The Sheffield Industrial Projects Scheme – SHIPS

The University Of Sheffield.

Second Year Industrial Projects
Department of Electronic and Electrical Engineering
First Semester 2017

Project Title :

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The technical content of this report has been the responsibility of the second year undergraduate students listed above and the project has been carried out purely as an academic exercise. The students have carried out this exercise part-time, over a 2-3 month period, alongside their other academic studies.

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1. Abstract (Seif Khalil)

Over the past decade, problems have started to arise in the UK's energy generation mix and holes have started to appear in the UK's electricity grid. In 2016, fossil fuels like coal and gas made up 51% of the UK's generation mix, with renewables making up a mere 24.5%. Coal power plants are closing around the country due to worldwide carbon reduction protocols. Cleaner alternative energy sources are being looked at to fill the gap left by coal in the generation mix. While gas might be less harmful to the atmosphere than coal, there are still other cleaner and more preferred energy sources available that should be exploited instead of gas. With the energy generation margin falling from 14% to 4%, alternative energy sources that should be cost-effective, clean, profitable and applicable must be found and put into action before major problems start to appear across the UK.

2.Contents

3.Introduction (Ka Wu)

In 1992, the UK has signed the international environmental protocol, The United Nations Framework Convention on Climate Change (UNFCCC). An additional protocol of UNFCCC, Kyoto Protocol has required the UK to accomplish a target that the emission in the UK must be reduced by 20% by 2020 compared with 1990's emission level. [19, p.18]

In 2015, another protocol is carried out, the Paris Agreement, which stated World leaders must hold the increase in global warming below 2℃ above pre-industrial levels, to reduce the negative effect of climate change. [20, p.18]

In the UK regulation 2008, the Climate Change Act, the government has agreed to reduce the carbon emission by at least 80% by 2050 compared with 1990's emission level. And agreed to control the global temperature rise to as little as possible above 2℃. [21, p.18]

Because of the protocols, the emission of the UK has reduced 42% in 2016 compared with 1990's level. To accomplish the emission reduction target, all the coal power plants will be shut down by 2025, which leads the reduction of the UK's energy generation mix and cause the generation capacity margin falls.

The aim of this report is to determine an alternative to produce energy and fix the reduction of the UK's generation capacity margin, while keep reducing carbon emission.

4.Problem definition (Alvin Lo)

According to the UK government policy and international agreements, companies are facing challenges of achieving carbon reduction targets while keeping the light on and providing energy in a greener way. The usage of coal for energy consumption has been greatly reduced from 22% to 9% between 2015 and 2016 and gas becomes the substitute one due to the decommission of the coal-fired stations. Meanwhile, the generation margin is predicted to fall from 14% to 4%. To prevent the risk of supply shortfall, companies are desperately searching new generation capacity to maintaining the generation capacity for next few years. The goal is finding an alternative generation capacity with the aspects of green and cost efficiency for coal to fully fill the future UK energy demands.

5.Specification(Hamish Sams)

The generation capacity margin is predicted to move from 14% to 4% in the next few years meaning less variance in energy in the grid vs being used on the grid. Our system must **avoid energy shortfall** which would cause blackouts and also **avoid energy surplus** which costs money to create energy just to be dissipated wastefully.To do so we must first **estimate future demand** so we know what load our system may be put under. As power used in day to day life isn't constant our system must **account for variance** in energy demand in any way possible. While designing our system we must take into account **system costs** for the **entire lifetime**. Due to cost and morality a system which is **carbon neutral**, or as close as possible, would be preferred, once again this should be looked at for the **entire lifetime of the system**. If our system is viable what kind of **incentives** could be used to increase the use of this technology. Our solution(s) must **persuade potential investors** to agree **using reasons and facts** in a presentation about the technologies.

Our report must:

1. Persuade potential investors of our solution
2. Discuss possible solutions refining them down into a final solution recommendation
3. Solve or attempt to solve the grids power crisis
4. Avoid carbon creating solutions
5. Explain the advantages and disadvantages of each solution
6. Think about the entire solution lifetime

Our report Could:

1. Calculate the expected future demand
2. Explain possible incentives the government could put in place

6.Reduction of Carbon (Seif Khalil)

In this section, I will focus on how we can reduce our carbon footprint as individuals and as a country. We want to fix the grid of the UK using environmentally friendly solutions. In 2016, total CO2 emissions in the UK were 374 MtCO2, which is a 7% change from 2015. This is the lowest the UK has gotten since the 19th century and is a 35.7% reduction in emissions. However, there is still a long way to go as the UK has set a carbon reduction target of 80% reduction, of CO2 levels in 1990, by the year 2050. The UK is on track to achieve this target but several extra steps must be taken and they will be discussed in this part of the report.

