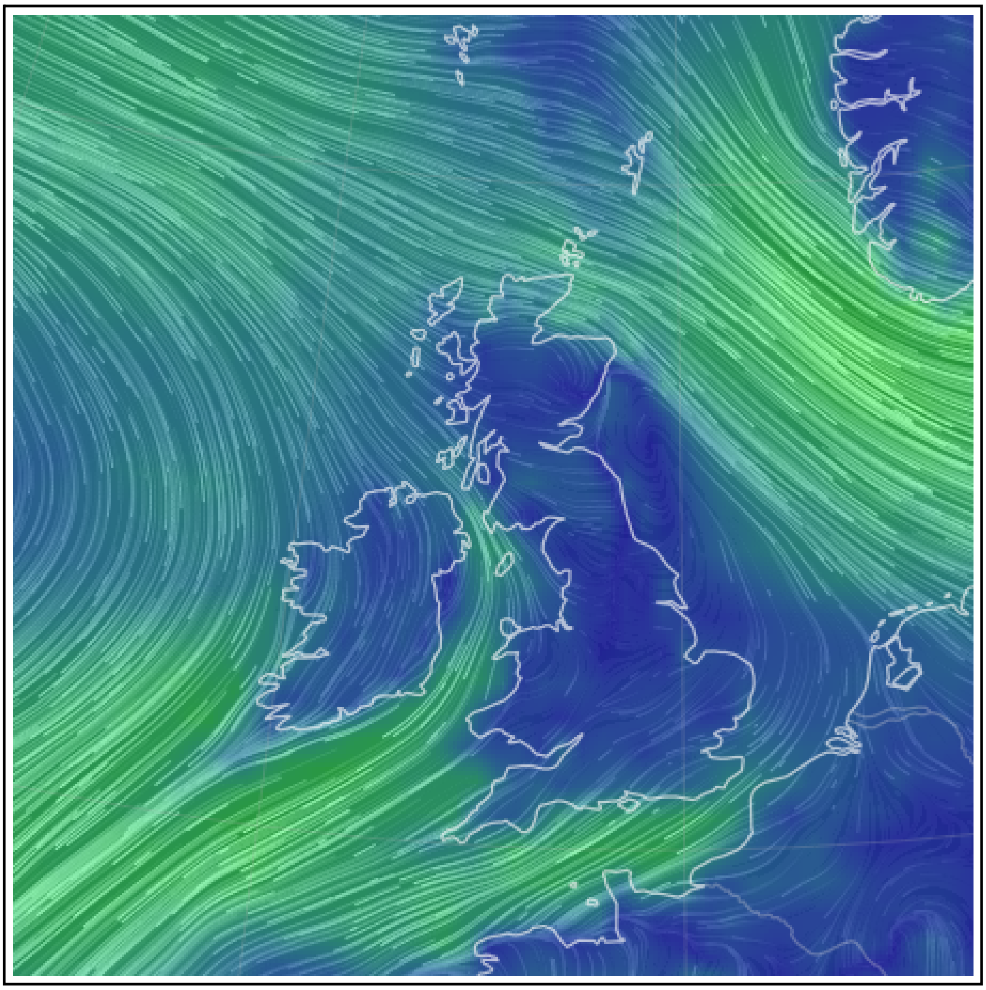
