GENI Global Energy Network Institute

Is 100% Renewable Energy Possible for the UK by 2020?

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List of Abbreviations

Organizations:

British Wind Energy Association (BWEA)
Climate Change Committee (CCC)
Department of Energy and Climate Change (DECC)
Department of Trade and Industry (DTI)
European Investment Bank (EIB)
Energy Technology Support Unit (ETSU)
Intergovernmental Panel on Climate Change (IPCC)
Marine Renewable Proving Fund (MRPF)
Marine Environmental Research Ltd (ABPmer)
National Renewable Energy Centre (Narec)
Office for Renewable Energy Deployment (ORED)
Renewable Energy Foundation (REF)
Renewable Heat Incentive (RHI)
Renewable Heat Premium Payment (RHPP)
Renewable Obligation (RO)
Renewable Obligation Certificates (ROCs)
UK Continental Shelf (UKCS)
United Nations Framework Convention on Climate Change (UNFCCC)
World Wildlife Fund (WWF)

Technical Abbreviations and Terminology

GW - gigawatt = 1000 megawatts
GWp – Gigawatts peak (in the context of photovoltaics)
kWh – kiloWatt hour
MWh – MegaWatt hour: a megawatt is equal to one million (106) watts
MWp - Megawatts peak (in the context of photovoltaics)
TWh - Terawatt hours: one terawatt is equal to one trillion (10^{12}) watts

Mt - Million tons
ppm - parts per million

Air-source heat pumps (ASHPs)

Combined Heat and Power (CHP)

Feed-In-Tariff (FiT)

Abstract

As the threat of global warming increases, the UN has warned that we are dangerously approaching several “tipping points” where the damage is irreversible, and future generations will be greatly impacted. At this critical time, there is still hope to save our planet from further damage if fast action is taken. This paper examines whether enough action is possible, in a short space of time. We first look at the current stage of energy and the percentage provided by clean or “renewable” energy in comparison to the potential that can be contributed by each form of renewable energy and the timeline and actions required to make this transition. The UK has a rich source of wind and marine energy that theoretically can meet the current worldwide demand many times over using just this resource. In fact, this report concludes that it is possible for the UK to become 100% renewable by 2020. More than enough resources and technology already exist to make this happen. The decisions made over the next few years must be the right ones to ensure a sustainable future.

Chapter 1 Introduction and Overview

Since the beginning of the Industrial Revolution, the average global temperature has risen by 0.8°C, with about two thirds of the increase occurring over just the last three decades. Scientists are more than 90% certain most of it is caused by increasing concentrations of greenhouse gases produced by human activities, such as burning fossil fuel and deforestation. If temperatures continue to rise, it **will reach a point of irreversible climate damage** identified as the "tipping point." Independent analyses indicate that this limit is **2°C.** (Verolme 2010) The UN warned that the world is moving closer to several "tipping points" beyond which some ecosystems that play a part in natural processes, such as climate or the food chain, may be permanently damaged. There is an urgent need to reduce greenhouse gas emissions before it is too late. (Verolme 2010) If nothing is done to curb the emissions from burning fossil fuels, current CO_2 levels of 380 parts per million (ppm) are likely to rise to 1,000 ppm. If global warming continues on the course of the worst-case scenarios predicted by the Intergovernmental Panel on Climate Change (IPCC), we are likely to reach this tipping point some time before 2200 (Connor, Scientists 'expect climate tipping point' by 2200 2010). The decisions we make over the next few years are of utmost importance to achieve a sustainable future.

It IS still possible to stay below the limit to save our climate from irreversible damage, but we need to actively change our energy system fast in order to do so. Hans Verolme, the WWF Climate Change Communications Manager, makes a strong and compelling point on the matter:

"The technology exists to dramatically increase the efficiency of our societies, produce energy with zero-to-low CO_2 and drive innovation. The challenge rather is a political one, whereby decision-making structures must be put in place in order to drive such change. It is not acceptable to dismiss 2°C without having attempted to change the politics so that we can avoid the associated impacts. Vast resources and decision-making structures have been put into place to deal with military conflicts which may have less likelihood of occurring than the impacts from climate change. The UK government and scientific community should focus its efforts on delivering this kind of change, rather than slipping into a world where devastating impacts would be the result." (Verolme 2010)

No one single technology is the answer. Although one may certainly have potential, other factors may come into play such as issues of reliability and consistency, but solutions exist as a combination of exploiting and feeding all available renewable energy resources together into the grid to provide more than enough energy to supply our daily needs and eradicate our dependence on oil & gas.

Figure 1 Effects of Global Warming Source: www.aboutmyplanet.com

1.1 Current UK Emissions

The latest statistics on UK greenhouse gas emissions are obtained from The Department of Energy and Climate Change (DECC). DECC published provisional estimates for 2010 UK greenhouse emissions together with final estimates for 2009 UK greenhouse gas emissions. According to this report, the UK was estimated to have emitted 491.7 million tons (Mt) of carbon dioxide, which is a 3.8% increase compared to the previous year of 473.7 million tons. This increase has been attributed to the rise in residential gas use as well as using coal and gas for electricity generation instead of nuclear power. Technical problems occurring at some of the nuclear power stations meant there was less nuclear power available for electricity generation and hence more coal and gas power stations were used in place. The resultant increase in CO_2 emissions was around 4 per cent.

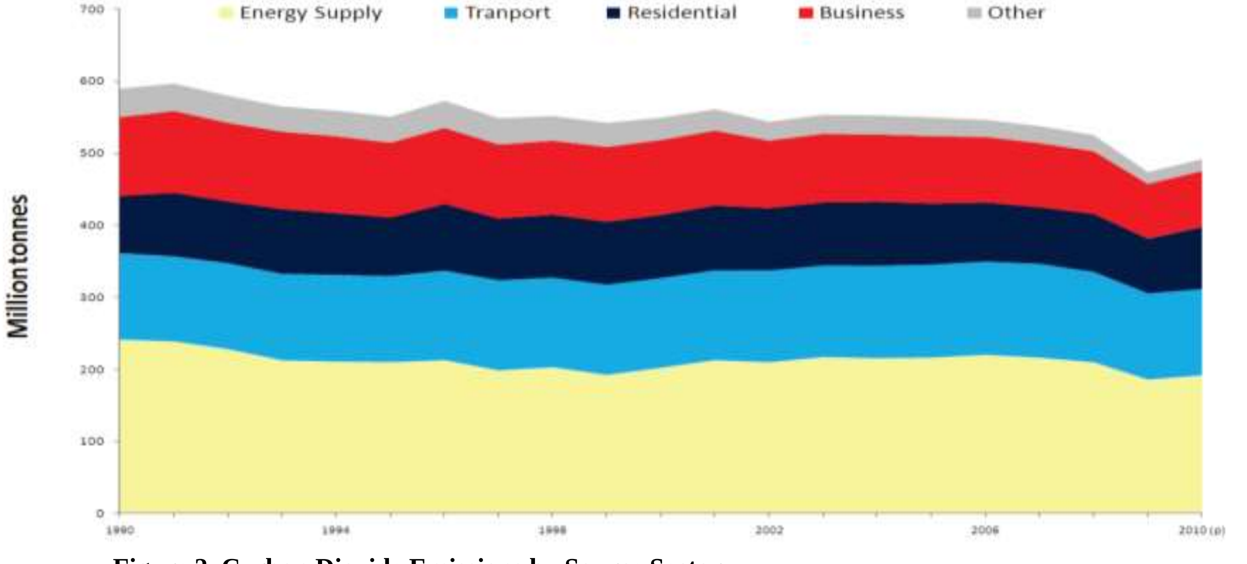


Figure 2. Carbon Dioxide Emissions by Source Sector
Source: AEA, DECC

In 2010, CO_2 emissions from power stations, at 156.2 Mt, accounted for just under a third of all CO_2 emissions (UK CLIMATE CHANGE SUSTAINABLE DEVELOPMENT INDICATOR 2010 GREENHOUSE GAS EMISSIONS, PROVISIONAL FIGURES AND 2009 GREENHOUSE GAS EMISSIONS, FINAL FIGURES BY FUEL TYPE AND END-USER 2011). 39% of these emissions in 2010 were estimated to come from the energy supply sector, with another 25% coming from transport, 17% from residential fossil fuel use and 16% from the business sector. As can be seen in Figure 2, energy supply is the biggest contributing factor of CO_2 emissions, followed closely by transport. Finding alternative ways of generating electricity and transport fuel is vital to stay below the “tipping point” and achieve a sustainable future.

For many years, the UK was the net exporter of oil and natural gas in the EU. In 2004, the UK became the net importer of natural gas and in 2005, the net importer of crude oil (Figure 3).

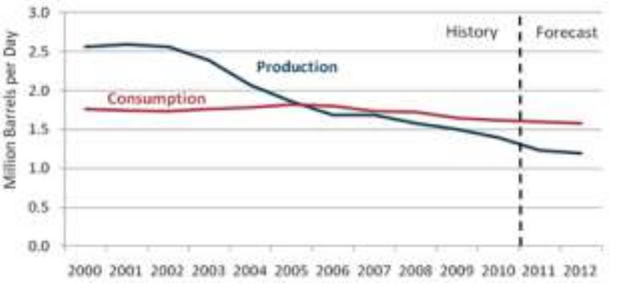


Figure 3. UK Oil Production and Consumption (2000-20012)
Source: U.S. Energy Information Administration

Now production is in decline, and the UK has become a net importer of energy with a dependency level of 28%. 90% of supply is from fossil fuels, although supply from renewable has increased to 3.3% of consumption on the EU agreed basis (Digest of United Kingdom Energy Statistics 2011 2011). While the UK is importing fuel for energy use and is dependent on foreign countries, it holds vast potential in its own vicinity to theoretically more than power the world. The majority of it still remains untapped.

So we recognize there is a problem, and we are heading down a dangerous road with disastrous effects. We have to act now and fast to change direction. The decisions and the actions made in the next 10 years are crucial to ensure a sustainable future for us and for generations to come. To alert us to act fast, this report gives a "reality check" of what will happen if we do nothing and remain on our current course of emissions in 2020. An article by *The Independent* reported that according to scientists the world will have exceeded the 2050 safe carbon emissions limit by 2020 (Connor, Climate chaos predicted by CO2 study 2009). Another study found that the world has already emitted about a third of the total amount of CO_2 emissions allowable between 2000 and 2050 to remain within the 2C global rise zone, known as the "safe threshold." The current global rate of CO_2 emissions is increasing by 3 per cent a year. If this continues the total limit of emissions of 1,000 billion tons set by international obligations for 2050 would be achieved 20 years earlier than planned.

Malte Meinshausen of the Potsdam Institute for Climate Impact Research in Germany led the study. She states:

"*Substantial reductions in global emissions have to begin soon – before 2020. If we wait longer, the required phase-out of carbon emissions will involve tremendous economic costs and technological challenges. We should not forget that a 2C global mean warming would take us far beyond the variations that Earth has experienced since we humans have been around.*" (Connor, Climate chaos predicted by CO_2 study 2009)

There is very little time left to make a turning point and change our direction, but we have not hit it yet, and there is still time.

This paper asks the question whether the UK can move entirely to renewables in the UK by 2020. If the technology exists and the urgency is there, what is stopping this from happening? The following chapters show the potential, the possibilities and roadmap to achieve it. Our future is in our hands.

Chapter 2 Government Legislations

2.1 Government Incentive

The Government believes a total of 29 GW of operational renewable energy capacity by 2020 is feasible (UK Renewable Energy Roadmap 2011). Scotland has its own target of achieving 100% renewables by 2020 and has set a Route map to do this. This makes Scotland the place to invest in renewable energy within Europe and puts Scotland on the map as one of the most enterprising renewable energy economies in Europe, as well as being a vital part of the UK's emerging low carbon economy (Scottish 2020 Routemap for 100% renewable electricity 2011). Scotland has great resource and expertise in renewable energy and has become a world-leading wave and tidal center of excellence with potential for substantial growth across all renewable energy sectors (Scottish 2020 Routemap for 100% renewable electricity 2011). Scotland has a strong renewable energy industry, always delivering and surpassing targets set and has attracted major companies like Doosan, Gamesa and Mitsubishi to set up bases there. Despite this, there are still challenges to the development of renewable energy which were outlined in the Route map, like improving grid capacity, technology advances and cost convergence which were all identified as areas where the Government and the industry should work closely together with communities and UK bodies such as Ofgem and the National Grid in order to create a framework which will ensure delivery of the targets. Scotland's incentive for the growth of renewable energy is by paying dividends. They recognize it as a major part of the energy mix and a significant part of their economy (Scottish 2020 Routemap for 100% renewable electricity 2011). If Scotland can at least try to achieve this, maybe there is a possibility in the UK as a whole to achieve 100% renewables by 2020 as this paper suggests.

The UK has signed the Kyoto protocol and is obligated to reduce its greenhouse gases emissions by 12.5% compared to the level in 1990 by 2010. The UK set its own more ambitious target to achieve a reduction of 20% by 2012. The UK is clearly concerned and has shown considerable commitment to doing its part (UK CO_2 Emissions 2005). The UK is on track to meet, and improve on, its Kyoto target (Figure 4). In 2010, the UK's emissions were predicted to be around 11 per cent lower than the levels required by Kyoto (International action on climate change 2012).

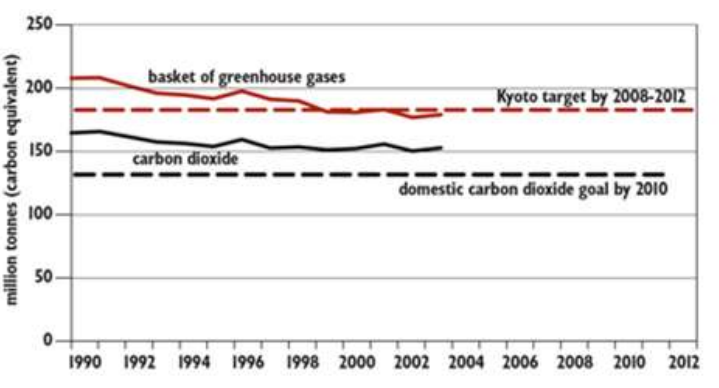


Figure 4. UK Emission of Greenhouse Gases   Source: UK Budget 2005

In addition to the Kyoto Protocol, the UK also signed the United Nations Framework Convention on Climate Change (UNFCCC). The UK government also has long-term plans to reduce the CO_2 emissions it releases to the environment. The Climate Change Act has legally binding targets including cutting 80 per cent of greenhouse gases released by 2050. The Stern report, published by the HM Treasury in 2006, analyzed the economic impact of climate change. Its findings show that **the costs of inaction far outweighed the costs of action** (A history of climate change 2012). The Climate Change Act, published in 2008, (Climate Change Act 2008: Impact Assessment (final) 2009) outlined the UK's position on climate change. The UK mainly wants to transition towards a low-carbon economy as well as demonstrated leadership internationally, taking responsibility and showing commitment to agreements. The UK also developed negotiations on post-2012 global agreements at Copenhagen in December 2009 (CLIMATE CHANGE ACT 2008: Impact Assesment 2008). The Climate Change Bill set what is referred to as "carbon budgets" which are legally binding 5-year budgets for the next 15 years. The first three carbon budgets will run from 2008-12, 2013-17 and 2018-22. This provides a clear pathway for the UK to meet its targets. To execute this, the government MUST promote the development of low carbon technology. The UK is legally bound, under the EU Renewable Energy Directive, to produce 15 per cent of its energy from renewable sources by 2020 from a present level of 2% (Figure 5). The UK Renewable Energy Strategy in 2009 set plans to meet this target and the government estimates that 30% of electricity, (5% at present) 12% of renewable heat (0.6% at present) and 10% of transport (2% at present) energy will be required to come from renewable sources (Figure 6). (UK Renewable Energy Strategy 2009 2009) Chapters 3, 4 & 5 will show the UK renewable energy resources and the potential to make 100% of the energy to come from renewable sources by 2020.