The main carbon emitters in the UK can be seen in the pie chart below:

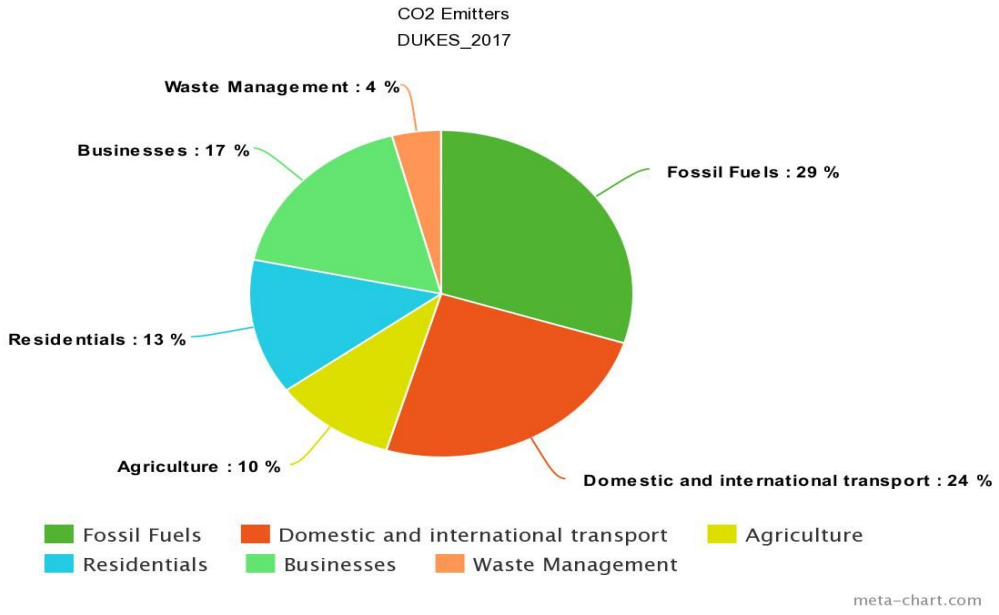

Figure 1

These are the main sectors that need to be addressed to reduce carbon dioxide emissions in the UK.

6.1.Mindstorm

- **Reduce fossil fuels** - Humans have increased carbon dioxide concentration in the atmosphere by nearly a third. The main contributor for this problem has been the burning of fossil fuels as they make up nearly a third of carbon dioxide emissions worldwide.
- **Carbon capture and storage-** If the UK is to continue using fossil fuels as a source of energy, then carbon capture and storage should be applied to all fossil fuel power plants.
- **Increasing renewables-** As fossil fuels are the main contributors to all carbon emission problems, they must be substituted with clean and near zero carbon emitting energy sources like renewable energy.
- **Increase electric transportation-** Electric vehicles are becoming more and more popular in the UK due to increased demand on them.

- **Improve energy efficiency** - Improving energy efficiency is an effective way to preserve economic development while maintaining the increase in energy consumption.

6.2.Refinement

Reduction of fossil fuels:

Fossil fuels are the main contributor to the increase of carbon dioxide concentration in the air. The main fossil fuels being used in the UK are gas, oil and coal. They make up almost 29% of all carbon emissions in the UK. This is a 6% reduction from the year before mainly due to the closing of coal power plants across the UK.

Coal is the most harmful fossil fuel to the environment and for a very long time, it was the main fossil fuel being used in the UK to generate energy. However, in an effort to reduce fossil fuel emissions, the UK has vowed to close all coal power plants by 2025. 3 coal-fired power plants already closed in 2016.There are currently 9 plants left with 2 set to close and 3 of them are set to convert to biomass power plants by 2019. As a result, emissions from coal fell by 50% in 2016. Coal use fell by 52% in 2016 and has fallen by nearly 75% in the last decade.

In 2016, generation by power generation from coal fell by approximately 22% from 2015. This gap in the energy generation mix was substituted with mainly gas and a small portion was substituted with oil. Carbon output from gas increased by nearly 12.5% and oil rose by almost 3% over the last 2 years. Gas and oil were chosen to substitute coal mainly due to their cheaper prices. Although they might be better for the environment than coal, they still produce a substantial amount of carbon in the UK's atmosphere. A better substitute for coal would have been renewable energy sources.

Advantages:

- Cleaner environment.
- Better health for workers.
- Getting rid of one of the most dangerous fields to work in.
- Less conflicts with other countries as fossil fuels are becoming scarce.

Disadvantages:

- Many jobs will be lost.
- Loss of a major source of energy.
- Loss of an efficient source of energy
- Loss of a cost-effective source of energy.

Increasing renewables:

Renewable energy sources produce near-zero carbon emissions in the atmosphere. They have unlimited potential and could power 100% of the UK's energy demand. Renewable energy supply of demand has been making slow progress and was close to 25% by 2015. The UK has promised to increase renewable energy generation to 30% by 2030. There are many types of renewable energy sources that can be used in the UK and they will

be discussed later on in the Generation Systems section by Chun.

Carbon capture and storage:

For the next few decades, it seems like the UK will be getting much of its energy from fossil fuel plants until renewable energy is capable of supplying most of the energy demand. Since this is the case, then carbon capture and storage (CCS) must be used to reduce CO2 emissions. CCS is an ingenious yet possibly a catastrophic way of solving the world's carbon problems. CCS is a technology where CO2 emissions from power plants and industries are captured then transported using boats or pipes to areas deep beneath the surface of the earth. This technology can capture up to 90% of CO2 emissions from fossil fuel plants.

