



# Renewable Energy Supply Methodology

Document Version 1.0

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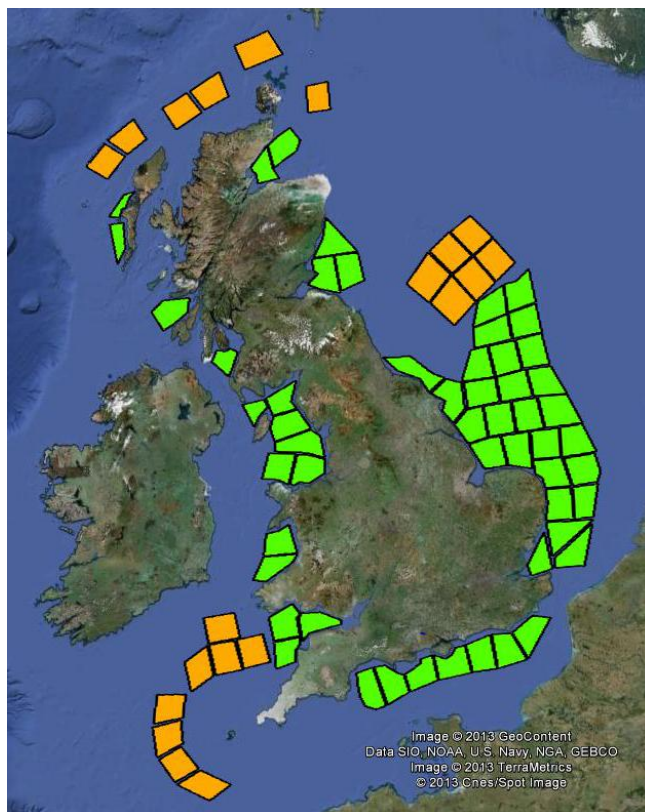
# 1 Introduction

This document provides background information for the sources of renewable energy in our scenario, explaining the assumptions about the installed capacity of the resource. The detailed hourly modelling of the amount of renewable energy produced is discussed in the separate document describing the **ZCB Energy Model**.

## 2 Offshore wind power

In our model we assume a total offshore wind capacity of 140 GW. Of this, 60 GW will be “fixed” offshore wind turbines with foundations embedded in the sea bed while 80 GW will come from floating wind turbines.

To assess the resource for fixed offshore wind, we have defined a total of 54 regions, each between 500km<sup>2</sup> and 2,600 km<sup>2</sup> in area, in water depth of less than 60m (green areas in Figure 1). In, these regions cover around 101,000 km<sup>2</sup>. Realistically, not all of this area is suitable for offshore wind power



**Figure 1: Offshore wind regions**

development. However, it was beyond the scope of our research to identify which constraints might affect offshore wind farm developments in specific locations. The Carbon Trust (2008) has analysed the constraint on offshore wind power development in the UK and concluded that due to various soft and hard constraints the maximum potential for fixed offshore wind potential in the UK is 36 GW. However, we believe that the Carbon Trust constraint analysis is too pessimistic as many of the ‘hard’ constraints can be overcome. The Carbon Trust report itself states that “[t]he London Array, currently the largest planned offshore wind development, has demonstrated that even in situations where there appear to be immovable constraints such as busy shipping lanes, creative solutions can be found that offer some benefit to all stakeholders”. Therefore, rather than trying to identify specific constraints for specific areas we have decided to model all the regions we defined as suitable but to assign a very low power density (installed capacity per area) of 0.59 MW/km<sup>2</sup> (or W/m<sup>2</sup>)