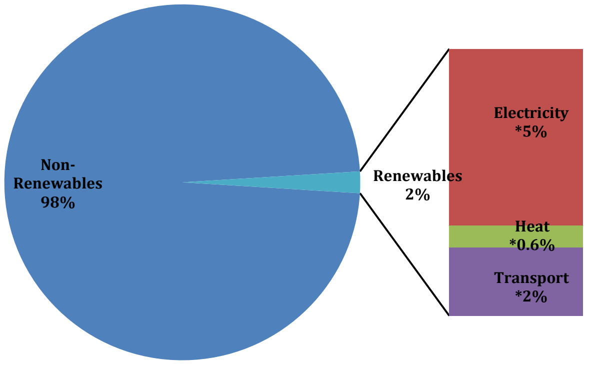


Figure 5. Current Energy by Source
**** amount currently required from renewable sources*.**
Source: Author

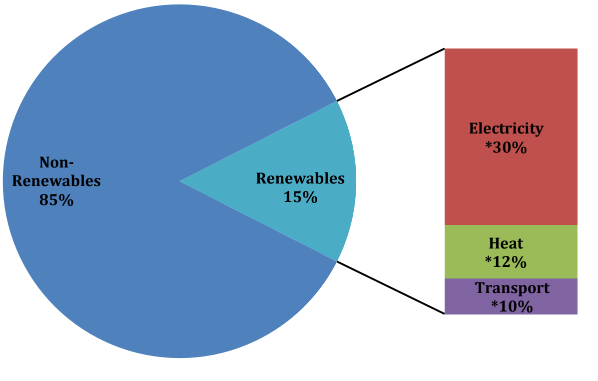


Figure 6. Amount Required by 2020 to Meet Targets
****amount supplied by renewable sources*. Source: Author**

According to statistics released earlier this year, UK emissions are now 19.4% below 1990 levels, not including emissions trading, and 22% including emissions trading. The report by the DECC suggests the cause of this decrease is from switching from coal to natural gas as well as lower fossil fuel consumption by industry and the transport sector (UK to over-achieve on Kyoto Protocol emissions target 2010).

2.1.1 ROCS

The UK government has also introduced Renewable Obligation Certificates (ROCs) as an incentive for this transition to renewable energy. A ROC contains details of how the electricity is generated, who produces it and who uses it. All UK licensed electricity suppliers are obliged to obtain a proportion of the electricity they sell from eligible renewable sources. Starting from April 2002, this renewable obligation was 3% and has increased every year. It reached 11.1% by 2010/11, and by 2015/16, it will reach 15.4% with a goal to reach 20% by 2020 (Figure 7). The cost to consumers will be limited by a price cap, and the obligation is guaranteed in law until 2027 (Bamber n.d.). In 2010, the scheme was extended from 2027 to 2037 (National Renewable Energy Action Plan for the United Kingdom 2009). Since its introduction, the Renewable Obligation has **more than tripled** the level of eligible renewable electricity generation (from 1.8% of total UK supply to 7.0% in 2010) (Digest of United Kingdom Energy Statistics 2011 2011).

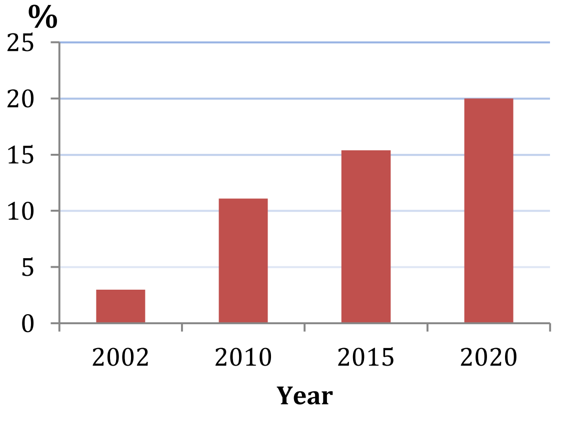


Figure 7. Renewable Obligation Percentage by Year
Source: Author

The following sources of electricity are able to attract ROCs:

- Biogas from anaerobic digestion
- Biomass
- Hydro electric
- Tidal power
- Wind power
- Photovoltaic cells
- Landfill gas
- Sewage gas
- Wave power

The way the ROC works is usually that for every 1,000 units (1MWh) of green electricity the company generates, they receive one ROC. However, some technologies get more, some less. For example, offshore wind installations receive 2 ROCs per MWh whereas sewage gas-fired plants receive ½ ROC per MWh. If a company generates more than its obligation, it is eligible to sell ROCs to energy companies that have failed to meet their obligation, who by law must purchase them or incur a fine (Bamber n.d.). This gives an incentive for energy companies to invest in renewable energy generation projects for financial gain. ROCs can sometimes sell for more than the power itself. This is especially true for wind power, which already produces electricity at competitive prices. The market sets the prices of ROC, and it is a reflection of the difference between the percent of electricity generated from renewable sources by the UK. The UK government aimed for 10% of its electricity to come from renewable sources by 2010 but failed to reach that target, and currently generates only around 6.5% from renewable sources, driving up the price of each ROC. Why the UK missed this target is discussed in Chapter 3.1. The current price of ROCs is around £36.99 (£/MWh). Prices could fall as more wind turbines and wind farms come online (THE RENEWABLES OBLIGATION BUY–OUT PRICE AND MUTUALISATION CEILING 2011-12 2011). ROCs are not just restricted to major utility companies. Even small-scale RE generators are eligible to receive and sell them (Renewables Obligation Certificates 2008). In order to meet the legally binding EU target of obtaining 15% of energy from renewable sources by 2020, the UK Government estimates that 30% of electricity demand will need to come from renewable sources (National Renewable Energy Action Plan for the United Kingdom 2010). The Renewables Obligation is a way for the UK Government to stimulate growth in the renewable energy industry to attempt to reach this target (Reform of the Renewables Obligation 2007). Government intervention has proven to stimulate growth in the industry and needs to continue to attain a rapid increase in installation and deployment. The Renewable Energy Strategy 2009 sets out measures to achieve targets including making changes to the RO to generate more larger-scale renewable energy as well as increasing the use of sustainable biofuels by making changes to the Renewable Transport Fuel Obligation (UK Renewable Energy Strategy 2009 2009).

2.1.2 Feed-In Tariffs

Feed-in Tariffs were introduced in April 2010 to offer financial support for the generation of low carbon electricity projects up to 5MW (UK Renewable Energy Strategy 2009 2009). The Office for Renewable Energy Deployment (ORED) was also established in order to support renewables' supply chains and renewables in the planning system. Increased investment in wave and tidal generation is to be made as key renewable technologies as well as improvements to offshore wind technologies. Also the southwest is to be identified as a Low Carbon Economic Zone for marine development (UK Renewable Energy Strategy 2009 2009). Feed-In Tariffs will replace the RO scheme, which will close to new accreditation in March 2017.

As Chris Huhne, UK Energy Secretary, says*:*

"A new generation of power sources including renewables, new nuclear, and carbon capture and storage, along with new gas plants to provide flexibility and back-up capacity, will secure our electricity supply as well as bringing new jobs and new expertise to the UK economy. Growth on that kind of scale will be challenging, but will be necessary if we are to make the UK more energy secure, help protect consumers from fossil fuel price fluctuations, drive investment in new jobs and businesses, and keep us on track to meet our carbon reduction objectives for the coming decades. It will require industry to carry on making the case for renewables and government and the devolved administrations to break through the barriers that are stopping new schemes being built."
(ELECTRICITY MARKET REFORM: KEEPING THE LIGHTS ON IN THE CHEAPEST, CLEANEST WAY 2011)

2.1.3 Renewable Heat Incentive (RHI)

The Government announced the Renewable Heat Incentive (RHI) details in March 2011 from large industrial sites down to the household level, through payments per kWh of heat produced from April 2011 (Digest of United Kingdom Energy Statistics 2011 2011). The incentive was in place to promote the delivery of 57 TWh of renewable heat which would be about 12 per cent of heat coming from new and diversified renewable sources which would save 44 million tons of carbon by 2020 (Energy Trends n.d.).

Chapter 3 Renewable Energy Resource and Potential

3.1 Why Did The UK Miss Its 2010 Target?

In 2010, only 6.5% of the UK's electricity came from renewable sources (about 25.7 TWh), failing to meet its target of 10% (Renewables Output in 2010 2011). Even though low winds in 2010 are accountable for part of the shortfall, it is clear the target would have still been missed by a large margin even if wind speeds had exceeded the highest annual average in the last 10 years (Renewables Output in 2010 2011). There have been many plan delays with the construction of large scale wind farms, onshore and offshore which were consented but remain un-built, but this does not appear to be responsible for the missed target. This 2010 shortfall has raised concerns for the UK's ability to meet its 2020 EU Renewable Energy Directive target for 15% of Final Energy Consumption, a level requiring at least 30% of UK electricity to be generated from renewable sources (Renewables Output in 2010 2011). An examination of the costs of various renewable energy technologies and their contribution to the targets confirm arguments that subsidies are inefficient for reaching these targets and suggests that these subsides need to be redesigned as a means of exploring an experimental field, with measures to reduce undue reward if they are to be used (Renewables Output in 2010 2011). In order to meet targets, the output from the most cost-effective technologies should be maximized, such as unsubsidized large hydro and energy from biodegradable waste, and emphasis put on those requiring fewer subsidies, such as biomass co-firing (Digest of United Kingdom energy statistics (DUKES) 2012).

3.2 Renewable Energy Potential

The Renewables Roadmap was published as a pathway of how the UK will achieve its target of generating 15% of energy from renewable sources by 2020. Eight technologies outlined here carry the capability of delivering more than 90% of the UK's renewable energy by 2020. It also works to reduce the cost of renewable energy over time.

They are:

- Onshore wind
- Offshore wind
- Ground source heat pumps
- Air source heat pumps
- Marine
- Renewable transport
- Biomass electricity
- Biomass heat

The main sources of renewable energy that currently contribute to electricity in the UK are Hydro, Biomass and Wind (Figures 8 and 9). Wind power is the second largest source of renewable energy currently in place in UK behind biomass but has been the largest growing over the past 10 years (Figure 9), and this trend is expected to continue with falling costs of wind energy, energy security threats and the urgent international need to tackle CO_2 emissions to prevent climate change (Onshore 2012). These sources have far greater potential than those currently in place but face obstacles to faster development. The 8 listed technologies have already been evaluated as the most capable technologies that should be maximized to deliver enough energy to meet the targets; therefore, they are the focus below along with their full potential and barriers.

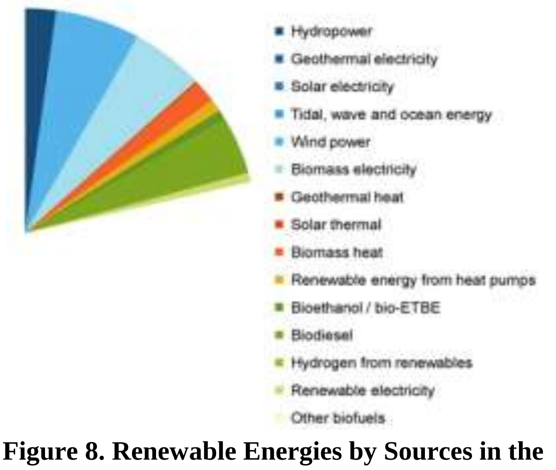


Figure 8. Renewable Energies by Sources in the UK (2010) since 2000. Source: DECC

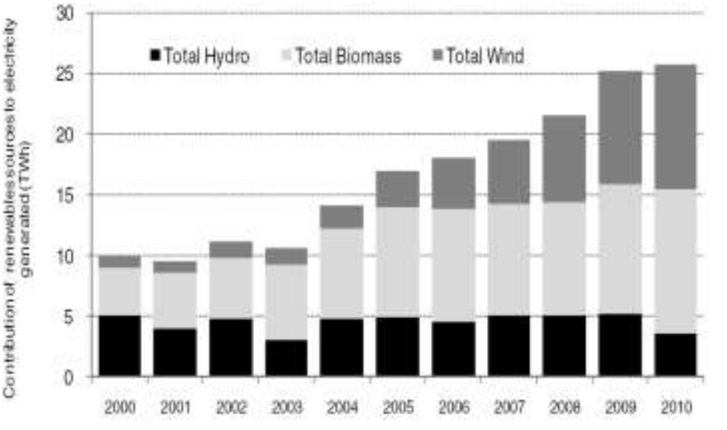


Figure 9. Electricity Generation by Main Renewable Sources. Source: DECC

3.2.1 Wind

The UK is the windiest country in Europe, so much so that **it could power the country several times over using this free fuel**. A modern 2.5MW turbine at a reasonable site will generate 6.5 million units of electricity each year, enough to meet the annual needs of over 1,400 households, make 230 million cups of tea or run a computer for 2,250 years (Figure 10) (Sinden, Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand 2005). Every unit of electricity

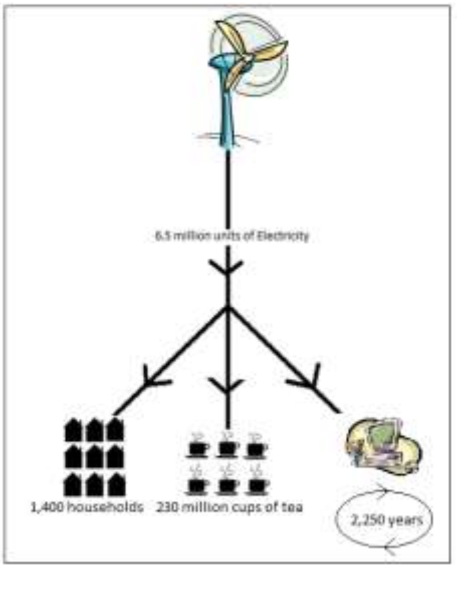


Figure 10. The Capability of a Modern 2.5MW Turbine. Source: Author

from a wind turbine displaces one from conventional power stations. In January 2009, **wind turbines in the UK had the capacity to prevent the emission of 3,682,563 tons of carbon dioxide per annum**. The Roadmap intends to establish an industry task force to reduce the costs of offshore wind to £100/MWh by 2020. The Government promised to spend up to £30 million on offshore development as well as mitigate the potential impacts of wind power on radar infrastructure that is estimated to have a potential impact up to 5GW of onshore and 7GW of offshore wind capacity. At the end of 2009, UK was the eighth country most powered by wind turbines in the world with 4.051 MW installed of a world total of 157.531 MW. The total installed capacity of wind power in the UK in 2010 was 5.194 GW, 1400 MW offshore, and 3,800 MW onshore with 2,283 MW under construction, about 1200 MW offshore and 1104 MW onshore (Figure 11).