The UK launched commercialisation programs for CCS in order for projects to be up and running by 2020. One billion pounds were promised to be made available in funding for CCS projects by the UK government. However, in 2015, just before the final steps were to be put into place, the government decided not to go through with the project. This was a strange and major blow to the efforts to reduce carbon emissions as CCS looks set to be an integral part in reducing carbon emissions in the UK. Other countries like Australia invest nearly a billion dollars in carbon capture and storage and have started seeing positives signs.

Advantages:

- Drastically reduces CO2 emissions.
- Allows continued operation of fossil fuel plants.
- Can be applied to any kind of plant or industry.

Disadvantages:

- Still not operational or proven as a method of reducing carbon.
- Very high start-up cost.
- Plants will require additional energy to have CCS technology working.
- If carbon leaks from ground then results could be catastrophic.

Increase electric transportation:

Since 2012, emissions reductions in the UK have been mainly been focused on the power sector and not too much attention has been given to the transport section. The transport section emits nearly a quarter of all carbon emissions in the UK. However, the UK is the leading country with electric buses in Europe with over 18% of all electric buses in Europe and electric cars have increased drastically over the last five years. Consumer cars have the most carbon emissions of all transportation in the UK. A solution to this is increasing fuel cell vehicles and this will be discussed later on in control of demand by Ka. Another way of reducing carbon emissions in the transportation sector is by increasing energy efficiency.

Advantages:

- Reduce carbon emissions.
- Cost-effective.
- Low maintenance.
- Less noisy.
- Saves money over the long term.

Disadvantages:

- High initial cost.
- Charging stations.

- Short driving range.
- Not as fast as petroleum fueled cars.
- Still needs more technological advances.

Improve energy efficiency:

Energy efficiency is just the reducing the amount of energy a product needs to provide the same service. For example LEDs use almost 80% less energy than incandescents for the same service. This makes them much more energy efficient. Investments in energy efficiency will cost money up front however, it will save more money on the long term. Improving energy efficiency decreases carbon emissions indirectly. For example, by increasing energy efficiency of fuel for a car, the car can drive more miles using the same amount of fuel so the car will need less fuel to drive the same distance so less carbon will be emitted.

Increasing energy efficiency can be a major factor for the UK if it is to reduce carbon emissions. The UK has been investing money in this area and signs of improvement have been showing. Experts say the UK can save up to 7.5 billion pounds using advances in energy efficiency. Houses could save 270 pounds a year on bills if they use simple saving methods. These simple methods can save up to 25% of energy use and electricity in homes. Further wall insulation and heat insulation investments for factories and plants will cut energy usage drastically. However, the UK has few incentives to owners to invest in these measures and the government is not giving any added bonuses to people who apply these energy saving methods. Although bills have continued to rise in the UK, this is mainly due to increased prices of fuels. Gas use in households has dropped by nearly 26% in the last decade and electricity consumption in households has fallen by 13% in the same period. If all energy saving methods are applied to households, then homeowners can cut their bills by nearly 50%. However, this can not be achieved unless the government gives bonuses to to homeowners or incentives to people buying energy efficient products.

Advantages:

- Saves money.
- Cuts carbon emissions drastically.
- Improve quality of life.

Disadvantages:

- High initial costs.

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7.Control of Demand (Ka Wu)

In this section, the methods of controlling and reducing the demand of energy will be discussed. In 2016, the transport sector is accounted 40 percent of the overall energy consumption in the UK, which make it be the largest share. The energy consumption in this sector has increased 2.3 percent compared to 2015. The second largest share is the domestic sector which is 29 percent of the overall. Therefore, the energy demand of these sectors should be the highest priority to be reduced. [1]

7.1. Mindstorms

- **Fuel Cell Vehicles** - electric vehicle that uses hydrogen gas as the power sources, high energy efficient and almost zero carbon emission.
- **Geothermal Heat Pump -** a heat pump that transfer heat from building to ground or from ground to building, an alternative to use HVAC (heating, ventilation and air conditioning).
- **All-Weather Solar Panel -** a solar panel that generates electricity by sunlight and rain.
- **LED lamps** - high electrical efficiency and long lifespan.
- **Passive Infrared Sensor Light -** Only turn light on for a small period when warm object is detected by the sensor
- **Passive Solar Building Design -** This design can let heat get into building during winter and prevent heat getting in during summer, so the energy used by the building can be reduced.

7.2. Refinement

Fuel cell vehicles -

Fuel cell can generate electricity using chemical reaction. Fuel cell consist two electrodes (anode and cathode), one electrolyte and a catalyst. Hydrogen enter the fuel cell from the anode, through the anode the hydrogen atoms are ionized, the negative charges of hydrogen provide current for electricity. Oxygen enter the fuel cell from the cathode, and combine with the positive charges of hydrogen to produce water and heat. [2]

Fuel cell vehicles use hydrogen to drive electric motor which produce almost zero emission. Also fuel cell with electric motor is more efficiently than an internal combustion engine. 80% of hydrogen can be converted into electricity, and the efficiency of a reasonable electric motor is about 80%. Therefore, the efficiency of fuel cell vehicle is 60% or above. [3] The efficiency of a gasoline vehicle is 12% - 30%, fuel cell vehicle has several times more efficient than gasoline vehicle. [4] Also, electric motor is quietly and has a lower maintenance cost than internal combustion engine.