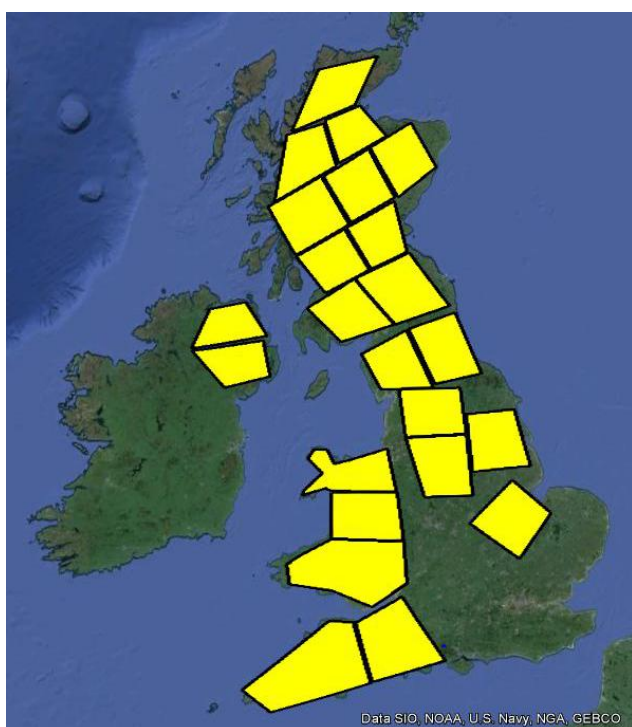
to each region. This is much lower than the array power density (deployment density) of actual offshore wind farms (for example, the London Array wind farm has an installed capacity of 630 MW in an array covering 100km<sup>2</sup>, 6.3MW/km<sup>2</sup>). Our assumption is that in each region we have defined only a fraction of the area will actually be covered in offshore wind farms. The total estimate of 60 GW for fixed offshore wind is significantly lower than the estimate for the total practical resource for fixed offshore wind of 116GW provided by the Offshore Valuation Group (2010).

Our report assumes that another 80 GW of offshore wind capacity will come from floating wind turbines in deeper waters. Prototypes of full-scale working prototypes of floating wind turbines have

been operational for several years (e.g. Statoil's HyWind turbine off Norway) and it can reasonably be assumed that this technology can be commercially available well before 2030. For our model we have defined 20 regions (orange in Figure 1), with a total area of around 45,000 km<sup>2</sup> for floating wind farms. Our regions are based on the mapping of the practical resource for floating wind farms by the Offshore Valuation Group (2010). We have assigned a capacity of 1.8 MW to each km<sup>2</sup> of floating offshore wind turbine region. This gives us a total floating offshore wind capacity of 80 GW, significantly less than the Offshore Valuation Group's estimate for the practical resource, which is 350 GW.

**Using hourly wind speed data, the average annual energy yield from offshore wind turbines is calculated to be 530 TWh. This calculation is described in more detail in the document describing the hourly energy model.**

### 3 Onshore wind power



**Figure 2: Onshore wind regions**

In our model we assume a total installed onshore wind capacity of 20 GW. This is less than the 30 GW in the "max" scenario proposed by Pöyry (2010) but is comparable with the "maximum feasible resource potential" of 20 to 30 GW described by Arup (2011).

For our model we have defined a total of 23 regions (Figure 2), covering the regions of the UK with the largest onshore wind potential. We are not suggesting that all these regions should evenly be covered in wind farms – within each region, the largest proportion of the land is probably not suitable for onshore wind power. But determining exactly where onshore wind turbines can be sited is beyond the scope of our research. Instead we simply assign a very low capacity density of 0.13 MW/km<sup>2</sup> – much lower than the actual power density of a wind farm (Whitelee wind farm near Glasgow has 322 MW capacity on 55 km<sup>2</sup> area, or 5.85 MW/km<sup>2</sup>).

**Using hourly wind speed data, the average annual energy yield from onshore wind turbines is calculated to be 51 TWh. This calculation is described in more detail in the document describing the hourly energy model.**

### 4 Wave power

In our report we assume an installed capacity of 10 GW of wave power. Our current understanding of the technical potential of the UK's wave power resource appears to be still fairly limited, and it is not yet clear what future wave energy converters will look like. The figure chosen for our scenario is in-between the assumptions for the "Very High" (6 GW) and "Max" (14 GW) in Pöyry (2010).

**Using hourly data on significant wave height and wave period, we calculated that the average annual wave energy yield is 25 TWh.**



## 5 Tidal power

On our model we assume an installed capacity of 20 GW of tidal power. This includes both tidal range (tidal barrages) and tidal stream generation.

The site with the biggest tidal range potential in the UK is in the Severn estuary, but there is also potential, but there is also potential in other estuaries, including Mersey, Duddon, Wyre, Solway and Conwy. Pöyry (2010) assume, in their “Max” scenario, a total tidal range potential of 9 GW. DECC (2010) use a number of 20 GW for tidal range in their “level 4” *2050 Pathways* scenario.

The key resource areas for tidal stream power generation potential in the UK, according to Arup (2010) are off the north coast of Scotland around the Pentland Firth, between southwest Scotland and Northern Ireland, around the north coast of Northern Ireland, between Scotland and the Isle of Man, off the north, west and south coasts of Wales, and in the English Channel in the region around the Isle of Wight. Pöyry (2010) assume 2 GW and 4 GW of tidal stream potential in their “Very High” and “Max” scenarios, whereas DECC (2010) assume a potential of 21.6 GW in their “level 4” *2050 Pathways* scenario.