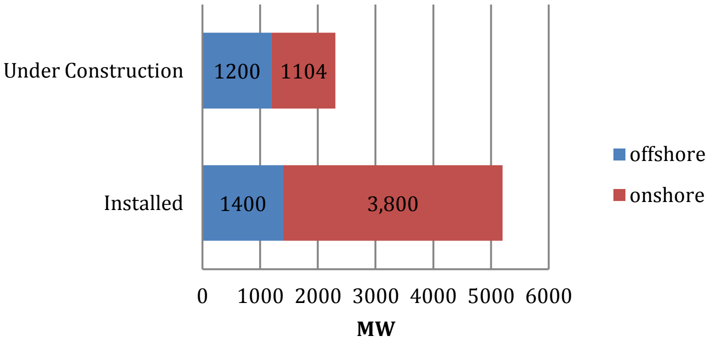


Figure 11. Capacity of Wind Power in the UK in 2010
Source: Author

In 2010, there was a recorded peak production of 1860 MW, which is 4.7% of total electricity production. Most coastal regions have mean annual wind velocities of at least 5m/s. Therefore, these areas are suitable for wind power stations. Particularly attractive conditions are found on the Shetland and Orkney Islands, the Outer Hebrides and the north coast of Scotland. See Figure 13 below.

3.2.1.1 UK Wind Potential

The UK has an excellent wind resource, both on and offshore. It is theoretically possible to obtain more than **1000TWh** of electricity each year from the wind. This is **almost 3 times the amount of electricity currently used** (Sinden, Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand 2005). We must take into account practical resource, meaning sensible restrictions like protected areas and the utilization of only the most economic sites to get an idea of a realistic resource. The estimate of likely practical resource by the Energy Technology Support Unit (ETSU) is something over 50TWh per year on land (Smith 2008). An average of approximately 2.2 TW (continuous output) of electricity was calculated as the theoretical resource of offshore wind turbines in UK waters. For context, current UK energy demand (electricity + heat + transport) is about 0.25 TW, and current UK electricity demand is about 0.04 TW_e. (Figure 12) (Smith 2008)

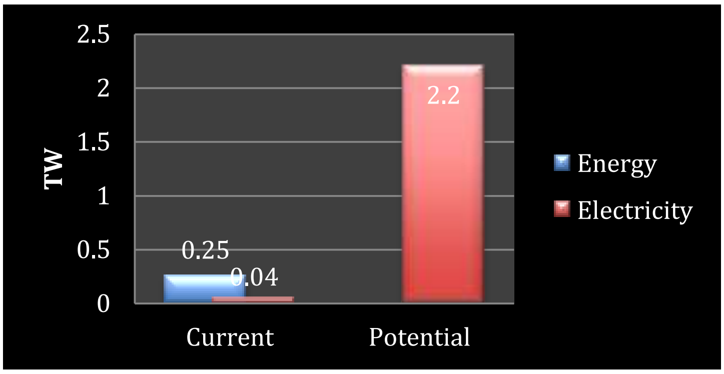


Figure 12. Theoretical Resource of Offshore UK Wind Turbines and Current Demand
Source: Author

The windiest places that are suitable for exploitation are on the coast and in the mountains, like off the coast of Scotland (Figure 13). Coastal winds have less exposure to the drag and turbulence effects encountered over land. Elevated land mean increased wind speeds as the air mass is forced to travel over or around the mountain. Wind speed increases with height above the ground or sea due to reduced frictional effects (Wind Resource n.d.). In comparison with Europe, Scotland appears to have the highest average wind speeds (Figure 14). However, the European neighbors despite having significantly lesser resources have harnessed their wind resource far more that Scotland (Bruce 2010).

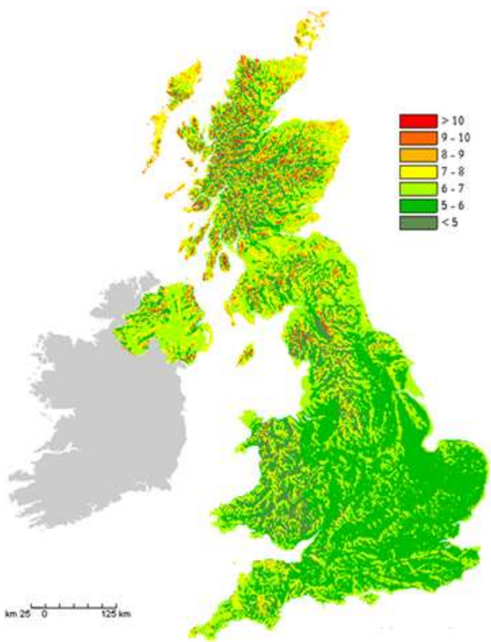
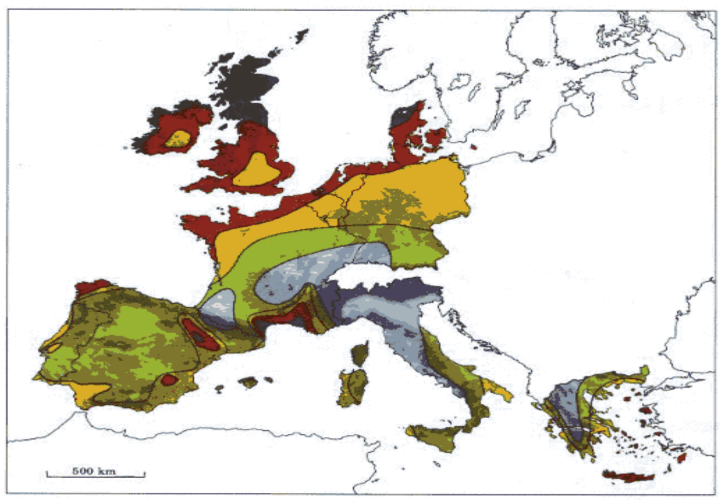


Figure 13. Annual Mean Wind Speed at 25m Above Sea Level [m/s]. Source: ETSU



Wind resources[1] at 50 metres above ground level for five different topographic conditions

	Sheltered terrain[2]		Open plain[3]		At a sea coast[4]		Open sea[5]		Hills and ridges[6]	
	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}	$m s^{-1}$	Wm^{-2}
	> 6.0	> 250	> 7.5	> 500	> 8.5	> 700	> 9.0	> 800	> 11.5	> 1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0- 8.5	400- 700
	< 3.5	< 50	< 4.5	< 100	< 5.0	< 150	< 5.5	< 200	< 7.0	< 400

Figure 14. European Wind Speed Map. Source: ESRU

3.2.1.2 Onshore Wind

In order to meet the renewable target for 2020, 14 GW is planned to come from onshore wind (National Renewable Energy Action Plan for the United Kingdom 2009). The European Investment Bank (EIB) will provide up to £700 million towards bringing forward onshore wind projects up to the value of £1.4bn over the next three years (Onshore 2012). Since the first wind farm in the UK was built at Delabole in 1991, onshore wind energy has established itself as a mature, clean energy generating technology. The Government's Renewable Energy Strategy states that the ambitious target of generating 15% of all the UKs energy from renewables by 2020 means that 35-45% of electricity will have to come from green sources. The lion's share of these renewables will have to be wind, some 33GW of capacity, delivering over £60 billion of investment and creating 160,000 green collar jobs.

The report, 'Building a Low Carbon Economy' (Committee on Climate Change, December 2008), stresses that onshore and offshore wind together can deliver 30% of the UK's electricity supply by 2020 and be part of a radical decarbonisation of the economy by 2030 (Engineering 2004).

A March 2006 report by the British Wind Energy Association (BWEA) forecast that onshore wind farms should be able to supply nearly 5% of the national electricity requirements by 2010 (6GW). The Royal Academy of Engineering conducted a study in 2004 on the price of wind power and found in 2004 that onshore installations cost 5.4 pence per kWh (p/kWh), and offshore installations cost 7.2p/kWh. In comparison, the price of gas was 2.2p/kWh and nuclear was 2.3p/kWh (MacDonald 2011). By 2011, onshore wind costs 8.3p/kWh, which is less than nuclear at 9.6p/kWh; however, according to Mott MacDonald, an engineering consultancy, offshore wind costs were at 16.9p/kWh which were significantly higher than earlier estimates due mainly to higher build and finance costs (MacDonald 2011). The way wind farms are made economically profitable is by subsidies through ROCs, which provide over half the wind farm revenue.

The biggest drawback with onshore wind farms is gaining planning permission. Many schemes are halted in the planning stage, and there is a high rate of refusal (Decision makers must heed Stern warning on climate change 2007), with approximately 7,000MW worth of onshore wind schemes waiting for planning permission (Harvey 2012). The approval rate of a wind farm is 40%, and there is an average wait of 2 years for an application to be considered by a local authority. Considering other major applications, like housing, retail outlets and roads, wherein about 70% are decided within the 13-16 week statutory deadline, for wind farms the rate is just 6%. For something as important as meeting renewable energy targets in a critical time, this waiting time has to be accelerated as well as a greater approval wait for the enormous amount of resource potential. The majority of the objections are from airports and traffic control on account of their impact on radar. This is currently the cause of objection to over 4GW worth of schemes, about half of the wind farms in planning applications. In 2008, NATS en Route, the BWEA, the Ministry of Defense and other government departments signed a Memorandum of Understanding seeking to establish a mechanism for resolving objections and funding for more technical research (Sinden, Wind Power and the UK Wind Resource 2005).

According to a report by the Environmental Change Institute at Oxford University, the UK has the best wind resource in Europe. The recorded capacity factor for onshore wind energy in the UK is 27%, which is even greater than Germany and Denmark, where wind farms are currently most widespread, with 15%

and 20%, respectively. The report, done in 2005, was the first methodical investigation of Britain's wind resource. It found that there has never been a time over the previous 35 years when the entire country has been without strong enough winds to generate electricity somewhere. It also found the stronger winds are abundant during the day and the winter months when demand is highest. In addition, there is only a chance every one hour for every five years of low wind speeds affecting 90% of the country and only one hour for every 10 years of wind speeds before being too high and causing wind turbines to shut down (Sinden, Wind Power and the UK Wind Resource 2005). Graham Sinden, author of the report, clarified that after examining such extensive wind records in the UK, both long-term trends and the most extreme conditions the UK will experience were identified in the study. He also says the wind energy in the UK could be greater than that in Germany and Denmark. Energy Minister Malcom Wicks concluded:

"The only sensible debate about energy is one based on the facts. This new research is a nail in the coffin of some of the exaggerated myths peddled by opponents of wind power." (UK has the best wind in Europe 2007)

Maria McCaffery, BWEA Chief Executive, also dismisses any claims that the UK wind farms are underperforming, pointing out that the wind energy industry is investing billions of pounds to produce clean energy in the UK in order to tackle climate change. Wind power supplies 1.5% of the UK electricity demand over 2GW, and wind farms generate electricity approximately 85% of the time (Wind Status Report UK breaks the 2 GW barrier 2007).

3.2.1.3 Offshore Wind Farms

The offshore wind industry is an important source of future energy supply for the UK, although it is a sector which has yet to fully mature (Renewable sources of energy n.d.). Out of the 39% that wind power is contributing to RE, only 6% is from offshore wind; yet offshore wind has far greater potential than onshore wind and being out of the way, more likely less objection. From 2009 to 2010, the largest increase out of contributing renewable energy generation was offshore wind. This is both in absolute and percentage terms and reflects the largest increase in capacity over the course of the year. The increase was 75% of offshore wind generation, from 1,740GWh in 2009 to 3,046GWh in 2010 (UK Offshore Energy SEA Scoping for Environmental Report 2012).

In December 2007, the Government set out its ambition to expand offshore wind capacity, with up to 33GW of offshore wind by 2020. The Government has an offshore wind ambition of 33GW (McCarthy 2008). Government and industry agree that offshore wind is the most appropriate technology to supply the majority of the renewable energy target. To meet the 2020 EU targets, the UK will need 7,500 offshore turbines (Actions for 33GW Report 2008).

In the report done by the BWEA in 2008 (Wind Status Report UK breaks the 2 GW barrier 2007), the barriers are laid out along with solutions and actions to delivering this potential in this time frame. They are primarily leadership, accountability and resourcing, constructive development of the supply chain, increase grid capacity and availability, optimization of the planning system and enabling economic feasibility. There has been an increased capital cost accompanying this growing industry, which is a cause for concern (Wind Status Report UK breaks the 2 GW barrier 2007).

"Meeting 2020 targets relies on supply chain companies making huge investment decisions now. That requires a stable industry with a long-term future. We welcome recent statements that the Government will take a more strategic approach, especially to grid, and hope to work with them to deliver the UK targets." Siemens Transmission and Distribution Ltd. (UK Offshore Wind: Charting the Right Course n.d.)

In October 2008, the UK overtook Denmark and became the world leader offshore wind power generation (Largest offshore wind farm opens off Thanet in Kent 2010). The UK is also home to the largest offshore wind farm in the world, called the Thanet wind farm, located of the Kent coast (Figure 15) [66].

Figure 15. Thanet Wind Farm Aeriel View
Source: www.experimentation-online.co.uk

In 2010, peak winter demand for the UK was 59.3GW (Smith 2008). In summer, it drops to about 45GW. One estimate calculates that wind turbines in one third of UK waters shallower than 25m (82 ft) would, on average, generate 40 GW; turbines in one third of the waters between 25m (82 ft) and 50m (164 ft) depth would on average generate a further 80GW, (i.e. 120GW in total) (RenewableUK - Offshore Wind Introduction 2004). Figure 16 shows how the total energy demand can be met with the resource laying at 25m deep. Beyond that at greater than 50m deep, the potential is vast. An estimate of the theoretical maximum potential of the UK's offshore wind resource in all waters to 700m (2,300 ft) depth gives the average power as 2200GW (James Oswald 2008). An estimated third of Europe's total offshore wind resource lies in the UK which is equivalent to three times the electricity needs of the nation at current rates of electricity consumption at times when the wind blows (Oswald, Raine and Ashraf-Ball 2008).