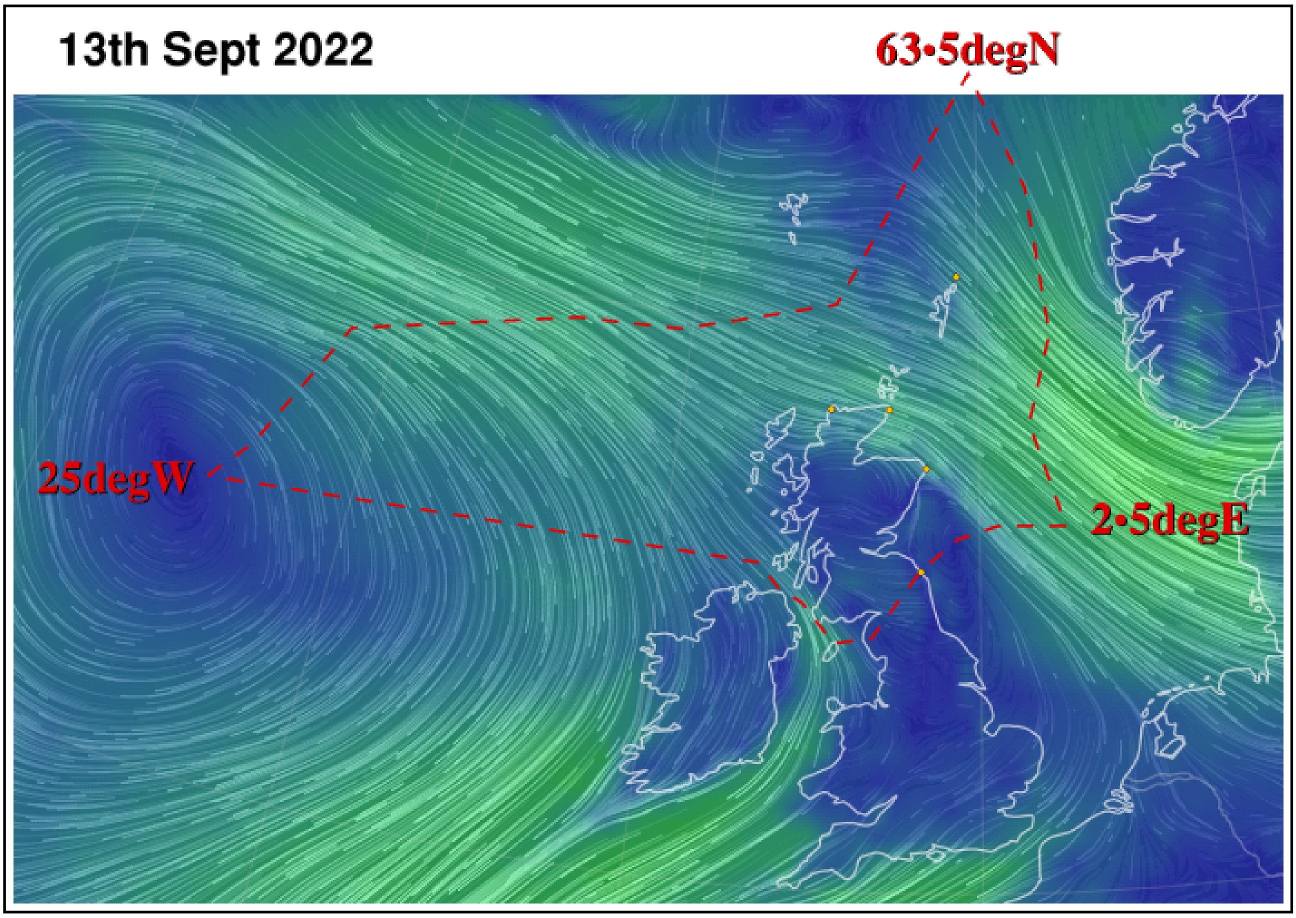
When the wind doesn't blow...