Fuel cell can be used in generous size vehicles such as bus and diesel vehicles, a fuel cell bus has two to three times more efficient than a diesel bus. Beside of the efficiency, the speed and stability of fuel cell bus is comparable to diesel buses, and reducing the noise pollution. [5]

The cost of fuel cell cars in the UK is about £66,000 each, but there are only a few choices of them. [6] And the cost of a fuel cell bus is about £520,000. The cost of hydrogen per kilogram is £10-15, which is quite a large amount to refuel a vehicle.[7]

Advantages of fuel cell vehicles

- High energy efficient
- Almost zero emission
- Do not need any conventional fuels (Only Hydrogen is needed)

Disadvantages of fuel cell vehicles

- High capital cost
- Cost of hydrogen fuel is higher than conventional fuels
- Explosion hazard (Hydrogen is flammable and form explosive mixture with air)

Geothermal Heat Pump -
Geothermal Heat Pump is an alternative to furnace and air conditioner. It exchanges heat between building and ground by long loops of underground pipes filled with water or an antifreeze solution. In summer, the underground liquid is cooler than the building, so the heat of building is transferred to underground, this process keeps repeating and cool the building. In winter, the temperature underground is higher than aboveground, so the heat pump system absorb heat from underground and circulate heat inside the building. The heat pump system can reduce 30% - 60% of electricity use in summer and 30% - 50% in winter. [8], [9]

The geothermal heat pump doesn't consist combustion process, so it doesn't emission carbon dioxide or other greenhouse gases.

There are several types of geothermal heat pump for different kind of buildings. [9]

- A horizontal type is suitable for residential and it is the cheapest type. The pipes are placed in at least 4 feet-deep trenches. A 2000 square foot building requires 400 feet of 2 feet-wide trenches.

- A vertical type is suitable for large commercial buildings and schools because it doesn't require a large land area. It requires four-inch -diameter holes which are drilled about 20 feet deep, then two connected pipes are placed in the holes.

- A pond/lake type is suitable for building nearby a water source. The pipes are coiled into circles and placed under eight deep-feet, the coils should only be placed in the minimum volume and depth of the water source.

The installation cost of a geothermal heat pump system is high, it costs USD 10000 to USD 30000 depending on the type of heat pump. A 2000 square foot building cost about USD 10000 to USD 20000. [8]

The geothermal heat pump system only has few moving parts. The indoor components have 25 years lifespan, and the loop system underground can last about 50 years. Therefore, the maintenance cost of geothermal heat pump is low. [8]

Advantages of Geothermal Heat Pump

- Reduce electricity consumption of heating and cooling system
- No carbon or greenhouse gas emission
- Low cost for maintenance

Disadvantages of Geothermal Heat Pump

- Require land space for looping pipes system
- High installation cost

All-Weather Solar Panel -

Solar panels cells consist servals layers of semi-conducting material such as silicon. When sunlight is irradiated on the cell an electric field is created and across the layers. This process produces electricity. [10]

Compare to conventional solar panels, an all-weather solar panel consist an external ultra-thin layer of electron-enriched graphene, the ions of raindrops can be reacted with the graphene and produce electricity. [11]

All-weather solar cell is a novel technology to produce electricity, so its development is still in early stage. The efficiency of an all-weather solar panel in sunny day is about 22.5% and 6.5% in cloudy day. [11]

The lifespan of a solar panel is 25 - 30 years, cleaning of solar panel is required a few times per year and it is not necessary to offer specialized cleaning (£25-£35) for the panel. Therefore, the maintenance cost of solar panel is low. [12], [13]

The cost of a solar panel in the UK is between £1,500 and £8,000 depending on the size and electricity output. [13]

Advantages of All-Weather Solar Panel

- Renewable energy source
- Minimal maintenance cost
- Suitable for all weather
- Long lifespan

Disadvantages of All-Weather Solar Panel

- High capital cost
- Low energy efficiency

LED Lamps -
The efficiency of electricity converts to LED lamp is about 85% more. LED lamps consume 85 percent less electricity than incandescent lamps and 50% less than fluorescent lamps. The capital cost of per LED bulb is 10 times higher than CFL and 30 times higher than the incandescent bulb. The lifespan of a LED bulb is 50000 hours, a CFL is 10000 hours and an incandescent is only 1200 hours. Therefore, many conventional bulbs are required to operate as the lifespan of LEDs bulb, resulting the cost of incandescent lamps operate in 50k hours is 4 times higher than the LED lamps. [14]

Unlike CFLs, LEDs do not emit IR or UV, so LEDs help reduce the light pollution. The performance of LED lamps is dependent on temperature and time, it operates well in low temperature, the illumination and color would be different or become badly at hot temperature and long operational time.