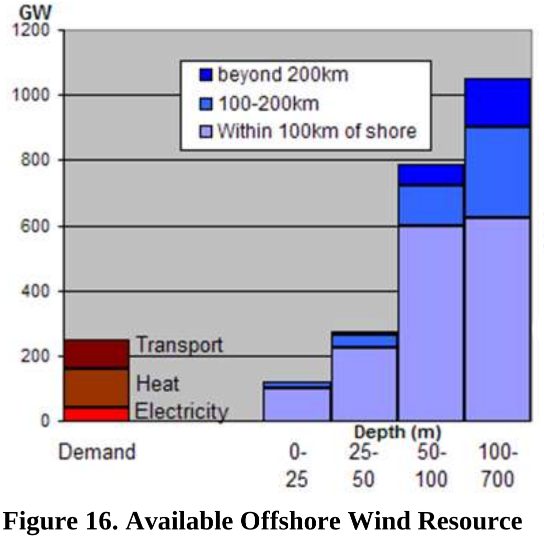


Figure 16. Available Offshore Wind Resource
Source: Claverton Energy Research Group

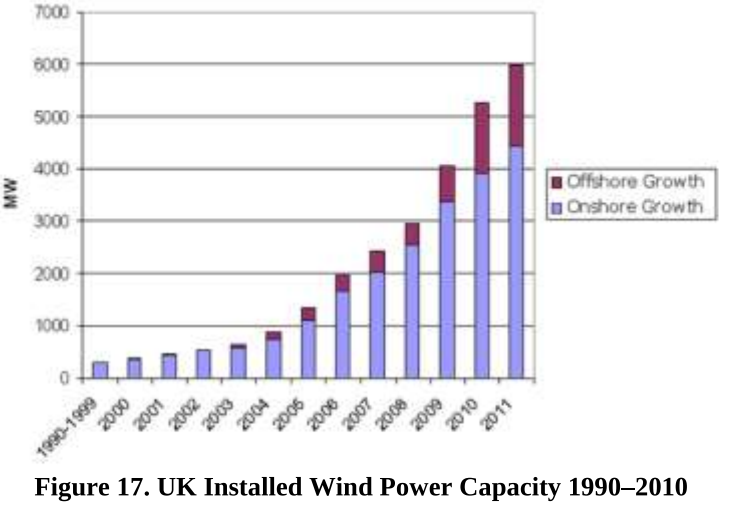


Figure 17. UK Installed Wind Power Capacity 1990–2010
Source: WIKI

The offshore wind industry has historically under-performed against delivery expectations – unlike the onshore wind industry, which outperforms on that front (Figure 17). Historically, projects have been beset by delays caused by a number of sources, including: planning delays, developer resource limits, waiting for transmission grid upgrades, weak economics, construction delays, and a shortage of wind turbines. The obstacles to developing projects are grid access and limitations, reaching financial hurdle rates, availability of capital, cumbersome and unproven OFTO regime, and consenting compromises on site area and capacity. These barriers must be addressed in order to exploit the rich resource laying in the UK (The Offshore Valuation 2010). Figure 18 shows the zones around the UK that are an indicative of economic potential.

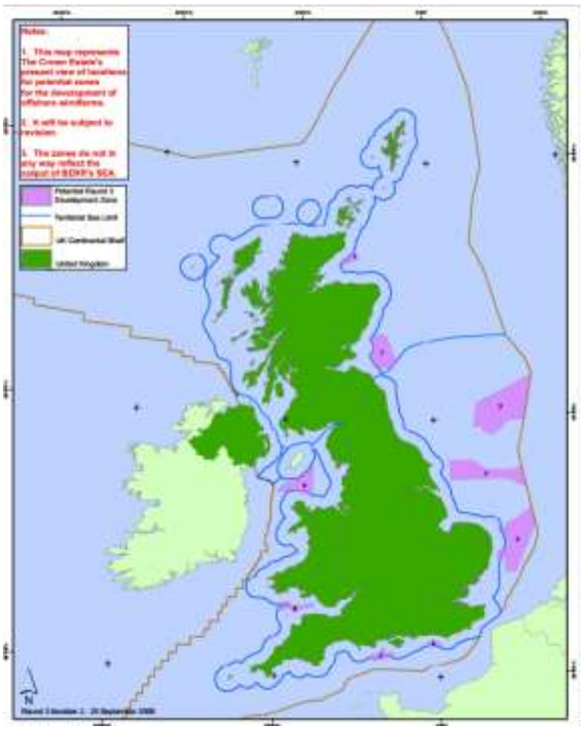


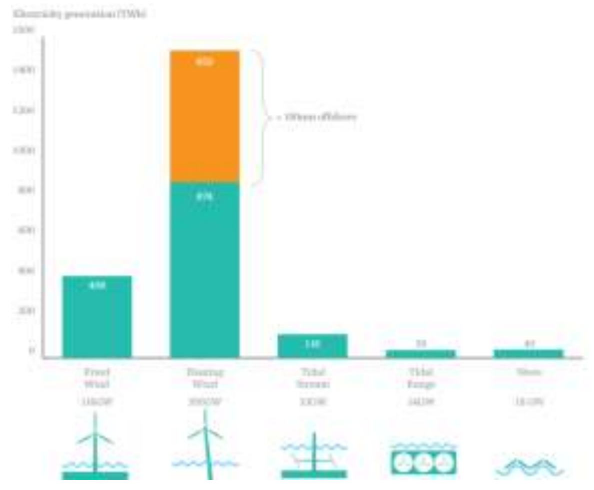
Figure 18. Indicative Economic Potential for Offshore Wind. Source: The Crown Estate

3.2.1.4 UK Total Offshore Potential (Wind, Tidal, & Wave)

Britain is known to have the largest resource of offshore wind, wave and tidal power within Europe, but until now the full scale of the economic opportunity this represents was unknown.

In April 2010, The Offshore Valuation Group published The Offshore Valuation, the first comprehensive valuation of the UK's offshore renewable energy resource over the long term that explicitly assesses electricity exports to Europe. The report envisions generating enough offshore renewable energy to meet the total UK electricity demand in 2050 and thus allowing the UK to export 50% excess to Europe, making the UK a net exporter of electricity. It could also mean the creation of 145,000 new jobs and provide the Treasury with €28bn in tax revenues annually. This could result in cumulative carbon dioxide saving of 1.1bn tons by 2050. According to the report, **the UK is using less than a third of the total available resources** and could potentially generate an equivalent of 1bn barrels of oil of electricity annually, which matches North Sea oil and gas production. It also states that if developed to their full practical potential, offshore renewables could theoretically allow the **UK to power itself six times** over at current levels of demand.

The UK's total practical offshore renewable resource is 531GW or 2,131TWh (Figure 19). The report examined how the UK could become a net exporter of offshore renewable electricity by 2050. If the UK were to exploit even just under a third of its total offshore wind, wave and tidal resource by 2050, it would become a net exporter. This would result in an infrastructure with a positive Net Present Value of



£35bn. The supply chain necessary to realize the central scenario would have annual revenues of £62bn in 2050, profits of £16bn. Furthermore, the benefits would be greater if fossil fuel prices rise higher than the Government's central projections.

Figure 19. Practical Resource by Technology (GW & TWh/yr)
Source: The Offshore Valuation Report

Key enablers to access this resource were outlined in the report which involves making Round 3 offshore wind grid connections 'super-grid compliant' to enable future potential electricity sales to Europe and taking a leadership role in current EU super-grid negotiations which will maximize the value of the UK's design and implementation (Huge potential of UK offshore renewable energy revealed 2010). Also, development of the UK supply chain is key to large scale deployment at least cost. New financing structures that can support the speed and scale required of industrial growth is needed.

Tim Helweg-Larsen, director of the Public Interest Research Centre (PIRC), which chaired the Group said, ***"This report seeks to present to the UK the true value of an energy resource right on our doorstep at a time when concerns over security of supply and climate change are ever present. To discover that we own a resource with the potential to return the UK to being a net power exporter, and on a sustainable basis, is genuinely exciting, and a wake-up call to those in a position to foster the further development of this industry."*** (The Offshore Valuation 2010)

3.2.1.5 Development of Wind Power

The current installed capacity of wind power in the UK was over 5.7 GW by mid-2011 [74]. The UK was ranked the eighth largest producer of wind power in the world. RenewableUK estimates that more than 2GW of capacity will be deployed per year for the next five years [75].

In 2010, significant offshore wind farms like Gunfleet Sands, Robin Rigg [76] and Thanet [77] were completed. This meant over 1.1 GW of new wind power capacity came online in 2010, which was a 3% increase from the previous year.

Onshore wind installations were at 815 MW in 2009 and dropped by 38% to 503 MW in 2010; however, there was a 230% increase in offshore installations from 285 installed MW in 2009 to 653 MW in 2010 (Figure 20). Offshore wind is starting to really take off in the UK, which is a great sign. A continuous rapid increase will be beneficial especially to balance the fall and barriers associated with onshore wind installations.

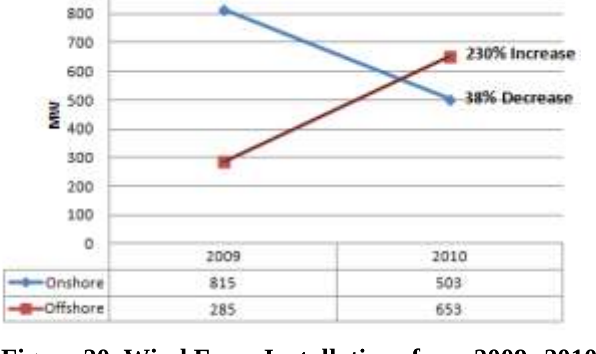


Figure 20. Wind Farm Installations from 2009 -2010
Source: Author

Table 1 shows the status of wind farms in the UK. If all were approved and completed, there would be a total of 929 wind farms in the UK generating a total of 24,989.78MW. Table 2 shows a summary of statistics from UKWED - one of the most definitive databases on wind energy projects in the UK.

Table 1. Current Statistics on Wind Farms in the UK. (Source BWEA)

	Operational		Under Construction		Consented		Planning	
	No.	MW	No.	MW	No.	MW	No.	MW
Onshore	301	4,247.52	37	1,635.27	235	3,725.72	325	7,660.17
Offshore	14	1,524.60	6	2,054.40	6	1,867.10	5	2,275.00
Total	315	5,772.12	43	3689.67	241	5592.82	330	9935.17

Table 2. Statistics of Wind Energy Projects in the UK
The data on homes equivalent is based on an estimated annual household energy consumption of 4.7MWhr
Source: UKWED

Currently operational - at a glance...						
Projects	***Turbines***	***Megawatts***	***Homes Equivalent***	***CO_2 reductions*** *(pa)*	***SO_2 reductions*** *(pa)*	***NO_X reductions*** *(pa)*
314	*3425*	*5770.615*	*3226633*	*6521026 tonnes*	*151652 tonnes*	*45496 tonnes*

Figure 21 shows the distribution of wind farms around the UK. [79]

Figure 21. Wind Farms in the UK
Source: BWEA

3.2.1.6 Plan of Action

How does the UK approach this enormous potential? The question they need to ask is: 'how do we become like Denmark?' in order to utilize the resource efficiently. The Danish Government invested £1.3bn in research & development and market stimulation measures between 1993 and 2003. This created a turbine manufacture and service & maintenance industry that earns £2.0bn in annual export revenues and employs 20,000 people, and today Denmark maintains a 40% share of the worldwide industry.

There are 3 possible scenarios, ranging from providing 50% of the UK demand to becoming a net energy producer listed in Table 3. To become a net energy producer, it would cost capital of £993bn, but this would utilize 76% of the resources with a 406GW capacity. The UK could reverse itself from being an importer and have more of a driving force in the energy industry depending on how much the government is willing to invest and how much of the untapped resource the government wishes to utilize.

Table 3. The 3 Scenarios. Source Author

	Installed Capacity	Resource Utilization	Capital Expenditure	Annual Revenue in 2050	
Scenario 1	78 GW	13%	£170bn	£28bn	50% UK demand
Scenario 2	169 GW	29%	£443bn	£62bn	Net *Electricity* Exporter
Scenario 3	406 GW	76%	£993bn	£164bn	Net *Energy* Producer

The Coalition agreement has agreed to deliver a new offshore electricity grid to support the development of a new generation of offshore wind power. The reality of the 2050 EU greenhouse gas target is that it cannot be met without very significant amounts of offshore renewable energy and the EU member states need the interconnection of a super grid to develop significant amounts of offshore renewable energy, which is vital for any of the 2050 scenarios. Therefore, the 2020 offshore grid connections must be super grid compliant [80].

Three reports on the wind variability in the UK issued in 2009 generally agree that variability, cut in and cut out speeds of the wind does not make the grid unmanageable; and the additional costs, which are modest, can be quantified [81]. It should be noted that although the output from single turbines can vary greatly and rapidly with varying wind speeds, as more turbines are connected over increasingly larger areas, the average power output becomes less variable [82]. According to a spokesman for the Scottish Government, renewables accounted for 27% of Scotland's electricity use. Scotland had an incident earlier in 2011 where wind speeds were too high; heavy rain created more hydroelectricity than normal, overloading the grid; and a transmission fault in the system prevented the surplus energy from being transferred to England, so the generation was cut [83]. This was an unusual event, and a spokesman for the DECC said more electrical storage is needed, as well as a greater interconnection with the neighboring EU so supplies can be bought and sold as required [84][85].

3.2.1.7 Small Wind Farms

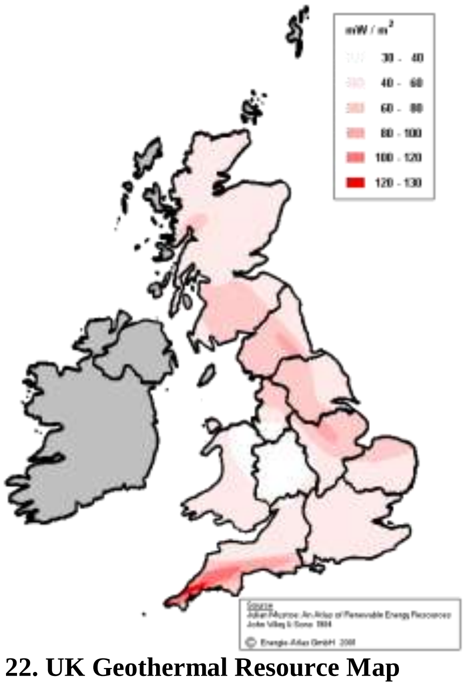
Feed-in Tariffs (FiT) (a.k.a. Green Energy Cashbacks) were launched in March 2010. This was considered revolutionary for the growth of homes and businesses producing their own renewable electricity for income according to RenewableUK. The feed-in tariff provides fixed rewards of up to 41.3p for every unit of electricity generated from eligible technologies such as small wind turbines and solar PB panels. In addition, all electricity sold to the national grid would be able to gain an extra 3p for every unit exported. This will transform the economics of small-scale renewable energy technology installation. Small wind turbines in good sites are now expected to repay their initial investment in less than 5 years. The UK leads the world in small wind system manufacturing, holding an 82% revenue share of the UK market and the world's second biggest market equating to 25% of global demand. UK manufacturers now export 50% of the output to over 100 countries. UK small wind system installed capacity now exceeds 20MW, with 7.24MW installed in 2008 alone [86].

