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ASSESSMENT OF ENERGY GENERATING MIX IN ADVANCED ECONOMY FOR 2030

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Abstract:

The future energy mix scenarios seem unclear as there is continual rise in demand all year round. Couple with this, the UK is poised to cut down its dependence on fossil fuel for energy production and concentrate more on renewable in its stead. The country is under legal obligation to reduce its greenhouse gas (GHG) by no less than 80% from the 1990 benchmark by the year 2050. This work focuses on the UK generation mix by year 2030. It dwells upon how the renewable technologies would constitute minimum of 30%, average emission brought down to maximum of 50gCO2/kWh. The entire research was centered on three major issues of interest to the UK; vis-à-vis security of supply, affordability and reduction of greenhouse (GHG) gas. This is done by using an excel-based Energy Optimisation Calculator, which captures the interaction of various inputs to produce a least-cost generation mix. The result shows that a carbon neutral electricity sector is feasible if low-carbon technologies are deployed on a large scale.

Keywords: Generation mix, Greenhouse gas, National grid, Optimization, Renewable energy.

Introduction

It has become a common knowledge in recent times that the issues of climate change, energy supplies and affordable energy are three major challenges that are connected together with regard to issues of availability and utilization of electrical energy. A holistic approach to encompassing the entire issues needs to be accorded a great consideration. According to the National grid, published on the UK future energy scenarios (UK FES, 2014) document, the future energy scenarios of UK were based around energy trilemma of security of supply, sustainability and affordability.

In the light of the aforementioned, many developed countries like UK, have been stepping up efforts to ensure robust strategies which are deployed to address the issues of climate change with the encouragement and development of sustainable energy system. The energy market is a dynamic system changing annually with many pieces of legislation and goals set by the UK and EU (**The UK renewable energy strategy,** 2009). The UK is under obligation to abide by these regulations as climate change and dwindling fossil fuel reserves are global issues in UK future energy scenarios (UK FES, 2014) and **the UK low carbon transitional plan; national strategy for climate and energy** report (2009)

The UK energy supply in the last three decades has been characterised by huge amount of coal and oil. To reverse the trend, the experts in the field of energy now adopts different scenarios among which is the gone green scenario that the usage of more of renewable energies to reduce drastically the greenhouse gases **(Progress report to parliament meeting,** 2014). In the light of this, all hands are now on deck to generate energy mix for the future of UK. It is based on this, among other laudable reasons, that this paper is designed to generate energy mix for 2030 to meet energy and climatic change goals without compromising the cost.

The figure below shows the current energy generation mix in the UK.

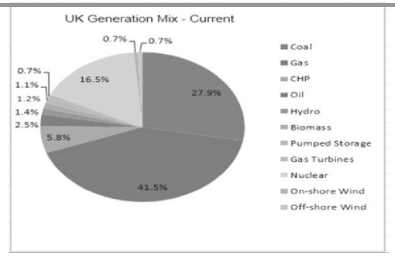

Figure : Current UK Generation Mix

Energy Generation Mix in UK

With the focus on reduction of green gas emission by at least 80%, the committee on climate change suggested the decarbonisation of UK electricity sector by 2030 (with average emissions of 50C0$_2$/kwh) by the report of committee on Climate Change in 2016,(Ekins*et al*, 2011). The advice put forward by the committee shows clearly a reduction in the use of fossil fuel to generate electricity and in order to meet the electricity demand. As at May 2019, the generation mix is dominated by the fossil fuel with coal leading the supply with 30% of the total generation and gas taking up 29% and other energy used. It was observed from the prediction made by the National Grid Gone Green scenario that in the future generation mix for 2030, the renewable energy will take up the large percentage of the generation mix and lower percentage of the fossil fuel due to the reduction in the use of coal.

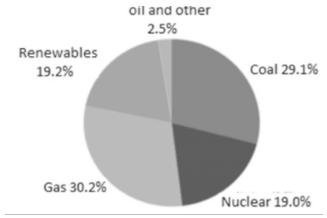

Figure 2: UK shares of electricity generation

The UK has started a 4-year research and development programme worth £125m to ensure the rapid development of the CCS technology (Ekins *et al,* 2013) because of its potential to reduce C0$_2$ emissions by 90% of the fossil fuel combustion.

Renewable electricity will play a key role in the future generation mix of the UK in order to meet the reduction of CO_2 emissions target. As at 2013, the renewable share of UK electricity generation was 14.9% and this is to rise to 19.2% by 2014 ((Ekins *et al,* 2011). The increase in the renewable electricity generation is expected to continue as renewable will play a significant role in the future UK electricity generation mix. Other renewables include tidal, wave etc. as reported by the UK holds 56GW out of which only 8.6GW can be exploited (Kannan, 2009).