In discussions about the desirability of 'green' energy sources and having them displace older 'fossil' sources politicians often throw out dismissive comments about when the "Wind doesn't blow". At first encounter this argument against taking renewable energy sources this seems like a serious drawback. However, out of scientific curiosity I decided to investigate the real situation to assess the real potential for wind energy, etc. Since I live in Scotland my curiosity caused me to focus in particular on Scotland's potential for reliable wind energy.



The above shows the pattern of wind over and around the UK at a time during the 22nd of August 2022. This is, I assume the kind of 'problem' that detractors have in mind when dismissing wind power as a reliable source. It does, indeed, show that there are times when the "Wind doesn't blow" over the UK. However in reality, by international Agreements and Law, has control and effective ownership of an area of sea which extends some way beyond land area.

'Scottish Seas' as defined by the methods applied for the above cover an area of just over 460,000 square km. This accounts for over 60% of the UKs Exclusive Economic Zone. As things stand this is pooled with the rest of the UK. But one possible change in the future may be political – that Scotland may get another 'Indy Ref' which then votes in favour of Independence. Should that occur, the result may be quite a valuable energy resource for Scotland, and aid it in having it's own National energy resources.

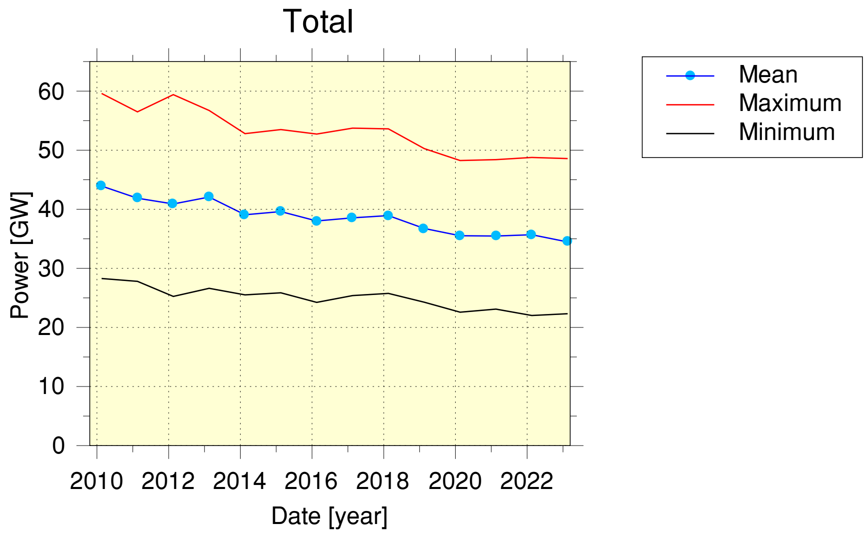


The above shows another map of the wind distribution pattern, again on a day when those inland would say that the "Wind isn't blowing". However I have overlaid the map with a plot (broken red line) showing the boundary of Scotland's part of the UK EEZ. This expands quite markedly the area of possible interest. It also illustrates something that those who go out to sea know very well. That the North Sea and North Atlantic tend to often be *very* windy – even when the "Wind doesn't blow" on the UK mainland!

In practice, of course, as I write this (2023) the bulk of wind power sources in the UK are land-based. However the scale and output of offshore wind farms is increasing. They are also gradually expanding to locations further from the shore. So we can expect the amount of energy they can provide to rise. How quickly – and reliably – wind power production may rise is quite a contentious issue in political terms. So to get some idea of what has been happening, and what may follow, I decided to look at the statistical data I could find.

National Grid statistics

The UK's electric power distribution system is operated by the National Grid (NG). They provide open data on where the power comes from, aggregated by the method used for production. Hence this gives values for electric power delivered via the NG grouped to represent that coming from Gas, Wind, Nuclear, etc. The values are provided as a time-series of values covering successive half-hour periods. So they can be used to examine how the situation has been evolving in recent years. To set the context we can begin by looking at the values provided by NG for the Total amount of electric power they have conveyed as a function of time.



The above graph shows three aspects of how the Total has varied with time during the period from 2010 to 2023. For the sake of clarity I decided to focus on the first quarter of each year (i.e. from the start of January to the end of March) as that tends to be when demand is high due to the winter. It allows the graphs to dodge any annual variations from season to season and give a clearer view of the long-term trends. There are over 4,000 values during each quarter-year, by taking the mean (average) of these we can also tend to smooth out short-term weather and other fluctuations to make the trend clearer.

The 'mean' values plotted above simply show the average over the values in a quarter. The 'maximum' and 'minimum' values are for the highest and lowest *individual* values amongst than series - i.e. for two individual half-hour periods during those three months. That tells us the extreme limits of the spread of values, but not how often any specific amount in between was provided. One fairly clear pattern for the totals shown above is that there has been a gradual decline in the power which tends to be being conveyed via the Grid.

When assessing what these National Grid values tell us it is important to understand that they do **not** tell us how much a given type of source *could* have provided during any half-hour period. They tell us how much energy the Grid 'purchased and transferred' during that time. Thus any of the individual sources may have been able to supply more, but it was not needed at that time.