Advantages of LED lamps
- High energy efficient
- Long operation time
- Reduce carbon emission
- Economic efficiency at long run
- High performance under low temperature

Disadvantages of LED lamps
- Higher capital cost than conventional lamps
- Performance decrease at hot temperature

Passive Solar Building Design -
The passive solar system is achieved by shading, south-facing windows and building materials which can absorb and slowly release heat. The passive solar system consists five main elements, including collector, absorber, thermal mass, distribution and control. [15]

South-facing windows are the collector that allow sunlight enter, it should be within 30° of true south to collect heat in high efficient. Phase change material is known as the heat absorber such as water container and Trombe walls (thermal storage wall which using dark surface to collect heat in daytime and conducted slowly inward through masonry), which can be placed in the direct path of sunlight to lead the heat to specified places. The thermal mass is the storage for the heat, they are connected to the absorber or beside it, high density materials such as concrete and stone floor slabs are good choices of thermal mass. Combination of absorber and thermal mass occur the distribution by conduction, convection and radiation. A control system such as thermostat can adjust the distribution to deal with the change of climates, by control the fans, vents and dampers in the buildings. [15][16]

The initial cost of a passive solar building is much higher than conventional building, but it can save more power and money over a long term.

Advantages of Passive Solar Building Design

- Increase efficiency within heating system of buildings
- Reduce the amount of heating required
- Economic efficiency at long run

Disadvantages of Passive Solar Building Design

- Higher capital cost than conventional building designs

Passive Infrared Sensor Light -

The sensor sensors use infrared to radiate moving objects, any warm object across its field of view will turn the light on. The lights will be shut down after 1 to 20 minutes unless any new movement has been detected. The Passive infrared sensor can apply to street lights to reduce the energy consumption and light pollution. [17]

The installation of the sensor is not complex, but the cost is depended on the functions and precise detection. Control system can be applied to the sensor to make the application of sensor more effectively.

Advantages of Passive Infrared Sensor Light

- Reduce electricity consumption
- Reduce light pollution
- Sensor is reliable
- Installation is easy

Disadvantages of Passive Infrared Sensor Light

- Prohibitive cost for multi-functional sensor

7.3. Feasibility

Fuel Cell Vehicle -

Fuel cell vehicle is suitable to reduce energy consumption in transportation and carbon emission of the UK, the production of hydrogen fuel is keep improving and the construction of hydrogen refueling stations is in progress. Therefore, fuel cell vehicle has a large potential to be succeed in future.

Geothermal Heat Pump -

The land and the weather in the UK is suitable for geothermal heat pump, [18] which help reducing the energy use in the winter.

All-Weather Solar Panel -

The solar potential in the UK is qualified for solar panels, but the quality-price ratio is low. Solar panels need an advanced development to improve the efficiency.

Passive Solar Building Design -

The solar potential in the UK is qualified for this design, [18] but the performance is not high compared to EU countries.

7.4. Solution descriptions

Fuel Cell Vehicles - Replace conventional vehicles to achieve reduction of energy demand and reduce carbon emission effectively.

Geothermal Heat Pump - Install at large commercial buildings to reduce the electric use of heating system effectively.**All-Weather Solar Panel** - Install on the rooftop of buildings to produce external energy, reduce the demand of energy from electric grid.

LED lamps - Replace the lamps on street and inside large commercial buildings, saving electricity energy and reduce greenhouse gas emission.
Passive Infrared Sensor Light - Install on street light to reduce unnecessary lighting in inactive time and area.
Passive Solar Building Design - Apply to new construction of buildings to reduce energy use of condition system. Constructed building can use decoration to achieve the same function.

7.5. Solutions conclusion

Fuel Cell Vehicles is the best solution to control energy demand, because of high efficiency and zero carbon emission, it can reduce the energy consumption of transportation sector. The development of fuel cell vehicles is improved rapidly, the disadvantage of them will be disappeared in the future.

Also, fuel cell technology is a suitable alternative to electricity production. The fuel cell is not only suitable for driving a vehicle, it is also suitable as a power source of large building and machine.

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8.Storage Solutions(Hamish Sams)

In this section we will focus on the storage systems and what they actually fix. The main ways these systems are used are:

Frequency regulation - The use of sinking and sourcing power into and out of the grid to counteract the demand affecting the frequency keeping it within the grids 1% tolerance.

Load levelling - This is the moving of load on the grid such as how less power is used overnight and therefore if we could take power at night and use it during daytime (like old brick heaters)

Capacity firming - Capacity firming is a battery storage technique to make intermittent sources of power such as wind and solar more reliable and able to output power constantly or can be mixed with load levelling to produce power as is needed.

8.1.Mindstorm

- **Battery storage** - Wide choice with advantages and disadvantages but need replacing every couple of years or so depending on activity
- **Hydro-Electric** - Solves other issues and is highly efficient but is expensive and not instant
- **Molten Salt Storage** - High energy density but inefficient and dangerous
- **Flywheel** - very fast response times but limited storage time and capacity
- **Compressed air(diabatic/adiabatic)** - diabatic very low efficiency due to wasted heat and re-heating, limited areas for useage and expensive setup costs.
- **Thermal storage** - Lots of different areas each with advantages and disadvantages but usually not efficient or well researched.
- **Chemical energy storage** - A general term for things such as flow batteries or even hydrogen storage, these tend to live longer than batteries and a very flexible layout given the modularity.[2]These tend to be a type of battery storage.
- **Lithium air batteries** - Higher energy density compared to other battery storage techniques while containing less harmful chemicals. Expensive but cheaper than lithium ion.[3] This is a type of battery storage.
- **Liquid air** - Stores energy for a long time but dangerous and not very efficient and costing more due to this.
- **Pumped Hydro** - Abundant in the uk and is cheap to run but expensive for an initial setup, fast(minutes) turn on speed but specific to location to build. This is just a form of Hydro-electric but purely designed for storage not constant use.