Other generation mix include combined heat and power (CHP), micro generation (MG), oil, pumped storage (PS) and CAES.

Methodology

The objective of the optimisation problem is to obtain a generation mix for 2030 with the lowest cost, in p/kWh, provided that the following targets are met:

Table 1: Targets for 2030 Optimal Scenario

Total Capacity	Total output	Average emission	Renewable resources	Low carbon	Max non-dispatchable
130GW	366TWh/yr	50g/kWh	At least 30%	At least 29%	40%

Different scenarios are used by National grid to forecast the electricity demand in 2030 (Hughes and Strachan, 2013) and National Grid **UK future energy scenarios** (2013), such as "Low carbon life", "Gone green", "No progression", "Slow progression". For this paper, "Low carbon life" scenario is chosen to indicate the total capacity and total output in 2030. The fraction of renewable resources and low carbon generators would increase to 30% and 29% respectively in order to reduce the average CO_2 emission to 50g/kWh.

The power plants that are considered to contribute to UK generation in 2030 are coal, gas, combined heat and power plant, hydro, biomass, nuclear, onshore wind, off shore wind, wave, tidal and solar PV.

Coal

Coal plants do not only have a large CO_2 emission, but also creates other kinds of pollution such as SO_2, NOx, and PM2.5. Although carbon capture storage technology could reduce the emission significantly, it would have a large amount of extra cost. In the meantime, fuel cost is expected to keep rising in the future.

Table 2: Various Coal Technologies Cost

Type	Capital (£/kW)	Fixed £/kW/yr	Variable £/MWh	Fuel £/MWh
ASC	1642.47	42.6	1.0	19.3
ASC+CCS	3584.0	66.7	2.5	23.1
IGCC	2366.8	59.8	1.0	20.5
IGCC+CCS	3953.4	77.1	2.4	22.5

The constraint of capacitor factor is introduced based on the highest scenario for coal generation.

Table 3: Coals Capacity Factor Range

Type	ASC	ASC+CCS	IGCC	IGCC+CCS
Max CF	85	85	85	85
Min CF	30	30	40	40

Nuclear

Nuclear is a type of power that extremely lacks flexibility. But at the same time, it is extremely clean and has no emission. Although due to the limit of speed of developing, the maximum capacity that can be reached in 2030 is 16 GW.

Table 4: Nuclear Power Generation Total Cost

Capital (£/kW)	Fixed £/kW/yr	Variable £/MWh	Fuel £/MWh
4148.8	84	2.5	5.0

Gas: Gas power station has less pollution than its counterpart in coal, and UK has a large amount of storage in gas at present.Thus, it would play a more important role in UK generation mix in 2030. The data for cost is obtained from Department of Energy and Climate Change **Electricity generation costs (2013)** and as listed below.

Table 5: Various Gas Technologies Cost

Type	Capital £/kW	Fixed £/kW/yr	Variable £/MWh	Fuel £/MWh
CCGS	670.0	17.0	2.4	49.6
CCGS+CCS	1408.0	21.4	4.6	49.6

Renewable and Low Carbon Techniques

The data for the expenses for renewable energies and low carbon techniques are collected from the report published by Department of Energy & Climate Change (2013).

Table 6: Low Carbon and Renewable Energy Sources Cost

Type	Capital (£/kW)	Fixed £/kW/yr	Variable £/MWh	Fuel £/MWh
CHP (renewable)	3500	150	20.0	49.0
CHP (other)	600	46.3	0.1	119.0
Hydro	3400	24.8	6.0	0
Biomass	2500	160	5.0	0
Wind-onshore	1513	41.3	6.9	0
Wind-offshore	2210	125.4	16.4	0
Wind-offshore(R3)	2273	125.4	12.3	0
Wave	3500	202.0	0	0
Tidal	3125	77.5	0	0
Solar PV	2011	25.0	0	0

CHP technology and biomass both have same emission with that of fossil fuel (DECC**UK,**2012). However, they either burn the fuel in such a way that is more efficient, or they use recycled resources that are from the waste of kitchens or agriculture. That makes them more like a low-carbon technology, which can also reduce both the emission and cost.

The constraints for the capacity of these energies are set according to either the limit of installing speed, such as wind agrees with Department of Energy and Climate Change **Electricity Generation Costs (2013)**, wave, tidal, and solar PV, or the maximum potential that can be reach in 2030, such as hydro and biomass, IEA **Projected costs of generating electricity** (2005)

Operating Life of Power Plants

Varies studies has summarized the operating life of different types of power plants. The data used in this study is listed as below.