The UK electric power 'market' has operated using a specific market mechanism which does impact both the price for end-users and the choice of supplier/source mix at any time. So it is worth outlining this process to avoid making misleading assumptions about what the NG data stats show.

In practice there are many suppliers, who use various methods to 'generate' power. Every half-hour the NG decide what amount they expect to need to transfer during the next half-hour. NG then essentially run a 'market auction'. Each potential (pun alert!) supplier then puts in a bid that essentially says, "We can supply *X* kWatts during the next half-hour for *Y* pounds/kWh".

NG then scans this list of offers to find the ones with the lowest price. It then accepts those, then it repeats this 'find the cheapest and accept it' loop repeatedly until it has obtained the amount of energy it needs. This approach then means it has rejected the most expensive offers. However, it then pays **all** the accepted bidders *the price per kWh of the **most expensive offer it accepted**!* As a result, those who made the cheapest bids may still get paid a somewhat higher amount. That means we pay more than if each bit was only paid its bid-price, but is assumed to encourage low bids as generators compete to get into the 'accepted' pack, knowing they might get more than then asked for.

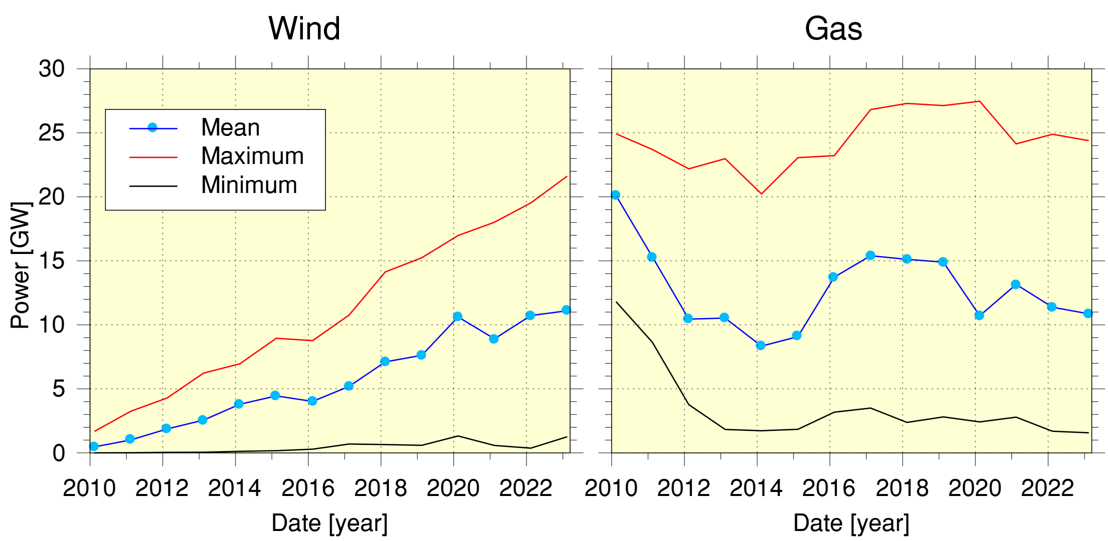
This has recently been great news for the owners of on-shore wind farms in particular as their price per kWh has tended to be much lower than the cost of Gas. Indeed for many it was cheaper than Gas before Putin invaded Ukraine and Gas prices soared. This is because if some Gas has to be bought at a high price, the Wind farmers also get a high price for their accepted output. That then attracts other investors to fund additional Wind Farms which can then make a profit.

Unfortunately, this approach has become problematic given the unexpected situation caused by Putin's invasion and a significant reduction in Gas supply! The resulting hike in Gas price then has a much bigger impact on the cost per kWh as the War Profiteering by Gas suppliers also raises what gets paid to other suppliers of electric power. The rise in the cost of electric power which consumers then pay will then tend to reduce how much is required as people cut down on their usage. Overall, this makes a case for reconsidering the current "pay them all the same" behaviour at the end of each NG bid cycle.