3.2.2 Ground Source Heat Pumps

The UK is generally geologically stable with very little seismic and volcanic activity. The gradient is about 25°C/km with 30°C/km at places. Geothermal energy provides 16GWh of heat per year.

Geothermal energy is currently in place with examples of the Wessex Basin well in Southampton, which now heats a number of buildings in the city centre by providing 8% of the heat distributed by a larger city centre district heating system that includes other combined heat and power sources. A commercial geothermal power plant was granted planning permission in 2010, which is to be constructed on the United Downs industrial estate near Redruth. The plant will produce 10 MW of electricity and 55 MW of renewable heat. Another project was given planning permission in December 2010 called the Eden Project in Cornwall and was to build a Hot Rock Geothermal Plant. The plant, expected to produce electricity in 2013, will produce up to 4 megawatts of electricity for use by Eden with a surplus, enough for about 5,000 houses, going in to the National Grid. [87].

In Newcastle upon Tyne drilling has started on a borehole which hopes to tap a **virtually inexhaustible** supply of groundwater which is kept at 80°C (176°F) by geothermal heat, naturally. This hot water would be **virtually free** and more than a mile below central streets [88].



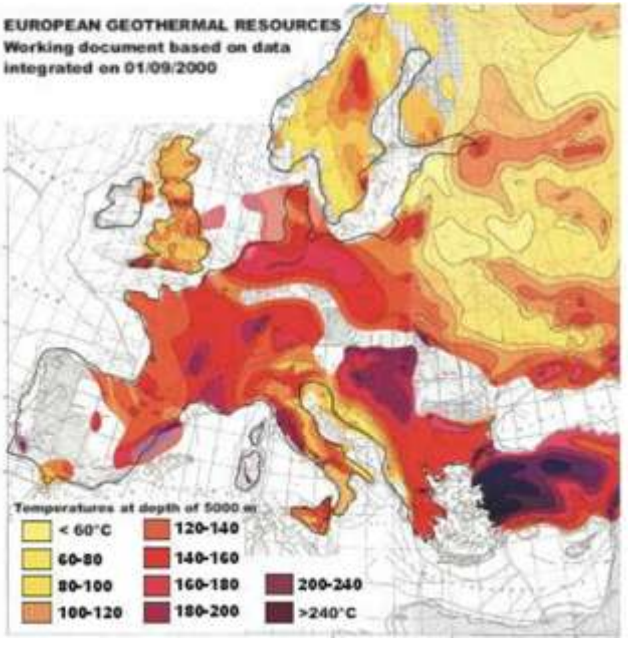


Figure 22. UK Geothermal Resource Map
Source: GENI

Figure 23. European Geothermal Resource Map
Source: Shell International

Figure 22 shows that the highest resource for geothermal heat is in the southwest of the UK. This area alone has been estimated to deliver 2% of the UK's annual electricity demand. As can be seen from Figure 23, this makes most of Europe comparable to countries having tropical climates. Figure 24 displays the electricity potential of different levels of geothermal over time. At least a level 2 effort of geothermal is required for any significant electricity production. By 2020, electricity generation for all other levels begins to take off, with significant increase by 2025 and leveling off by 2030-2035. The timeline until they cap off are the same but the steady amount of electricity that will be continuously output for years after just depends on the amount of initial deployment. The DECC report on 2050 pathways estimated that 5GW of electricity generation capacity could be delivered by an extreme ('level 4') level of geothermal effort by 2030. Level 3 efforts could deliver 3GW by 2030 and Level 2 efforts could deliver 1GW by 2035 [89].

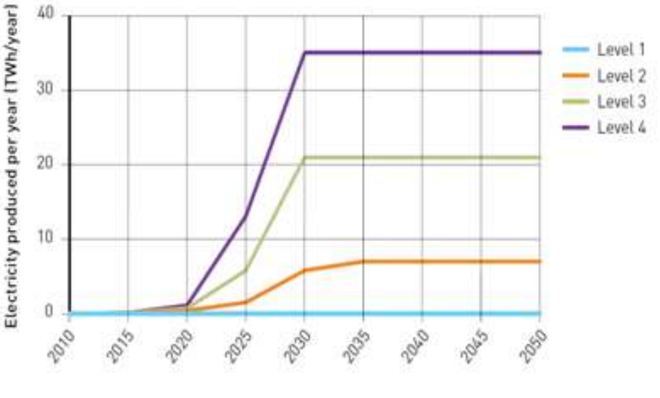


Figure 24. Trajectories for Geothermal Electricity Generation under 4 Levels of Deployment. Source: DECC

Industry estimates are higher for deep geothermal potential, but not much. There is an enormous cost accompanying exploitation of the heat at this depth. There is a high technical potential but not a high economic potential. An estimate of the potential of deep geothermal heat generation is unclear, although it is an easier, cheaper and less risky form of the technology [90]. According to the Renewable Energy Roadmap, the potential of ground source heat pumps by 2020 is estimated to be 14 TWh [91].

3.2.3 Air Source Heat Pumps

Half of energy use in the UK is due to heat as well as associated CO2 emissions (around 263 mtCO2). Currently in the UK, fossil fuels and electricity provide nearly all the heat demand with less than 1% coming from renewable technologies, which could theoretically meet much of the demand provided by fossil fuels and electricity. According to the Renewable Energy Strategy, in order to meet energy targets by 2020, 12% of heat demand could be provided by renewables.

Air-source heat pumps (ASHPs) absorb heat from the outside air. They could help lower household carbon emissions by replacing other carbon emitting fuels. Air-source heat pumps are becoming a standard technology in the UK commercial sector although their suitability for large parts of the domestic sector carries certain degrees of uncertainty as the required potentially high electricity input causes high cost of abatement in many cases.

There is a lack of availability in the UK market for domestic ASHPs, as well as slow technology development. There is also limited financial incentive for heat pumps, unlike France, which has tax breaks or Sweden, which has subsidies and higher energy costs. Technology knowledge is also limited in the UK, which is why there is a lack of installed ASHPs in the public and private sector. There have been recent developments in the technology from the manufacturers in order to mass-market ASHPS to the UK by making them perform better and bringing coefficients of performance (COPs) up and driving prices down. The Renewable Heat Incentive should also help drive the industry forward. [92]

According to the Renewable Energy Roadmap, the potential of ASHPs by 2020 is estimated to be 9TWh [93]. The installed capacity of both ground and ASHPs in 2010 generates 0.7 TWh. A combined potential of 22 TWh is estimated by 2020 [94]. The major barriers to the development of this technology are cost, planning & licensing processes; thin installer base; demands on the electricity grid; and performance & technical issues. The Renewable Heat Incentive should assist with the constraints on cost. These issues must be addressed in order to develop this technology within the timeframe [95].

3.2.4 Marine (Wave and Tidal)

Marine power in the form of wave and tidal stream energy can deliver a substantial and secure amount of power to the UK and has the potential for the UK to create a world-class domestic industry in developing, manufacturing and installing devices for an emerging global Market. The potential of wave and tidal technology is roughly 2GW [96]. The UK is already the global leader in the development of wave and tidal energy. The industry will see rapid growth with already present well-developed plans for the commercial deployment of projects, a host of testing facilities and significant private investment in the past year [97].

3.2.4.1 Government Incentive

Despite the potential, the industry is still very young, and the biggest issue the industry has to face is the level of funding and incentive to encourage utilities as well as equipment manufacturers to deliver the world's first marine energy arrays over the next few years [98]. The renewable roadmap set up to £20m to develop wave and tidal technology over the next four years and to commission marine energy testing facilities in early 2012 at the National Renewable Energy Centre (Narec) [99].

3.2.4.2 UK Resource

There is great, untapped tidal potential present in the UK. Tidal power is a very predictable and reliable source of power, which makes it appealing compared to other forms of renewable energy such as wind [100]. Forty-two potential sites for tidal stream generation were listed in 2001 by Brian Wilson, former Energy Minister. This is also reflected in the ETSU paper that identified 10 of the most promising tidal stream sites holding a potential of 36 TWh/y. It was estimated by the Scottish Enterprise that tidal currents in the UK could deliver at least 34% of the UK's electricity demand, which would contribute to nearly 5% on a European level [101]. The Scottish Government has already approved plans for a site near Islay of a 10MW array of tidal stream generators. The project cost 40 million pounds will have 10 turbines with the first expected to be operational by 2013. This would be enough to power over 5,000 homes [102]. A recent report estimated that the UK could harness up to 35GW of marine energy by 2050, representing over 20% of the country's current consumption [103].

According to tidalenergy.eu, tidal power could generate an estimated 20% of Britain's needs. Due to the great practical challenges with this form of energy, only twenty sites in the world have been identified as being ideal locations for large-scale tidal power arrays. However, eight of these sites are in Britain. This could potentially make the UK a key player in the World Green Energy market. Good sites for tidal barrages in the UK are The Severn, Dee, Solway and Humber estuaries. Good sites to host tidal turbine arrays are Islay and the Pentland Firth, which is possibly the best site in the world to generate electricity from tidal power. In terms of research on tidal energy, The UK is generally seen as world leaders. However, the US and Canada are also making big investments in this field [104].

In September 2010, what was referred to as a "ground-breaking project" was launched. Wave Hub, the world's largest test-site for wave technology was installed off the Cornish Coast. It is a grid-connected socket and has the capacity for four technology developers to connect 5MW of wave energy devices in real sea environments without additional costs of electrical sub-sea infrastructure.

Oliver Wragg, Wave and Tidal Development Manager at RenewableUK, said:

"This is a momentous occasion for the rapidly developing marine energy industry. Wave Hub is viewed as an integral infrastructure project both nationally and internationally, which will aid development of a new breed of technologies and allow us to harness clean green renewable energy from our coast, whilst facilitating the creation of thousands of jobs. The UK has an abundance of

wave and tidal resource on its doorstep. With the right support, the marine energy industry can play a pivotal role in achieving our renewable energy targets in 2020 and beyond." [105].

Marine renewable technologies are at the same stage that wind was 10-15 years ago. In all of Europe, the UK holds the best wave and tidal resources (Figure 25). This can provide a considerable amount of power to the UK in the next years. Some of the leading marine energy devices in the world today have been produced in the UK showing a strong history of innovation. The devices still have challenges that are holding them back from meeting their full potential and break into large-scale commercialization ahead of their global competition, but the outcome will make it worthwhile.

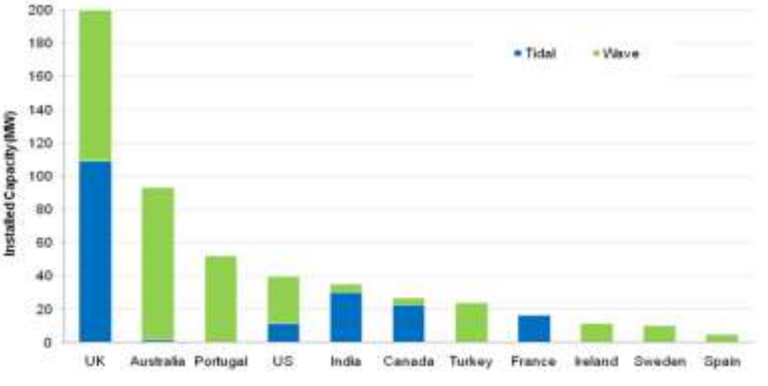


Figure 25. Wave & Tidal Installed Capacity
Source: www.renewableenergymagazine.com

Denmark and Germany have shown from their experience with the wind energy that innovation must be supported early in order to develop a global competitive manufacturing industry, right in the stage marine is now in the UK, and the UK is fully committed to developing the emerging wave and tidal energy market [106].

Many studies have been done on the UK marine resource, and they all suggest that **there is enough energy stored in the form of heat, currents, waves and tides to meet the total worldwide power demand many times over**. The most significant around the UK are marine currents and waves.

3.2.4.3 Wave Power Potential

Future Energy Solutions has estimated a huge worldwide wave power resource with a potential being around 8,000-80,000TWh/y (1-10TW). This is in the same magnitude of the world electrical energy consumption. The best climates for wave power are in temperate zones (30-60 degrees latitude) where strong storms occur which give annual average power levels of between 20-70 kW/m of wave front. While regular trade winds blowing at climates of within +30 degrees latitude are also attractive, wave climes and smaller wave power variability compensates for lower power levels [107].

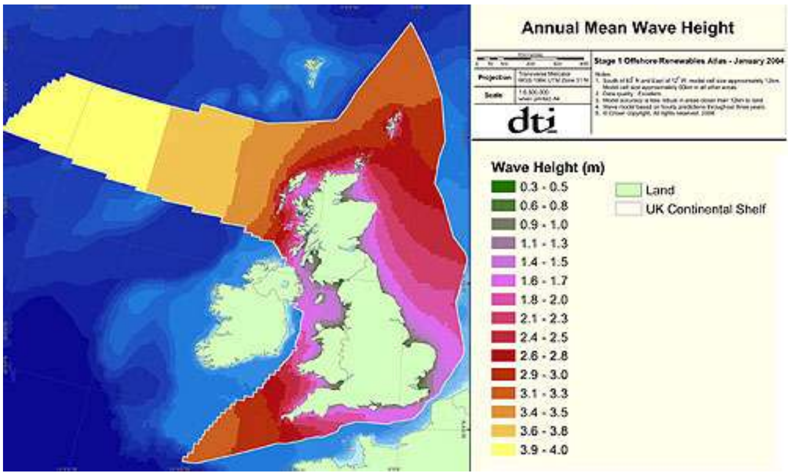


Figure 26. Annual Mean Wave Height
Source: BWEA

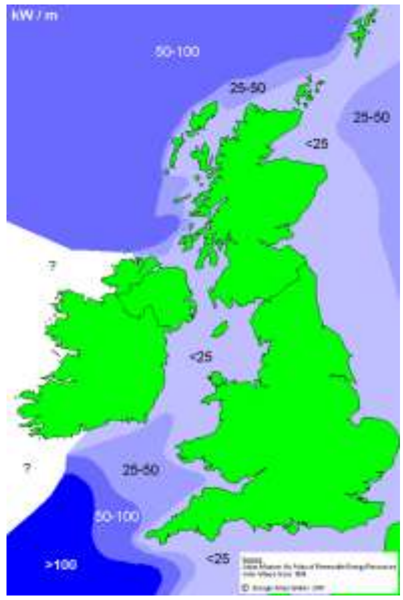


Figure 27. Average Wave Power
Source: BWEA

Figures 26 & 27 display the average wave height and correlating wave power in the UK. The North Sea in the northeast around the coast of Scotland and the Celtic Sea in the southwest around Plymouth have the best resource. Unlike tidal power, wave energy decreases towards the coast. Constructing stations further away from the coast is expensive; therefore, coastal islands and peninsulas are more suitable for wave power stations [108].