Table 7: Expected Operating Life of all Energy Sources

Coal ASC	29	Hydro	150
Coal ASC+CCS	25	Biomass	22
Coal IGCC	29	Nuclear	60
Coal IGCC+CCS	25	Wind onshore	20
GAS	25	Wind Offshore	24
Gas with CCS	25	Wind Offshore (R3)	22
CHP renewables	20	Wave	20
CHP (other)	20	Solar PV	30
Tidal	25		

It can be seen that the operating life of most types of power plants distribute from 20 to 30 years. However hydro stations and nuclear stations could operate much longer than the others.

Emissions

Coal driven power plants have a large amount of CO_2 emission, and gas driven power plants have relative lower emission than coal. Installation of carbon capture storage devices could reduce the emission significantly(DECC**UK, 2012)**

Table 8: Power Sources Emissions

Technique	Emission	Technique	Emission
Coal ASC	786	GAS	350
Coal ASC+CCS	220	Gas with CCS	56
Coal IGCC	786	CHP renewables	180
Coal IGCC+CCS	220	CHP (other)	440
Biomass	165		

Results

Efforts to reach the emissions target of 50gCO_2/kWh wind power generation had a dominant role. Even though the majority 49.79% of the optimised scenario incorporates wind power, nevertheless it is an expected scenario due to wind power huge growth.

The total cost of the system is expected to be relatively higher since wind power and especially offshore wind power is an expensive form of energy. Therefore, combining the entire factors above, total cost of this scenario reached **£50,473.9**£bn/year, when at the same time emission target was not only reached but overcame reaching 49.5gCO_2/kWh. Figure 1 shows the results obtained from the optimization solver.

Comparing both Figures 2 & 6, it is noticeable that wind power enjoys the biggest increase in comparison with other power sources. Both onshore and offshore rise dramatically from 1.4 % to a stunning 49.79% of total generation mix.Comparing both charts, it is noticeable that wind power enjoys the biggest increase in comparison with other power sources. Both onshore and offshore rose dramatically from 1.4 % to a stunning 49.79% of total generation mix. Offshore wind power seems to provide the biggest portion in whole optimised model with 31.33% of power generation by 2030.The only drawbackcould be the installation period and the capital cost.

Nuclear power on the other hand, seems to have reduced mainly due to the replacement of old facilities and growing***opposition*** to ***nuclear power, especially*** after Fukushima disaster, National Grid **Future energy scenarios** (2015). Nevertheless, the percentage of 12.3% classifies nuclear power as one of the most essential power sources in 2030 with zero emissions.

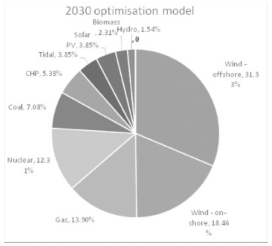

Figure 3: 2030 Optimised model

At the same time gas and coal shrinkage which are currently the vast power providers offering together more than 69.4 % are proposed to get reduced to 20.98% of total contribution, projecting this as the most

important outcome of the whole study. It is worth mentioning though, that the small portion of 20.98% from gas and coal is mainly combined with CCS technology, reducing further the total emissions.

Also, large percentages offered by solar PV contribution to the proposed energy mix seems a very surprising result. Their 3.85% growth considering their long operational life combined with the short development period classifies Photovoltaic technology among the most promising ones.
Tidal power, like PV technology, accounts for 3.85% of the overall energy mix. Although this technology is not proven yet, in UK it is expected to contribute at least 5GW of power.

Conclusion

It is more than clear that the UK power sector is about to face large changes and rearrangements over the next two decades in order to accommodate the 130 GW in **The UK Low Carbon Transitional Plan** (2009) of total capacity with 366 TWh/year total output as resulted from excel optimiser solver for 2030 energy optimisation mix.

Combined heat and power schemes as well as hydro power generation enjoy further raise in 2030 in comparison with today power generation contribution. Though the percentages are the same,the total power capacity in 2030 is expected to reach 130 GW meaning 40 GW raise in comparison with 2013. CHP raise is mainly due to biomass schemes that are expected to be deployed in UK the years to come and also due to their flexibility and high efficiency Barnacle, Robertson, Galloway and Barton (2013). Hydro power is also expected to rise but not in significant rates mainly due to the refurbishment of existing schemes and some micro sites. According to these results in excel optimiser, it is expected that the total cost will reach 13.8p/kWh when today it ranges between 9.39gCO2/kWh to 11.1gCO2/kWh.

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