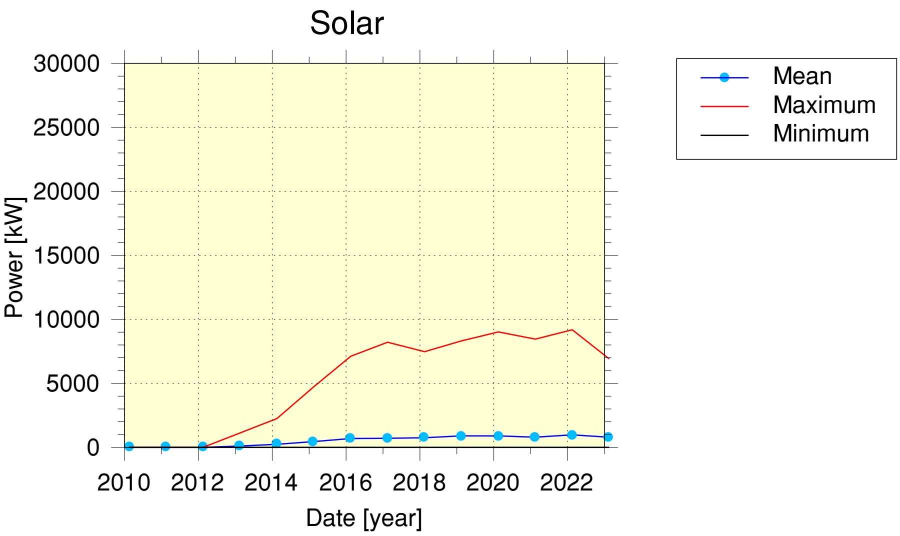
The above process has another implication. The amount of energy bought and transferred by NG doesn't always equal what levels *could* have been supplied if more had been needed. Some potentially available energy went 'unused'. How much more might have come from a given source is uncertain. But it means the real potential to supply power may be higher than the values shown by the data being analysed here. In addition, having seen the gradual decline in the mean Total over the years that may indicate two trends.

- That users are becoming more efficient and using less electric power than in the past. For example, using better insulation in homes, or employing heat pumps. Each of which can reduce the demand for electric power.
- That an increasing number of users now have installed Solar Panels, and perhaps a local battery to store some power. Thus needing less power via the 'mains supply' than before.

Whatever the truth of the above may be, it indicates that the NG data may omit some factors of growing significance. But it does remain the case that the Grid does dominate the supply of electrical power as things stand. And represents the 'market' so far as generators are concerned.