The estimated potential of accessible wave energy in the UK is 700TWh/y according to detailed studies, which have taken into account constraints on available sites. This is **almost double the electricity consumption.** The technologies will have to be developed, both near shore and in deep water to successfully harness this amount of energy. The Science and Technology Committee estimated that the practical contribution of wave energy devices was more that 50TWh/y. This report was done in 2001 and was based on estimates from the Department of Trade and Industry's (DTI) Energy Technology Support Unit (ETSU).

3.2.4.4 Tidal Power Potential

The DTI released a report (The World Offshore Renewable Energy Report 2002-2007) suggesting that there was an estimated 3000 GW of tidal energy available; however, only 3% is located in areas suitable for power generation. Tidal current energy is site specific and optimized only where tidal range is amplified by factors such as shelving of the sea bottom, funneling in estuaries and reflections by large peninsulas.

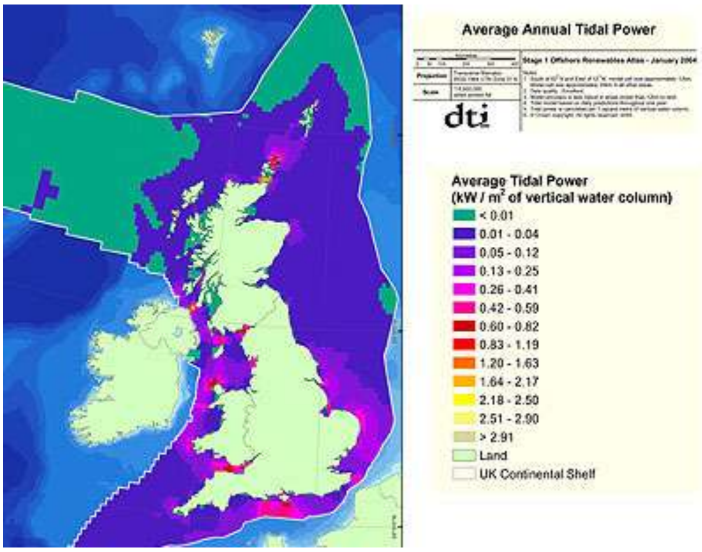


Figure 28. Average Annual Tidal Power
Source: BWEA

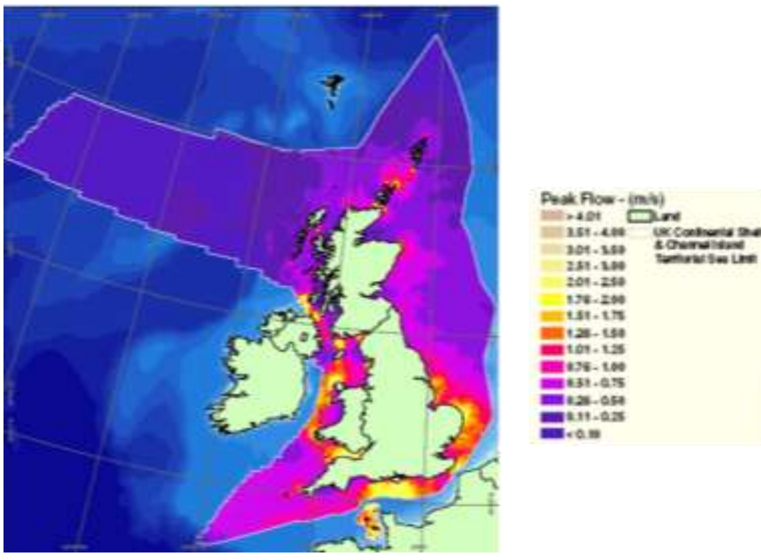


Figure 29. Tidal Power in the UK
Source: BWEA

Figures 28 & 29 show the tidal power in the UK. The enormous potential of the UK wave and tidal resource was demonstrated by the overwhelming success of the Pentland Firth and Orkney Waters Strategic Area leasing round. Six wave energy projects of around 600MW and four tidal projects of 600MW were awarded leases by The Crown Estate.

The Severn Estuary has huge potential for a tidal barrage. With a range of 14 meters between high and low tide, up to 5% of the UK's energy supply could be harnessed with this barrage. There is, however, great opposition from environmental groups to this barrage as well as cost constraints. The government is assessing these issues. If this were to go ahead, it would be a valuable contribution to the renewables plan [109].

Oliver Wragg, RenewableUK Wave and Tidal Development Manager, said:
"The leasing round has exceeded all expectations by awarding 1.2 gigawatts (GW) of project leases, considerably up from the originally scheduled 700 megawatts (MW). This clearly demonstrates that the industry has now reached a stage where it is ready to deliver. In order to facilitate the transition from research and development to scaling up and delivery, and in response to the Government's Marine Energy Action Plan, RenewableUK has produced a key document published today 'The Next Steps for Marine Energy."

The recommendations in *The Next Steps for Marine Energy* is that the a minimum of 220 million in capital support for technology development over the next five years is committed by the government aiming at 1.4 million homes be powered with marine energy by 2020 and producing an annual sector turnover by 900 million by 2030.

Peter Madigan**,** RenewableUK Head of Offshore Renewables, said:
"RenewableUK's report demonstrates that by investing now the Government can generate jobs and income in the long term. We have a once in a generation opportunity to build a world leading industry, which will help ensure we meet our carbon reduction targets and deliver economic benefits. ***The industry is ready and the Government must act now."*** [110]

In July 2009, the Renewable Energy Strategy and the Low Carbon Industries Strategy were launched by the Government with a total of £60 million (roughly 15% of the £405million) of funding dedicated to the marine renewables industry. An additional, £22 million of grant funding will be provided by the Government under the Marine Renewable Proving Fund (MRPF) for testing and demonstration of pre-commercial wave and tidal stream devices. This assists the acceleration of wave and tidal technologies towards commercial demonstration, and the Marine Renewable Deployment Fund aids the development of successful projects. The MRDF is also intended to extend its operation to cover new devices reaching demonstration stage in the period of 2011-2014 [111].

The UK Marine Renewable Energy Atlas is being produced by the Marine Environmental Research Ltd (ABPmer), which was commissioned by the DTI, to spatially map the wave, tidal and offshore wind resource potential within the UK Continental Shelf (UKCS) [112].

The marine industry is at a critical stage of development. There are many barriers it must overcome before releasing its full potential. The Path to Power is a project created by the BWEA to map out the hurdles the industry faces. This created a number of key recommendations for action [113].

In 2006, the UK's largest electricity supplier, npower, issued a report named 'npower juice Path to Power Report' in association with BWEA which is a route-map to utilize the full potential of marine energy in the UK. According to the report, marine renewables could theoretically provide up to 2.1% of the UK's electricity demand by 2020, which could power around 1.6million homes. There are significant hurdles to harnessing this potential highlighted in the report, namely financing, grid access, and consenting. Recommendations for the most effective way of overcoming these hurdles are set out in this report.

Michael Hay, marine renewables development manager at BWEA, commented,
"We believe the 'npower juice Path to Power Report' will be vital in securing the support required to help move the wave and tidal stream industry from the testing stage towards commercial reality. With the right support, marine renewables could start to contribute towards meeting our carbon-free energy needs in the near future as well as developing a domestic industry for the emerging global market – a win-win result which can only enhance the UK's reputation as a global leader in the fight against climate change." [114].

Marine technology is predicted to generate approximately 8TWh per year by the BWEA. If you divide this by the annual average UK electricity consumption of 4,700kWh per year, it's enough to power 1.6 million homes [115].

The Marine Action plan outlines the actions require for the marine industry and the public sector to drive the development and deployment of marine technology with a vision for 2030 (with reference to 2020).

Key recommendations include:

- Forming a UK-wide strategic coordination group to develop a planning and consenting roadmap for all types of marine renewables;
- Consideration of support levels for marine technologies under the review of banding of the Renewables Obligation in Autumn;
- Ensuring that the appropriate levels of targeted funding are available to bridge the technology market failures that exist in this developing sector, subject to the budgets in the next public spending round;
- Leveraging private equity, and in the longer term, project capital into the sector;
- Establishing guidelines and best practice in the development of new technologies; and
- Building a UK marine energy supply chain and utilising the current skills base already established from the offshore wind, oil and gas, and maritime industries. [116] [117].

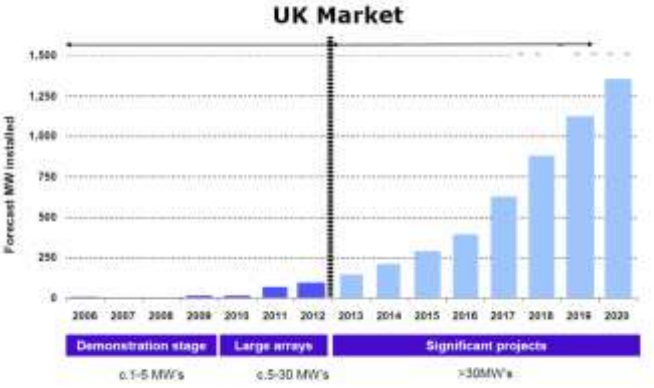


Figure 30. The UK Market
Source: Marine Strategy Group

3.2.5 Renewable Transport

There is a large potential for the production of renewable transport fuels in the UK. 40% of current transport energy consumption in the UK can be provided by renewable resources, which is about 55% of road transport energy consumption. This is assuming a conversation efficiently of 50%. Biomass, waste and direct renewable electricity sources make up the practical renewable energy resource for transport fuel. There are constraints, technical and economical, that may reduce this potential. Also if renewable transport fuels from abroad become cheaper, the UK will need to become more efficient in this industry and make cost reductions [118].

Biofuels for road transport already contribute over 3% by volume to all transport fuels. The Road Map proposes to increase this to 5% by 2014. In 2004, biofuels provided 105.9 GWh, 38% of it wood. This represented an increase of 500% from 1990.

3.2.6 Biomass

Biomass was the UK's leading renewable energy source in 2004, providing 129.3 GWh, which was an increase of 690% over 1990 production. Biomass represented 39.4% of renewable in the UK, hydro included. Biomass, along with on-and off-shore wind, is expected to be the key growth areas in the UK's renewable energy strategy, based on current understanding of costs and constraints. The two primary applications of biomass are electricity and heat.

3.2.6.1 Biomass Electricity

The main incentive for renewable electricity is from ROCs. ROCs was banded according to the type of renewable energy in April 2009 and had a positive discrimination towards efficient use of indigenous resources like biomass with a reward of 1.5ROCs per MWh for dedicated regular biomass, the same as offshore wind and 2.0 for dedicated regular biomass with combined heat and power (CHP) as an emerging technology [119].

3.2.6.2 Biomass Heat

Renewable heat has been identified as a particular priority by the DECC. Renewables source less than 1% of the heat market, and the UK's primary energy consumption is over 40% from heat. The Government plans to promote the increase of biomass heat and bio-methane into the grid with the Renewable Heat Incentive (RHI) and the Renewable Heat Premium Payment (RHPP) [120].

12% of land area in the UK is trees, woods and forests with England having over 1,000,000 hectares of it. 9.5 million green tons of wood is produced by the UK forestry sector each year. Forestry Commission England has set a target to bring back to the market an additional 2 million green tons of wood by 2020. This will have a yearly carbon savings of 400,000 tons. This is a significant volume of wood representing a 60% increase in harvesting in England. However, it is only half the annual growth of their trees, woods and forests. This resource is being targeted by the England Woodfuel Strategy [121].

In 2007, Ernest & Young conducted a Government commissioned study and concluded that the greatest technical potential and market for renewable heat delivery within in the UK is biomass. The potential was close to 40TWh, both at 11% and 14% renewable heat targets. The Commercial and Industrial potential for biomass is alone estimated to be between 10TWh and 17.5TWh (1TWh = 1,000,000MWh), which is equivalent to between 1.5% and 2.4% of the current UK total heat requirement.

Figure 31 shows the potential for heat from 4 types of renewable sources and the associated resource costs, for both the 11% and 14% targets. The figure shows that in both cases, biomass wins the majority for potential and has the least costs for resources. This makes biomass very appealing and a renewable resource.

This study shows the DECC consult measures to help achieve the 14% renewable heat target by 2020, as well as introducing a range of measures in the Renewable

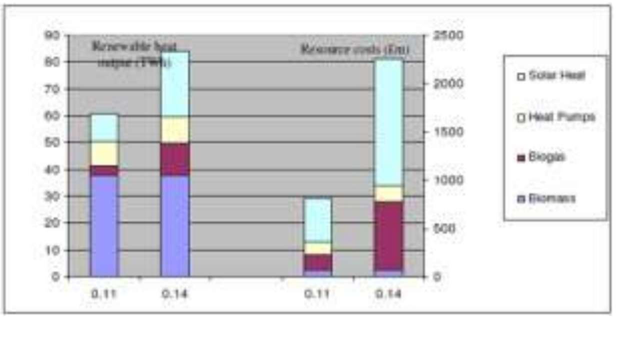


Figure 31. Potential and Costs of 4 Renewable Resources at the 11% and 14% Targets. Source: E4TECH

Heat Incentive in 2009 and/or the Renewable Heat Obligation. The RHI measures have preference as they would give support at a 'set price per MWh' to renewable heat generators, which will give a predictable income stream paid for by a levy on fossil fuel heat generators [122].