**Using a mathematical formula to calculate hourly variations in tidal flow patterns, we calculated that the average annual power output from tidal power is 42 TWh.**

## 6 Hydro power

Our model assumes a total of 3 GW of hydropower is installed. This includes the existing 1.5 GW of “large” (>5 MW) hydropower generation plus an additional 1.5 GW of “micro hydro”. The total amount of hydropower in Pöyry’s (2010) “Max” scenario is 6 GW, the DECC (2010) “level 4” *2050 Pathways* scenario assumes 4 GW.

**Assuming an average capacity factor of 30%, our model assumes that 3 GW of hydropower capacity will produce 8 TWh per year.**

## 7 Solar photovoltaic (PV) power



**Figure 3 Solar regions**

Our model assumes a total installed solar PV capacity of 75 GW of solar PV. We do not explicitly state that all this capacity is roof-mounted, but significant field-based solar farm developments would conflict with other land-use in our scenario. For England, statistical data on roof areas is available from the Generalised Land Use Database (ONS, 2005). According to that source, there are 1,508 km<sup>2</sup> of domestic buildings and 869 km<sup>2</sup> of non-domestic buildings in England, giving a total of 2,377 km<sup>2</sup> of area covered with buildings in England. Assuming that the roof area is roughly proportional to population numbers, it can be assumed that around 2,800 km<sup>2</sup> of the total surface area of the UK are covered with buildings. As we assume that in our scenario around 6 km<sup>2</sup> of roof area are required per 1 GW of PV capacity (17% module efficiency) the area required for 75 GW is 450 km<sup>2</sup>. Depending on the average roof slope (as the roof area available is greater than the area covered by buildings) this means that for 75 GW capacity around 15% of the total roof area of the UK would need to be covered in PV modules. DECC (2010) in their “level 4” *2050 Pathways* scenario

assume that covering all domestic south facing roof space in the UK allows for a PV capacity of 95 GW.

The PV capacity is spread over 11 solar regions, shown in Figure 3, proportionate to the proportion of the UK's population that lives in each region.

Using hourly solar radiation data, we calculate the average annual electricity yield from 75 GW of solar PV to be around 58 TWh.

## 8 Solar thermal heat

The research on the technical potential for solar thermal heat (solar water heating) in the UK. DECC (2010) state that with  $1.6\text{m}^2$  of solar thermal collectors per person the UK could produce 58 TWh of heat per year (level 3) and with  $3.1\text{m}^2$  of collector area per person this would rise to 116 TWh (level 4).

**For our scenario we assume that solar thermal collectors will contribute 25 TWh of heat per year.**

## 9 Geothermal electricity & heat

The research on the technical potential for geothermal heat in the UK is at an early stage. According to a report by Sinclair Knight Merz (2012) there are both medium (160C) and low temperature (below 90C) aquifer (HSA) resources in East Yorkshire and Lincolnshire, Cheshire, Worcester, Wessex and Northern Ireland, though power generation can only be considered a possibility in Cheshire and Wessex. According to the Sinclair Knight Merz (SKM) report, the main areas with "hot dry" (EGS) potential for electricity generation are Cornwall, Weardale and the Lake District. SKM estimate that the total installed generation potential is 9.5GW for electricity and 100GW for heat. However, these figures describe the geological resource and do not consider limiting factors or parasitic energy consumption of power stations (which can be significant). SKM assume that by 2030 realistically 0.68 GW of geothermal electricity and 4 GW of geothermal heat capacity can be installed. DECC (2010) in their "level 4" *2050 Pathways* scenario assume 5 GW of geothermal electricity generating capacity.

**For our model we assume that there is a total capacity of 3 GW of geothermal electricity generation capacity, producing 24 TWh of electricity.**

**Our model also assumes that 15 TWh of heat per year can be produced from geothermal sources.**

## 10 Biomass

Our model assumes that biomass provides a total of 274 TWh of energy per year. Of that,

- 37 TWh is from biomass waste, for anaerobic digestion
- 57 TWh is from grass silage, for anaerobic digestion
- 143 TWh is from Miscanthus and Short Rotation Coppice (SRC), for producing synthetic fuels
- 37 TWh is from Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF), for domestic and industrial heat

## Sources

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