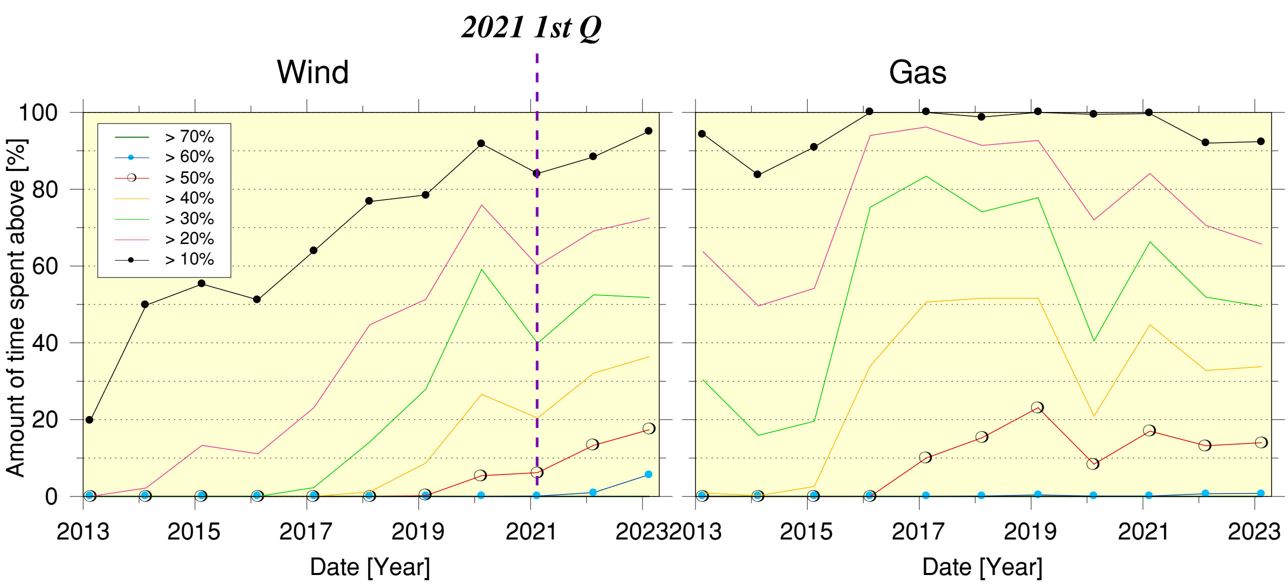


The two above graphs show the mean/max/min power vs time patterns of the NG data over the same period as used for the Total. What is interesting about these plots is that the mean Wind energy level is now comparable with electric power provided by burning Gas. It also continues to rise steadily, whereas the values for Gas have been falling gradually.



In comparison, UK Solar contribution looks minimal, and even may be declining. However as above, this doesn't include Solar power from sources on domestic homes that powers the home without going via the NG. Instead, this may show up as a disguised reduction in the Total value handled by the Grid.

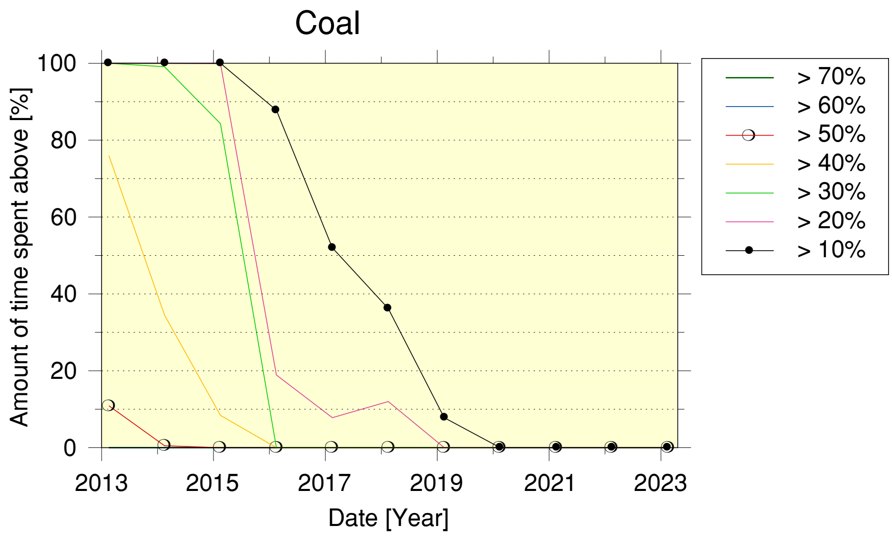
Knowing the peak and minimum individual half-hour power levels isn't very useful for assessing what may be 'typical'. So to try and clarify that I decided to take a more detailed approach.



The above compares the percentage of the Total NG energy stream that Wind and Gas sources supplied during the first quarter of each year. However, it does this on the basis of seeing how many half-hour periods during each quarter it supplied an amount above various given 'threshold' percentages. To help clarify what this means I've selected a specific example above – the values for the 1st Quarter of 2021. (Indicated by the broken vertical line.)

This illustrates that – during that quarter – Wind sources supplied more than 50% of the total power during 6·2% of the half-hour periods (red line with circles), more than 40% during 20·4% of the periods (yellow line), etc.

Although more complex to assess, the overall pattern shows a rise in both the amounts of power available from Wind during the time from 2013 to 2023, and that by 2023 the levels of nominal reliability became comparable with Gas. In effect this shows that Wind generation is already a big, and statistically increasingly reliable, source. The levels of Wind power available also continue to rise as more wind farms, better wind turbines, etc. continue to come on-line.