A report done by E4Tech on the potential of Biomass in the UK saw that theoretically biomass could potentially provide up to 21% of electricity demands by 2020 at a viable cost. Taking into the consideration the rate at which plants are built, by 2020, it would realistically be more like 13% but still make a carbon savings of 19million tons in 2020 (Figure 32). [123]

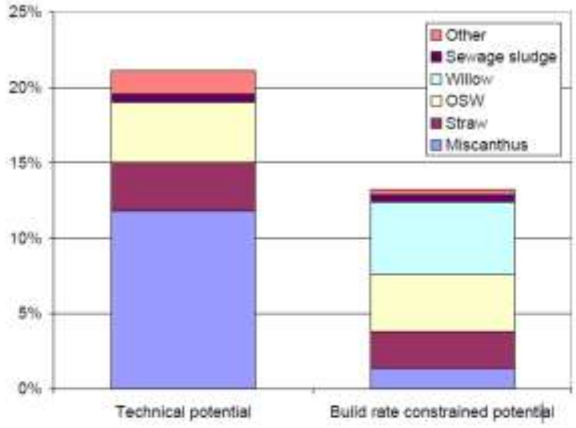


Figure 32. Potential Contribution to 2020 Electricity Demand. Source: E4Tech

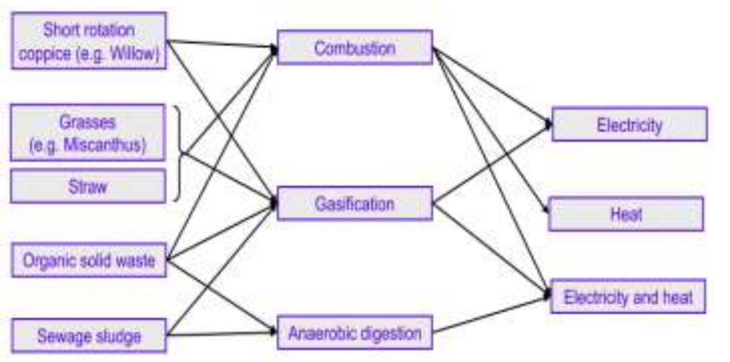


Figure 33. Primary Fuel Chains for Electricity and Heat in 2020. Source: E4Tech

Figure 33 shows the 4 primary fuel chains that can contribute to the electricity and heat demand in 2020. All could provide significant contribution to the UK energy demand. Biomass, like other renewable technologies, does have barriers it must overcome to unlock its full potential. They are, namely, the complex system of fuel chains involving multiple actors, feedstock, energy and financial flows. Therefore, barriers to even one actor will have an effect on the other levels of the system, as they are highly interdependent. This, in turn, causes problems of simultaneous lack of supply and demand. There is also present a lack of a functioning marketplace to transmit supply and demand through the chain, in many cases [124]. These barriers must be addressed and developed so this worthwhile renewable resource can reach its potential while at low costs. Suggestions include reviewing Renewables Obligation for Biomass, increasing research and development in areas of high potential, and reduced costs for grid connection amongst others [125]. Once passed the drawbacks, and with money invested to develop the technology, the benefits and potential would by far pay off for many years to come.

The potential of renewable energy is not an unknown risk; it is currently in use, has been successful and proven but has just not yet been exploited to its full potential and developed at scales which ensure it's the most worthwhile in terms of costs, fuel, security and sustainability. There is resource and vast potential, although many are still in the early stages. This can all change quite quickly, collectively developing a variety of resources may incur initial investment but once operational, savings will be huge and environmental savings even greater. It’s all about making the correct decisions and acting fast.

Chapter 4 Other Sources of Renewables

4.1 Solar

Although solar is a minor source of energy in the UK, there has been significant development in solar technology over the past few years, and it should not be overlooked. Technology has improved, causing capital costs to fall. In the UK, around 200MW of solar photovoltaic power were installed as of August 2011, with a capability of producing around 200GWh per year of electricity [126]. Solar photovoltaic (PV) installations receive support through the Renewable Obligation and Feed-in Tariffs. By the end of May 2011, 38,000 solar PV installations in Great Britain were being supported. The Feed-in Tariff, instituted in April 2010, offered at least 36p per kWh. Three times as much as the previous year of photovoltaic capacity was installed in its first year – 77.8 MWp. This still only represented 0.1% of total electricity production [127]. In 2006, the installed capacity in solar energy in the UK was 12.5 MWp (Megawatts peak) [128] and represented just 0.3% of the European total of 3.4 GWp [129]. For comparison, the ability of Germany is 3.0 GW (in 2006), 90% of European capacity [130]. The largest solar park in the UK was completed in July 2011. In Newark-on Trent in Nottinghamshire, the 5 MW free-field system was built in just 7 weeks after receiving planning permission. It is estimated to generate 4,860 MWh of electricity (an average power of 560 kW) into the national grid each year [131].

4.1.1 UK Solar Resource

The UK's insolation is less than 120 W(th)/m² (2.9 kW·h/m²/day, or 1050 kW·h/m²/year) [132]. Although this is just a fraction of the amount received in subtropical places like Spain and North Africa, the south of the country has insolation which can be compare to much of German, which has one of the largest photovoltaic markets of the world (Figure 34).

The southwest of England and south of Wales are the most promising sites for solar PV installation as the annual solar radiation increases by nearly 100% from the north of the country to the south. (Figure 35) [133]. Higher wind speeds present in the UK can actually work in favor of this technology by cooling PV modules which in turn leads to increased efficiency over what could be expected at these levels of insolation.

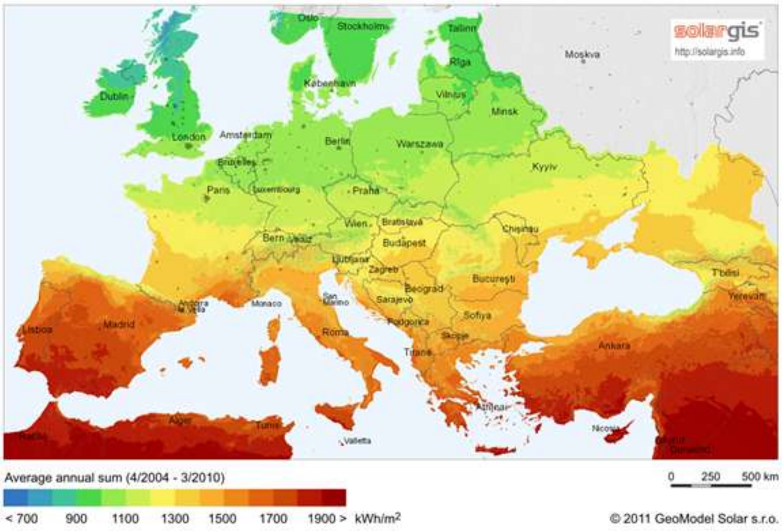


Figure 34. Global Horizontal Irradiation.
Source: European Commission

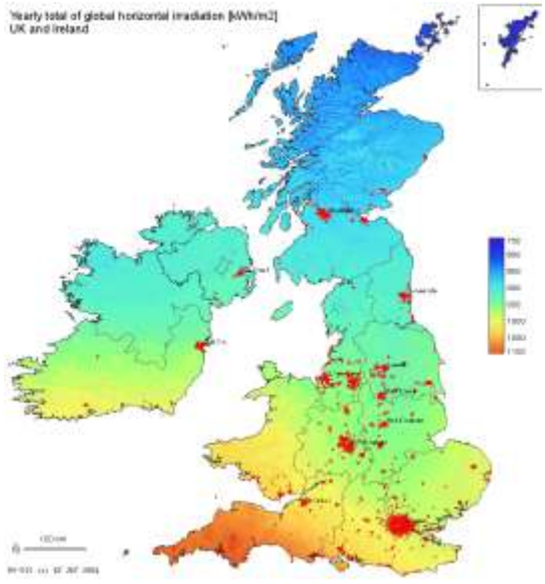


Figure 35. Yearly Total of Global Horizontal Irradiation [kWh/m2] in the UK and Ireland.
Source: European Commission

4.1.2 Government Incentives for Solar Energy

The new Feed-in Tariffs caused a rapid growth in this market with many thousands of domestic installations as well as many commercial, community and industrial projects. There are several 4-5MW field arrays of photovoltaics in the UK. In April 2010, the Government agreed to pay an initial rate of up to 41.3p (US$0.67) per kWh, whether used locally or exported, for all grid-connected generated electricity [134]. The DECC fast-track review announced the cut to the feed-in tariffs in June 2011, as these rates proved more attractive than necessary. Rates were drastically reduced for installations over 50kW [135], making investment in large arrays of photovoltaics a lesser attractive investment for developers, especially projects greater than 250kW, so after the 1 August 2011 cut-off date, large field arrays were less likely to be built. This policy change was criticized as marking ***"the end of the UK's solar industry as we know it"*** [136]. The existing tariff of 43.1p had an implemented deadline of December 12, 2011. MPs and organizations opposed this deadline. There was a rise of installations in the market to 12,000 in the week ending in November, slightly declining to the week ending November 26 (Figure 36). [137]. After a 4 month waiting period, where the UK solar market remained uncertain and customers weren't able to know the feed-in tariff rate they would receive for their installations, the Governments appeal to the cuts was lost, meaning the original, higher feed-in tariff rates would be received for all systems installed between December 12, 2011 and March 3, 2012 for 25 years. The result means that over 60,000 installs will be eligible for bumper FiT rates as high as £0.454/kWh. [138]

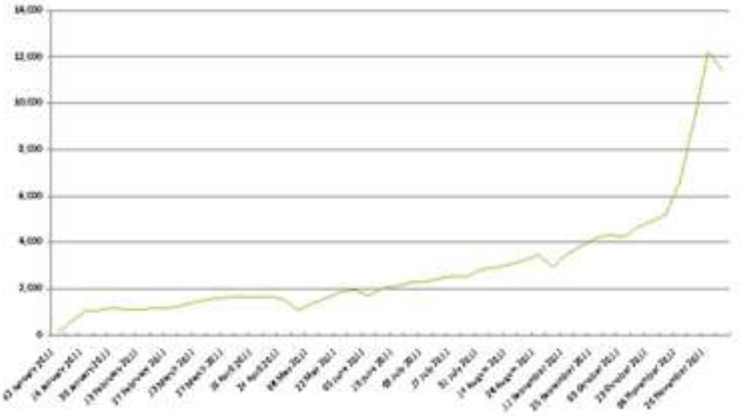


Figure 36. Number of PV Installations Per Week in 2011 (All Tariff Bands)
Source: Solar Power Portal

Grants for domestic photovoltaic systems are administered by the Energy Saving Trust. Estimated by the Low Carbon Building Programme, an average-sized house would cost between £5,000–£8,000 per kWp for installation. Usually, most domestic systems are between 1.5 and 3kWp, which would yield savings of between £150 and £200 annually [139]. The Government also has a programme to provide 100 schools across the UK with solar panels, known as The Green Energy for Schools programme. The Tavernspite School in Wales was the first to receive solar panels under this programme. The solar panels, worth £20,000, can sufficiently produce 3000 kWh of electricity each year [140].

On average, customers deploying PV systems should be received a 5 per cent return, if it is greater than this, the energy users will not be getting value for money in funding the scheme. The good news is that the costs of PV components have fallen 50% in 2011 and will fall by at least another 20% in 2012. For most installers to generate a reasonable return, the 21p tariff is very achievable because of this. With PV costs falling while energy prices rise, the inflection point where generation from PV becomes as cheap as fossil fuel based generators from the grid is getting closer. Some predict this will occur in three to four years from now. The cost dynamics of the large-scale field-based solar technology will drive its return in the New Year. Some global analysts believe that by the end of 2012, PV at-scale will actually be cheaper than offshore wind in the UK. If true, the Government would be forced to recognize PV and drive it forward. The release of phase 2 of the DECC's consultation on the PV FiT will show just how serious the Minister and DECC are about putting solar on a secure footing for the future. The Government plays an important role is helping the solar industry drive forward, and the decisions need to be made quickly, especially if solar is to be kept in the energy mix [141].

Greg Barker, Minister of State for Energy and Climate Change, keeps driving the message that in these desperate fiscal times, the UK's best hope lies in creating a sustainable solar industry. It's a difficult period for the solar industry. If the UK were to have a solar revolution, the benefits would be not only cutting carbon emissions and improving our energy security, but it's estimated that 360,000 jobs would be created by 2020 and billions would be saved in infrastructure costs to consumers as solar requires no new expensive infrastructure. This technology is very easily deployable today. If solar is exploited at large scale, it will be able to grow further without subsidy and make the cost of solar panels fall faster.

As far as decentralized energy and behavior change are concerned, solar is an important part of the energy mix. However, it is not part of the Renewable Energy Strategy for the UK to meet EU 2020 targets. Solar has not been included in the Renewables Roadmap; however, many mainstream analysts expect solar to be cheaper than fossil fuel generation before 2020 [142]. Given the right feed-in tariff and regulatory regime, the European PV Industry Association (EPIA) calculates a deliverable of over 20TWh in the UK, which is around 5% of the UK electricity by 2020 [143].

If sufficient cost reductions on solar PV installation are achieved so that viable projects will not be dependent on significant subsidy, the UK Government believes that in the future solar technology can potentially have a bigger role to play in larger-scale UK renewable energy deployment. According to the industry, it is suggested that this point may be reached during this decade. Modules and inverters account for over half the final cost of an installation, so this is where cost reductions need to be evaluated. The UK is small in the international solar PV market but benefits from the global cost reductions as a "price taker" [144].

4.2 Nuclear

Nuclear is excluded from the renewable energy roadmap, and subsequently, from the 100% 2020 renewables mix. Although, indeed, nuclear power will save in carbon emissions, it does impose other factors that cause its disqualification as a "clean renewable" form of energy, mainly, the long-term waste disposal as well as threats to people and other living things and to the environment.

The debate on nuclear power is whether it is a sustainable form of energy and whether it is needed to drastically reduce carbon emissions. Nuclear power has been around and a proven source of power since the early 20th century. This is a known, mature and in-use technology compared, for instance, to marine technology, which is still in the early stages of commercialization. An analytical approach to the pros and cons of nuclear power in the UK and whether it is a viable source begins with looking at the current state. 18% of electricity in the UK is generated by nuclear. There are 17 reactors currently operational generating a total of 10.5GWe capacity, but by 2023, all but one will be shutting down. Plant availability is affected by aging-related problems. Nuclear power plants have a limited life; plants have to be built.

The government announced its support for additional nuclear power plants in 2008 to help meet projected energy needs. In 2009, a series of national policy statements (NPSs) were issued which identified potential sites for new plants and outlined its policy which promotes installing new nuclear plants by 2025. EDF proposed four new European pressurized reactors (EPR) totaling 6,400 MW, the first one of which would start up in 2017 [145]. In April 2009, a list of potential sites for nuclear power stations was released by the government. They are: Dungeness in Kent; Sizewell in Suffolk; Hartlepool in Cleveland; Heysham in Lancashire; Sellafield in Cumbria; Braystones in Cumbria; Kirksanton in Cumbria; Wylfa Peninsula in Anglesey; Oldbury in Gloucestershire; Hinkley Point in Somerset and Bradwell in Essex [146].

Nuclear power is intended to still exist in the year 2020 in the UK, however, in terms of going 100% renewable energy by 2020, it has been excluded in the proposal. Not to say it need not to be operational but just that there is enough other renewable sources that it is 'not required.'

