simple: the easily accessible fossil energy resources are in decline, mostly because their extraction is not economically sustainable any longer (because the easily accessible resources have already run out) and due to known environmental concerns and their evident contribution to global climate change. In this progressive system, energy resources (especially wind and solar) will be increasingly favoured and this is the only way for *Europe* to become more independent on import fuels from outside the continent which is the definite result of the reduction of fossil fuels. The *European Union's* physical geographical properties indicate that the entire continent could move towards and be by 2050 a decarbonised, reliable and efficient, largely renewable energy resources-based power system (PwC, 2011). But one has to see that the members of the *European Union* have to stick together to create a sustainable energy network and the key part of this is a wider integration and the independent use of the 'constant' resources available (shared) among the (currently) 28 member states.

8. Further researches

As it was presented in the case of *Japan*, the energy structure of an economy can change significantly, if an unaccepted event happens. The *Fukushima accident* has had a major impact on the Japanese, which has spiralled implications globally onto other energy economics. The energy structure of these other local formations may change overnight which has to be frequently analysed and updated. The author of this paper is planning to carry on developing a measuring method (which started a few years ago as a co-operation—BOKOR, L. – NEMES, V. 2014) to emphasise differences, for example between the *United Kingdom* and *Norway*, by employing indexed data which will give more understanding to the *Need* and *Co-operation models*.

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