This is also in the context of Coal-burning essentially vanishing as a source of electric power generation, as can be seen by the equivalent plot for Coal!

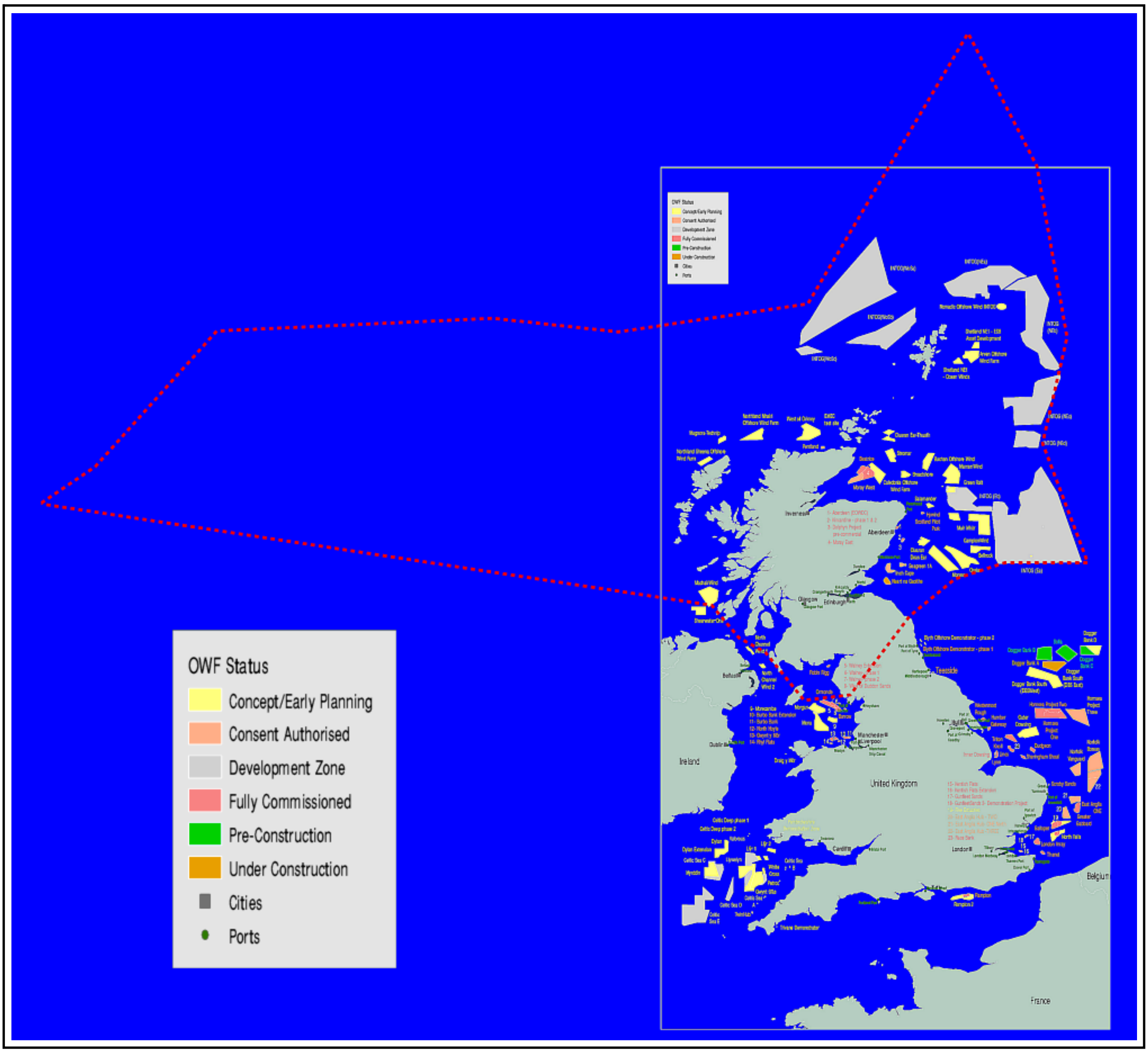
Maps, Politics, and Plans...