Chapter 5 Plan to achieve 100% by 2020

To achieve 100% renewable by 2020 is possible, but a lot has to be done and most importantly, the right decisions have to be made. Barriers must be overcome; solutions and technologies must be developed. The UK has shown its commitment in making ambitious goals that far surplus those required. The UK is dedicated to making changes and the intentions are clearly present. The UK needs to know that even greater ambitions of 100% is not off the radar, providing that the UK channels this drive into making the correct decisions and actions over the next few years to make it happen. The question is not "can" anymore; it is "how."

What needs to be done and what steps need to be taken to make the transition to a 100% renewable energy environment? The initial steps of analyzing if the resource and potential exist have already been undertaken. Various studies of resource potential outlined in the document show there is more than enough resource even with constraints to deliver enough energy to supply UK's demands. Next, we need to analyze how to put this potential into effective use and how to do it at a rate that ensures a safe and sustainable future.

The UK has shown capability for surpassing targets with a 21% reduction in emissions from the 1990 levels, more than twice the Kyoto target and now has over 800,000 people employed in low carbon businesses. Of course, this will require a certain amount of investment and as with any change, there are costs associated, but as discussed, the costs will be far greater if this change doesn't happen.

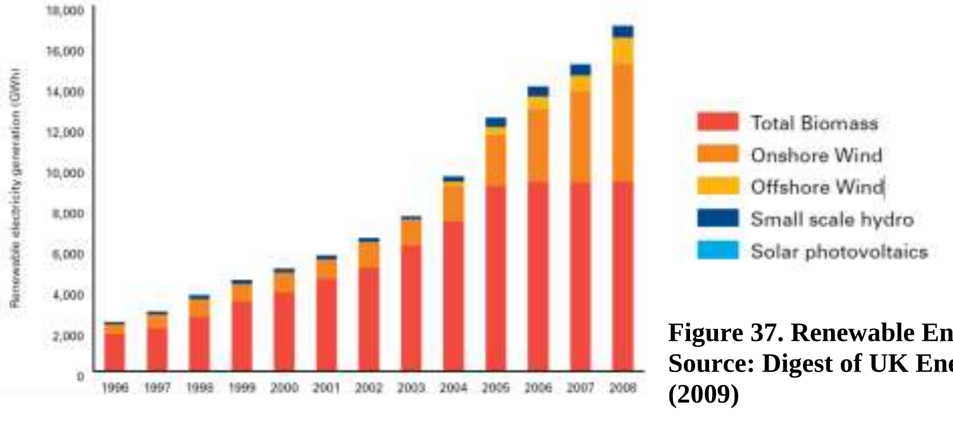


Figure 37. Renewable Energy Generation Over Time Source: Digest of UK Energy Statistics, Energy Trends (2009)

Electricity in the UK is a private sector and hence must be profitable to companies for them to build new power stations and make investments. It is a risk, as it depends on how projected costs of fossil fuels, electricity prices, and technology costs will evolve over time. At the moment, using renewables to generate electricity costs more than fossil fuel and this is slowing down the rate of deployment. There are ways to minimize the costs. Since the government introduced the ROs, RE generation has tripled. In 2002, it was less than 1.8%, and in 2008, it was around 5.3% (Figure 37). This shows government intervention makes a huge difference and needs to continue to make this possible. [147]

The need for a bigger, smarter electricity grid is highlighted as a requirement to transition to 100% RE. This is something the government needs to do in order to make this renewable transition really take off. Increasing grid capacity and speeding up connection to the grid for renewables will support the development of new technology. Also, lack of an effective supply chain becomes a big barrier as well as does planning support. If the government ensures these areas are strengthened, the industry would grow more rapidly. Further investment in infrastructure, innovation and manufacturing plus the availability of skills will also increase growth and stability [148]. As shown above, government incentives have paid off, and there is much more the government can do to make this happen quickly. A win-win situation exploits the potential whilst saving our environment in time. As anything, it just takes initial actions and investments to get the ball rolling. Operational costs of renewables are low, and it is essentially free "fuel," so once developed at-scale, we will mainly be reaping the benefits.

5.1 Cost Analysis

It is difficult to do a cost analysis of technologies that are still in the early stages of commercial deployment, such as marine. Biomass heat technologies have not had their supply chains tested at-scale. For technologies such as offshore wind and solar, supply chains and technologies are developing to 2020, and cost reductions are expected in occur. Complimenting this, fossil fuel generated heat and electricity is expected to rise over time. It is essential that costs of renewable technologies fall over the decade as deployment increases [149]. Given the amount of facilities to set up for 100% renewable energy production, a huge investment is required.

According to Renewable Energy Foundation (REF), who has carried out a study of the costs and implied costs of the UK Renewable Electricity subsidies, the results of which indicate that the total cost of the subsidies to renewable electricity generators would be in the region of **£100bn** by 2030.

The empirical portion of the chart below, up to 2010, shows fairly rapid growth from a low base. A very rapid increase is required to meet the 2020 targets. The scenario covered in Figure 38 entails the generation of approximately 75TWh in 2020, whereas meeting the 2020 target requires according to government estimates about 117TWh of electricity overall. Figure 39 shows that the cost to date, from

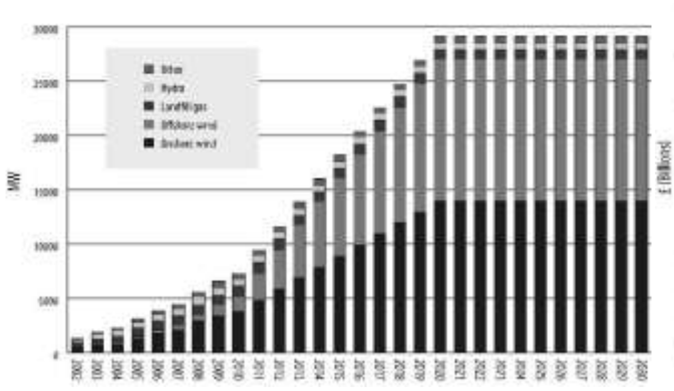


Figure 38. Installed and Projected Renewables Capacity the United Kingdom
Source: REF calculations from empirical Ofgem data

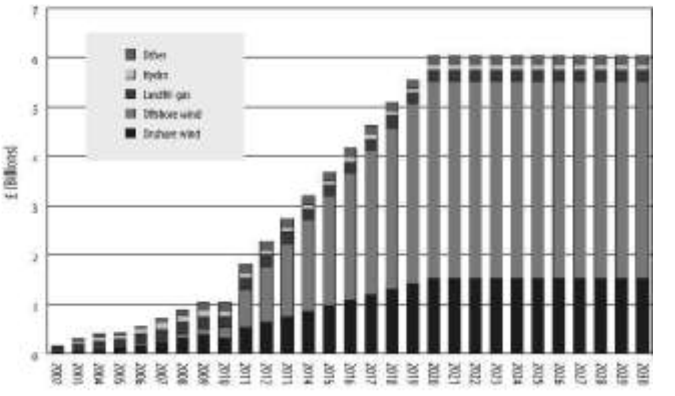


Figure 39. Cost and Projected Cost of the Renewables in Obligation to UK Consumers. ****Projected costs assume a ROC price of £50.* **Source: REF calculations from empirical Ofgem data**

2002 to 2010, amounts to approximately £5bn. The annual costs follow an upward trend towards £6bn a year in 2020, with the total cost of 2011 to 2020 reaching £39bn.

Even if we assume that after 2020 no further efforts are made to expand capacity, but that, as is reasonable and expected by the industry, subsidies are maintained for capacity already installed under the RO, the annual cost is around £6bn a year, and consequently a further £60bn cost is incurred over that decade. Thus, the total cost of the scheme from 2002 to 2030 would amount to approximately £100 billion. The Climate Change Committee (CCC) estimates that the cost of the renewables policies will put approximately 2p/kWh extra on the United Kingdom's electricity bill in 2020. To be precise, the CCC estimates the cost range being from an extra 1.1p/kWh in the low case to an extra 2.2p/kWh in the CCC's high case [150].

In terms of offshore renewable, where greatest resource lies, the Net Present Value is 50% of UK demand of £17 billion. £36 billion net electricity exporter and £55 billion net energy producer. A study by RenewableUK found that an 11kW device with an installation cost of around £50,000 on a site with a wind speed of around five meters per second could yield a total income of £10,026 per annum; while a 6kW device costing in the region of £22,000 under the same parameters could return £3420 per annum [151].

Chapter 6 Conclusion/Summary

The DECC estimates an energy demand in 2020 of 1,557TWh, although they admit an 8% marginal error due to uncertainty factors [152]. It has already been understood that cost effective technologies must be maximized.

The wind potential could provide 30% of UK's electricity supply by 2020. 1000 TWh electricity per year (50TWh onshore). This is almost 3 times the current energy used. This would be a carbon savings of 3,682,563tons per year. The biggest barrier is gaining planning permission. This needs to be made easier, and subsidies need to be issued to make it profitable. The potential for offshore wind is 2200GW of average power, 19,000TWh per year, 2.2TW of electricity. There are barriers, like capital costs, which need to be lowered, resource limitations and delays. Grid capacity needs to be increased.

There is a great geothermal potential in the south west of England, which could provide 2% of the annual electricity demand. The biggest barrier is the high cost.

The potential of air-source heat pumps is 9TWh by 2020, and ground source is 14TWh by 2020 which is a 22TWh. The main barriers are the lack of availability, slow development, limited financial incentive, high cost and limited technology. There are also demands on the electricity grid, difficult planning & licensing process and performance & technical issues.

Marine has the best resource in the UK. Studies show there is enough stored UK marine to meet the total worldwide power demand many times over. The main barriers are that it is a young industry and the level of funding. The tidal potential is 36TWh/y, which is 34% UK's electricity demand. There is 3000GW tidal energy but only 3% can be harnessed. It is recommended that 220 million in capital support is needed for technology development in the next 5 years. The estimated wave potential of accessible wave energy is 700TWh/y, which is almost double the electricity consumption. The practical contribution of wave energy is 50Twh/y. The barriers are technology development, financing, grid access and consenting.

To summarize we found that the offshore potential (Wave, Tidal & Wind) could theoretically power the UK six times over at current levels of demand. What needs to be done to make this happen by 2020 is to make Round 3 offshore grids super-grid compliant, develop the supply chain, make new financing structures, reduce plan delays in the constructions of wind farms, and redesign subsidies. The UK also needs to take a leadership role in EU negotiations and will, therefore, make sales to Europe and become a net exporter.

There is a large potential for the production of renewable transport fuels in the UK. 40% of current transport energy consumption in the UK can be provided by renewable resources, which is about 55% of road transport energy consumption.

The potential of biomass was close to 40TWh, both at 11% and 14% renewable heat targets. It was found at a viable cost, biomass could potentially provide up to 21% of electricity demands by 2020. Realistically, given the rate at which plants are built, we are looking at around 13% but still make a carbon savings of 19 million tons in 2020.

Solar, although not included in the roadmap, could actually make a contribution to the mix. By providing 20TWh by 2020 this would be 5% of the UK electricity demand. It needs to be recognized as a capable part of the mix. This will also create 360,000 jobs created in 2020 and save billions in infrastructure. The main barrier is the cost; the government needs to help especially for the materials, like modules and inverters.

It has already been shown there is enough potential in marine and wind alone to provide way more than the energy demand for the UK. Taking into account the instantaneous energy needed, i.e. the wind may not be blowing at peak times, a viable storage system for the energy needs to be present as a backup but also the other form of renewables that can have a significant contribution can come into play at these times. Offshore renewable energy is the key component to the mix, and the reality is that targets cannot be met without significant amounts of offshore renewable energies [153].

To make this happen by 2020, the barriers that are frequently occurring in different forms of technology must be worked on. The need to improve the grid is constantly highlighted, as well as gaining planning permission and development of supply chain and financial incentive. The key enablers are to speed up unnecessary delays, development of the supply chain and facilitate new financing structures. A super-grid is vital for this scenario, and the UK needs to take a leadership role in the current EU super grid negotiations [154]. Many officials and authorities agree that decision-making and fast acting is essential and must be done now even for 2050 scenarios.

6.1 Is it possible?

It has already been achieved in countries (Figure 40) with much less resources so a definite yes.

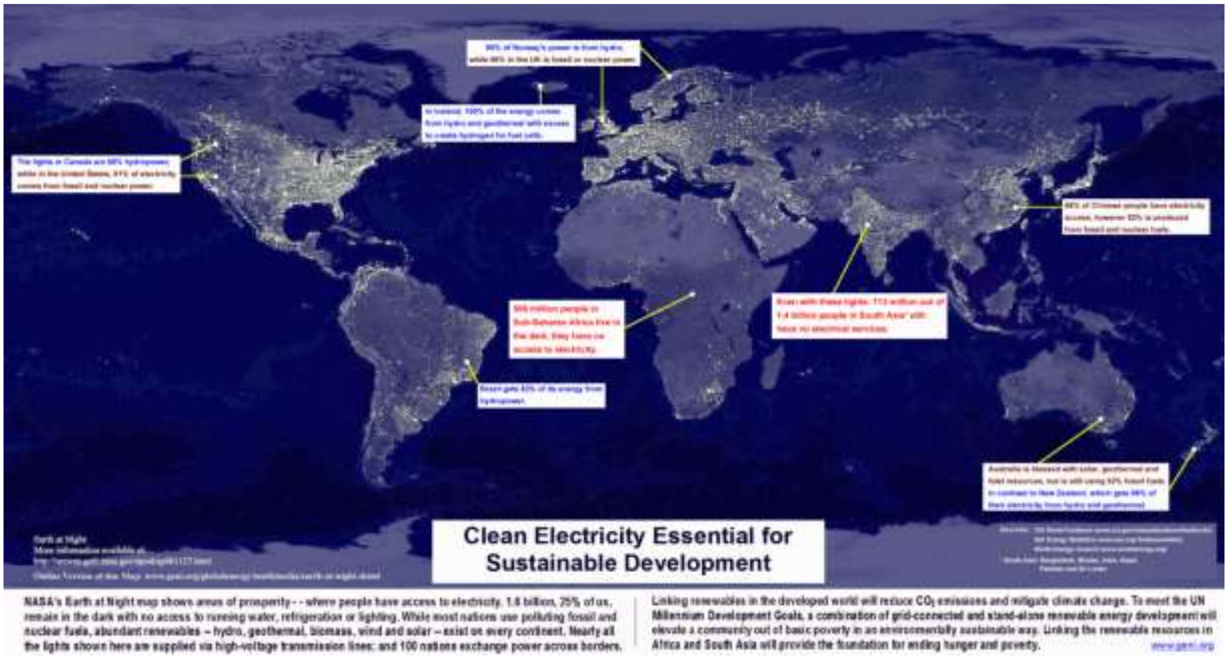


Figure 40. The Earth At Night.
Source: WRSC

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