8.2.Refinement

Due to the reasons shown above, two solutions seem the most applicable:

Solution	Advantages	Disadvantages
Battery storage	High energy density, Well researched, Fast switching, Technological advances due to wide amount of applications	Fire Hazards, Expensive, Short life
Hydro-Electric	Uk has good land for this, Cheap to run, Little upkeep needed, Efficient, Can be used for constant generation,	Location specific, Slow switching speed compared to others,

Both of these solutions have multiple ways to be implemented and the main ways are:

Battery storage:[3]

Battery type	Advantages	Disadvantages
Lithium-Ion	Very very common, Easy to cool, Little standby energy leaked, High energy density, Low maintenance,	Expensive, Short life span, Complex management,
Lead Acid	Low cost, Reliable, Robust, High current, Easily recycled,	Short life span, Heavy, coulombic charge efficiency low, Overheating, Dislikes being uncharged, Toxic materials
Nickel Cadmium	Cheap, Simple to charge, Robust, Good in a range of environments	Very short lifespan if used constantly, Low energy density, Self discharge, Toxic materials

Hydro-Electric:

Facility name	Advantages	Disadvantages
Impoundment (Dam)	Constant power or storage, Hugely efficient,	Big ugly dam required, very location specific, Expensive, Slow response
Pumped storage	No dam needed, Lake storage can bee man made, Less Efficient,	Hard to limit flow rate(production), Expensive, Slow response

To meet the requirements of our specification the two best solutions would be:

- Lithium-Ion battery storage
- Hydroelectric Impoundment(Dam)

8.4.Solution descriptions

Lithium-Ion

Lithium ion storage is useful due to the huge energy density meaning that this system stores huge amounts of energy in tiny amounts of space allowing a lithium ion station to be placed almost anywhere with little room needed but allows for a large effect on the grid. As of the large research due to the use of these batteries in the mobile phone business these batteries have gone down in price given their technical development. Lithium-ion storage is very efficient with the storage of energy meaning there is little leakage of power while the batteries are holding energy.Lithium cells have fast switching speeds(to a point) allowing for these to be turned on and off quickly if needed to keep the grid within tolerance allowing them to be used in many different regulation systems. On the other hand lithium-ion has a bad reputation for bursting into flames if treated badly or pierced which beyond the fire hazard could make things such as insurance much more expensive. Despite dropping in cost due to the amount of factories that make such devices they are still rather expensive compared to other storage techniques. If these systems are overused and take too much current the internals become worn out and can drastically reduce the capacity over time reducing the efficiency. Because of the consequences of over charging and the lack of response from the battery from being charged complex circuitry is required to protect the batteries.

Hydro-Electric

Hydroelectric power is a good solution as the UK has huge amounts of available land where these stations could be built and therefore large systems or a lot of small stations (Distributed system) around the UK could be created allowing the grid to be regulated. These stations are also remarkably efficient as the energy is stored in a gravitational field (Non deteriorative) . This system, while acting as storage, can also act as a constant generation station if built in the right area and therefore also helps to solve the future generation techniques. Hydroelectric power is also clean as there is no burning involved (unless you include the power used to pump water back up in a pumped storage system such as Dinorwig) this means the system should start reducing the dependence of carbon releasing sources in the UK. Hydroelectric power is also nice to use as there are no harmful chemicals or systems involved purely the flow of water.On the other hand while hydroelectric power is fast in response compared to other constant generation techniques such as coal fired power station it is rather slow in comparison to systems like lithium-ion batteries meaning using purely hydroelectric cannot fix fluctuations to the smallest of degrees and can only be relied upon to fix the larger fluctuations and may work better using a collection of systems to get these smaller fluctuations. On top of this Hydroelectric is generally unwanted by the public due to the huge eyesore created especially where the best places for these systems are generally in protected areas like the lake district. As the system

is generally rather large costs tend to be high to create such an infrastructure but this also creates lots of jobs for engineers and locals which would be rather useful given the UKs current economy and from the recent brexit vote.

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9.Generation Systems

9.1 Nuclear energy - The UK nuclear power generates about 24.8% of the country electricity in 2017 with the data collected from March to May. There are 15 active operational nuclear reactors at 7 plants (14 advanced gas-cooled reactors (AGR) and one second generation pressurised water reactor (PWR)) but almost half for them will be decommissioned by 2025. Two units of European Pressurized Reactor (EPR) at Hinkley Point C in the United Kingdom have received final approval in September 2016 and are expected to be completed by 2025.

Advanced gas-cooled reactor - AGR is a British design of nuclear reactor. AGRs are the second generation of British gas-cooled reactor, using graphite as the neutron moderator and carbon dioxide as the coolant. AGR is developed from the Magnox reactor. It uses a slightly enriched uranium dioxide clad with stainless steel. Due to the higher gas temperature operation for improving thermal efficiency, stainless steel fuel cladding is required to withstand the higher temperature. Because the stainless steel fuel cladding has a higher neutron capture cross section than Magnox fuel, so low enriched uranium fuel is needed.