During the last decade or so UK Wind power generation has grown from being tiny to having essentially replaced Coal entirely, and beginning to reduce our problematic dependence on obtaining electric power from Gas. Even before Putin's War land-based Wind power from many Wind farms was cheaper per kWh than from Gas. As the number of farms has grown, so have the size and efficiency of the improving designs of Wind Turbines. The above shows that, overall, we have already reached the point where Wind can provide as much electric energy per year as Gas. And the trend continues to rise. So what are the snags and problems we need to tackle to go further, and move on from our being hooked on fossil fuels, often bought on an international market and imported?

One problem is that recent UK Governments at Westminster have stubbornly impeded the expansion of land-based Wind Farms. NIMBY tends to rule. However the Scottish Government, although not fully independent, has been able to adopt a different policy and has tended to welcome and encourage Wind Farms being built. And offshore the politicians have tended to be more willing to accept or encourage the development of Wind Farms. NIMBY being less of a factor there for Westminster!

The advantages of offshore are that they offer large areas where the winds tend to be quite strong - and unimpeded by local geography! The drawbacks are the engineering challenges that have to be coped with to ensure the Wind Turbines can be installed out at sea, operate safely and reliably, and we can then transfer the power back to land. Some have claimed that the environment was too harsh and this would be impossible. However a few decades ago similar comments were being made, asserting that the prospects of North Sea Gas becoming significant were a 'fantasy' as it would be impossible to engineer the process at an economic price.

Similar comments have often been made since about the prospect of offshore Wind generation. Yet a number of offshore farms are already in operation and return a profit from delivering energy to the UK. And the energy capture capability of designs continues to rise. In addition, newer turbines are also being developed which include solar panels. That then boosts their energy output if the Sun happens to be shining! Extensive farms may also become convenient locations to place arrays of tidal-flow turbines that can collect energy from large areas of ocean.



The above shows a recent map of the various UK offshore wind farm areas. Relatively few are already in operation, and these are often quite small in area. Hence they are hard to see on the above diagram. In effect, the vast majority of the farms marked on the map are ones that it is intended will come into use in the next decade or so. The Scottish Islands allow the UK to extend its area far to the north of the mainland – into an area that tends to be quite windy! I have also added the outline (broken red line) which delimits the offshore area that is assigned to Scotland for exploitation. This lets us see that another huge area is nominally available given suitably developed technology and the will. Although some of these waters are quite deep modern offshore turbines don't need to be directly mounted on the ocean floor. Many are now 'tethered' designs that float, with strong lines that tether it to the sea-floor.

In addition we can expect to reach a situation where various countries 'swap' wind-generated energy via interconnectors, just as has been routine for decades with power generated in other ways. As countries expand the areas they use for turbines this also becomes more practical because the wind farms will be built with underwater cables reaching back to the land. Thus a large network of cables will be installed. Again, just like decades ago when oil/gas pipelines were built despite some critics claim it would never be practical.

In the long term, therefore, we can expect to be able to draw Wind (and probably also tidal, etc., energy) from a rather wider area than at present. Which takes us back to the points made at the start of this consideration. Not only the amount of energy potentially available is vast. The sheer scale of the area means that when the "wind doesn't blow" onshore it is probably howling in other parts of that area. Bigger, taller turbines also reach higher where the wind speed is generally higher than at ground/sea level. As a result the problems all come down to a combination of engineering and politics.

In terms of engineering and changes to the status quo the main challenge isn't in reality the ability of wind farms or "when the wind doesn't blow". It is the challenge of completely changing the 'National Grid' within the UK, and the interconnections that can transfer generated energy from sources to users. This is a big change because in the past the number of generators was relatively small, and they were established in a few places. We will probably also need to install more in the way of mass-storage of energy. Schemes that use methods like using 'spare' power at one time to pump water uphill which can then be used to drive turbines to recover energy when it is poured downhill again. These also may become smaller-scale systems distributed more widely than the past. These are all solvable, but mean we have to make many modest-scale changes in a co-ordinated way. Which makes it a political problem as well as one for engineers. But that's another story...

JCGL 12th May 2023