European Pressurized Reactor - EPR is a third generation pressurized water reactor (PWR) design. PWR is most powerful and safest reactor in the world. It has an electrical production capacity of more than 1,650MW which can provide 1.5 million people. The EPR is based on tried-and-tested technology. It has 4 extra safety systems and a concrete, metal-lined containment shell to protect the reactor which provide resistance to plane crashes and earthquakes vibrations. This low-carbon reactor also reduces the amount of long-living radioactive waste by around 30% per kWh. It uses around 17% less uranium per unit of electricity generated than the older PWR. The EPR has about 60 years lifespans and total cost of the power station is likely to be £19.6 billion or more. The two new EPRs are expected to provide 7% of the UK electricity needs within its lifetime.

Advantages of EPR

- most concentrated form of energy
- various choice of fuels - 5% enriched uranium oxide fuel, reprocessed uranium fuel and 100% mixed uranium plutonium oxide fuel
- plants do not give off greenhouse gases
- high reliability
- high level of safety - active and passive safety system
- output can be controlled between 60% and 100%
- higher environmental protection - reduced radioactive waste

Disadvantages of EPR

- need to maintain water high pressure in the system
- disposal cost is high
- decommission cost - retired reactors take up valuable land space for a long times
- Water pollution

9.2 Wind power - The UK wind farm generates about 11% of the electricity in 2016. UK is considered one of the best location for wind power generation in the world. There are 6,565 onshore wind turbines and 1,502 offshore wind turbines in UK. The onshore and offshore total operational capacity is about 11GW and 5GW respectively.The UK government has also made a commitment to invest in offshore wind energy for generations . The current installed offshore wind capacity of 5GW is due to increase to 10GW by 2020, and then to increase by an estimated 10 GW by 2030. In addition, the world's first floating wind farm has started delivering electricity to the grid in September at the off coast of Scotland. The five 6MW turbines can provide 20,000 Scottish homes.

Floating wind turbines (Hywind) - The turbine towers extend 176m above the water and 78m below it. The towers have a rotor with diameter of 154m. The floating substructures are ballasted by 5000 tonnes of iron ore based on the oil and gas platform technology. Each turbine is moored to 3 lines which are connected to giant suction anchors on the seabed. The motion controller system of the hywind turbine can pitches the blades to certain direction to reduce unwanted motion and stabilize the floater for increasing the power production. The generated electricity are running through a cable undersea to a power station onshore. The Hywind turbine can go into more windy areas and deeper water. It allow wind power generation to move further and further from onshore. The Hywind Scotland project cost about £200 million to construct. In the future, these floating wind farm can be built more faster and cheaper.

Advantages of Hywind

- The farther out offshore turbines, the steadier and faster the wind
- avoiding any community arguments about the noise pollution
- components can be delivered by sea rather than by land
- Much cheaper than bottom fixed turbines
- No greenhouse gases generation after construction
- low operational cost and maintenance
- overall cost are decreasing - the cost of offshore wind had come down 34% in the last four years

Disadvantages of Hywind

- manufacturing and installation of wind turbines requires heavy upfront investments
- threat to wildlife
- community arguments over clean ocean view

9.3 Wave and tidal power - The waves in the ocean contain a large amount of kinetic energy. These kinetic energy can be harnessed to generate electricity to provide the entire planet. The ocean is such a rich resource due to water has 1000 times the density of air. UK currently is a global leader in the marine energy sector. A quarter-scale prototype wave energy device WaveSub which is developed by Marine Power System (MPS) was recently launched on October 13, 2017, in Wales, UK.

WaveSub - The device is a wave energy converter, which is a barge and floating sphere tied together by cables. It is designed to generate power from the relative motion of the sphere that reacts to the orbital subsurface flow of the waves by the hydraulic generators. A hydraulic circuit smooths and use the hydraulic energy to turn an electrical generator for electricity outputs. The transportation barge make the the device can be easily transport to access services and maintenance. The device also has a floating surface configuration and a submerged operating configuration. The device sink below the water surface by using ballast tank. It also able to adjust its depth and cable lengths depending on the sea condition. The device can descend completely onto the seabed to protect itself from storm. A full scaled 100m long WaveSub can generate 5MW thought the undersea cable and can power around 5000 homes.

Advantages of WaveSub

- immense efficiency in power generation, construction and installation
- green
- long lifespans
- effective on low speed
- adjustable
- easy to transport

Disadvantages of WaveSub

- Can only operation on coast
- new technology - still in developing

9.4 Solution Conclusion

All of the energy generation above are indispensable in the future generation mix. They have a very high potential to become the top 3 best energy generation in UK and lead the future energy generation mix. With those new technologies, they will provide a better and greener low carbon system in UK to provide a stable energy future.

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10.Solution recommendation

Together we have decided the best solution is to use Wind power with Lithium ion capacity firming and this could be subsidised by the government to increase the usage of these types of power sources.

10.1Wind(Chun)

Wind power has lots of potential in UK specially with the location and the new technology, floating wind turbine. The turbines can be built further from the shore and get steadier and faster wind. Moreover, wind power also has the government's commitment to helping the wind power development in recent years such as building a highly skilled workforce, offering support to UK-based companies and providing market confidence and demand visibility. With all these efforts, more wind farms can be implemented and wind power can be the dominant of the UK energy generation mix in the future.

10.2.Lithium-Ion(Hamish)

Lithium-Ion storage works well with wind power as the large energy density of Lithium ion batteries means that large amounts of storage can be built into the wind turbines themselves meaning no more space is needed except that the turbines themselves would take up. The batteries are used for capacity firming meaning the intermittent nature of wind power would be negated and these systems could be used to power throughout day and night. This capacity firming would most likely be used with load regulation to reduce the peak strain on systems with large switching times to reduce their need for an increased output.

10.3.Subsidies(Ka)

In the 2015 auction for clean energy projects, the cost of subsidies for offshore wind farms was between £114 and £120 per megawatt hour. The price of subsidies for offshore wind farms has been halved now. Three companies are promised to build offshore wind farms by 2021-2022 with guaranteed prices £57.50/MWh - £74.75/MWh. The fall in subsidy price of offshore wind proved the offshore wind technology is well-developed.

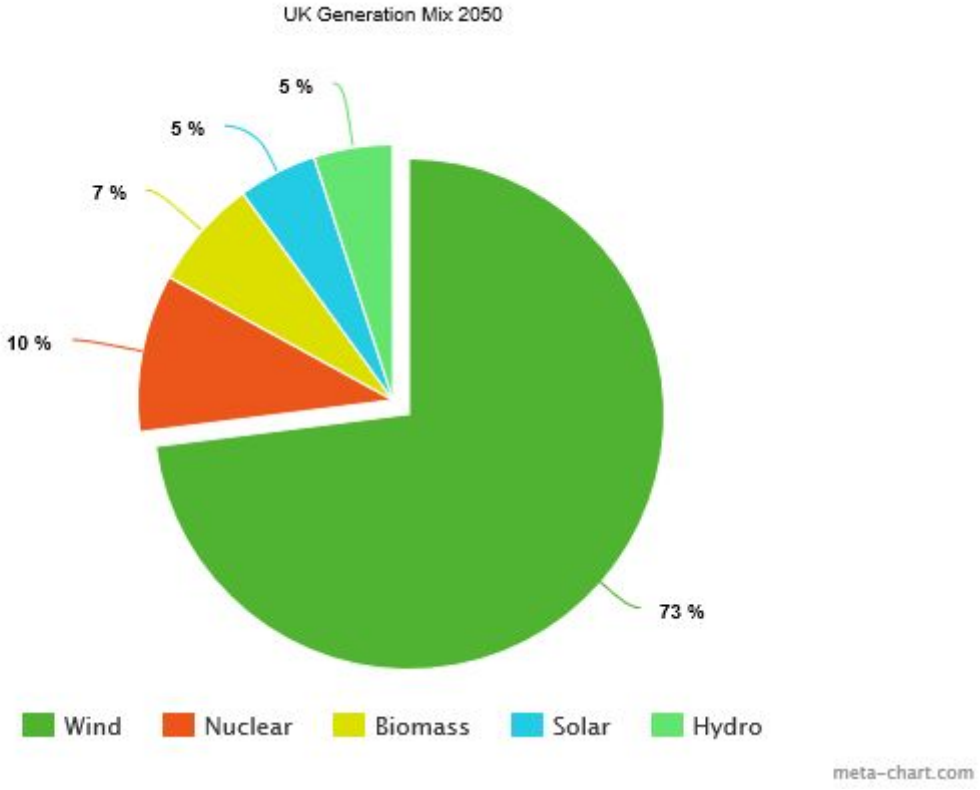
11.Conclusion (Seif)

In conclusion, our solution system was made up of wind power for energy generation and lithium-ion batteries for energy storage. Our system had several requirements that must be met in order to meet the specification. It should avoid energy surplus, energy shortfall and it should account for the fluctuation in energy demand. We took into account that our system must be eco-friendly and sustainable. In addition, we looked at the incentives that could be applied by the government to encourage the widespread use of our system in the UK.

Wind power was chosen because it is a clean energy source and because of it's enormous potential in the UK due to it's high wind speeds. Onshore or offshore wind farms can be built however, there is a preference of building offshore farms due to higher and more consistent wind speeds. Lithium-ion battery storage was chosen because it is the perfect energy storage partner for wind power due to it's large energy density and that it can be built into the turbines which will save valuable space. The solution system is capable of supplying power throughout the whole day and can adjust to the energy variance throughout the year.

Government incentives would be beneficial as this would encourage major companies and consumers to buy and apply these systems throughout the UK. Government incentives are being applied on wind power however it has nearly been halved over the last few years and increasing incentives back up again would make a significant effect to the UK's generation mix problem.

The UK has vowed to close all coal power plants by 2025 with some of these power plants converting to biomass plants. Furthermore, the UK plans to reduce 80% of it's carbon emissions by 2050. With energy storage emerging, an increase in electric vehicle popularity amongst the public, an increase in investment on renewables and fossil fuels becoming scarcer, the generation mix is set to drastically change and the figure below shows our estimation of the future generation mix.



Our final results were estimated by substituting fossil fuels with renewables, mostly wind. For nuclear energy, we decided that it will be cut by more than a half due to the fact that half of the reactors will be decommissioned by 2025 and that the energy demand will increase gradually.