

# IESIS

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## **Levelised Cost Analysis Update**

**Paper by Capell Aris**

### **Summary**

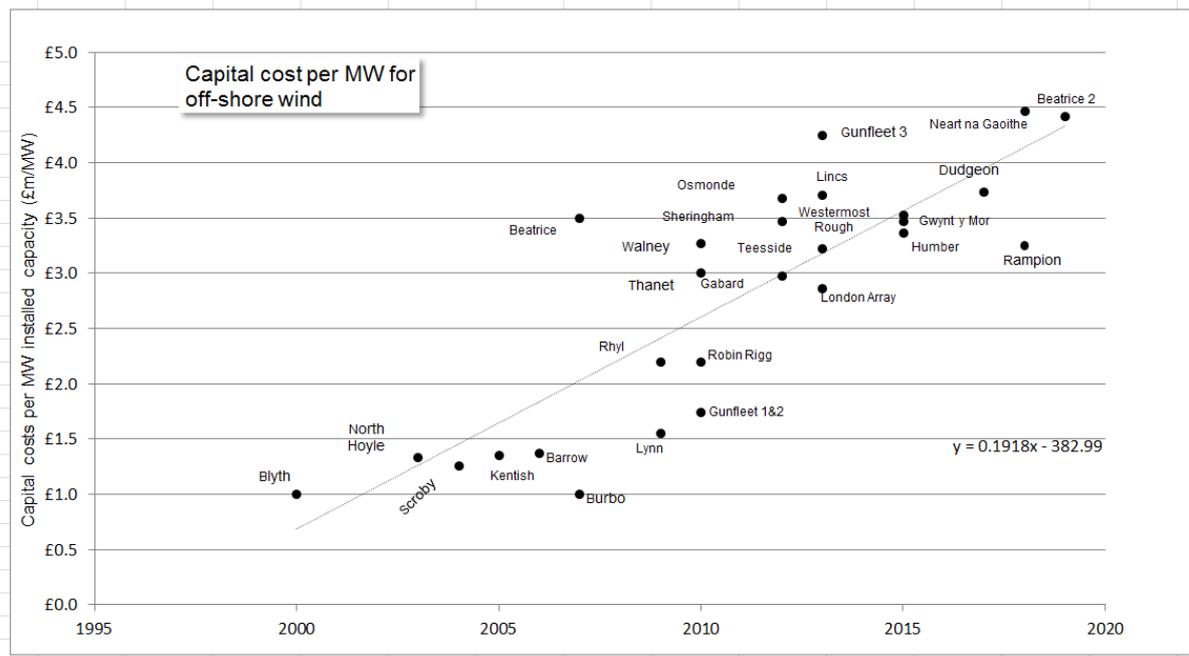
Since the original paper was written we have seen a rapid expansion of UK electricity generation using wind turbines and solar panels. A similar expansion of generation using roof-top and ground mounted solar panels has occurred. Further, papers have been written studying the ageing of both technologies and its impact upon production. This short note responds to these developments. It includes:

1. An analysis of historic onshore and offshore wind farm capital costs and capacity factors,
2. A new analysis of the levelised costs for solar generation, and
3. Inclusion of reported ageing effects on both wind and solar generation.
4. Creation of a new coal with carbon capture analysis sheet in which progress at the Boundary Dam (and other) project is considered.

Other small modifications have been made to the gas and nuclear generation sheets. The supporting spreadsheet has been revised to follow the revised factors described here.

### **1 Historic capital costs for off-shore and on-shore wind farms**

The capital costs of offshore wind farms is well reported and a simple Wikipedia query gives all the information we require. This is graphed in Figure 1.



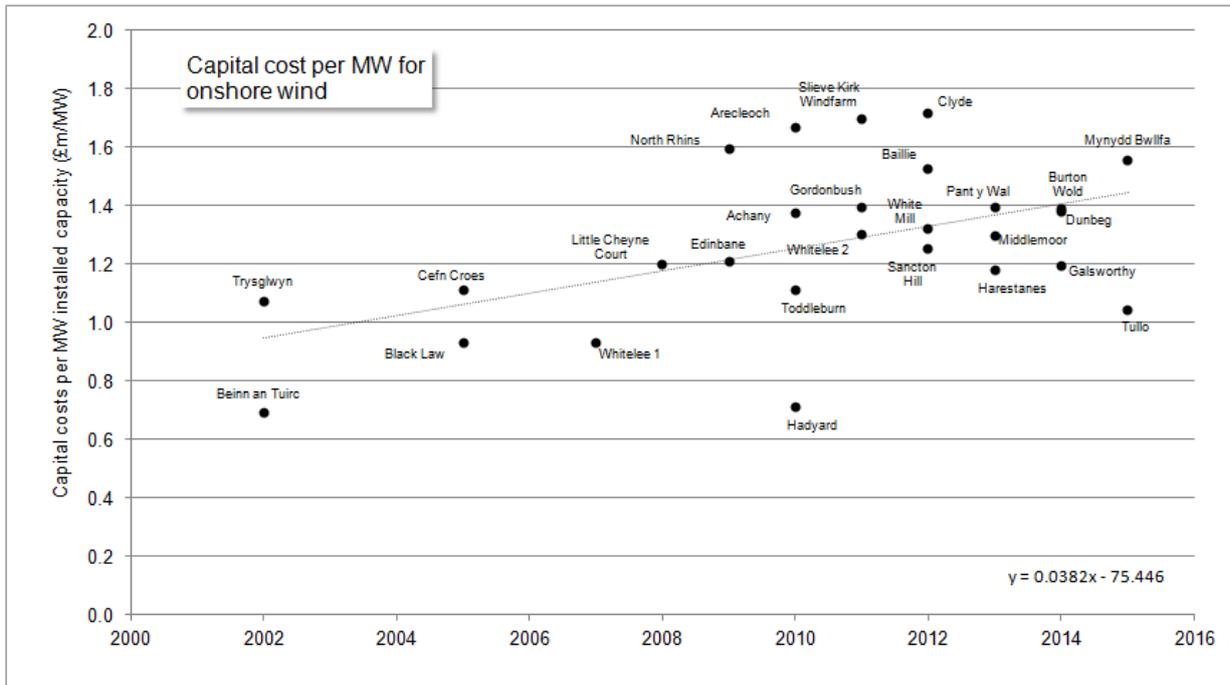
**Figure 1** Capital cost (£m) of offshore wind farms. Data from [https://en.wikipedia.org/wiki/List\\_of\\_offshore\\_wind\\_farms\\_in\\_the\\_United\\_Kingdom](https://en.wikipedia.org/wiki/List_of_offshore_wind_farms_in_the_United_Kingdom)

These are represented in the levelised cost spreadsheet as a range of likely costs as given in Table 1.

Possible future off-shore wind farm capital costs					
Capex (£m/MW)	£2.00	£3.20	£3.50	£3.80	£4.30
Probability	7.5 %	15 %	55 %	15 %	75 %

**Table 1** Possible capital costs for off-shore wind farms

Although details of on-shore wind farm size, likely production, benefits to the community and carbon dioxide savings are well documented, it is rare for the build cost to be given. But from time to time these figures are reported, and given the scale of number of wind farms we now have adequate data as shown in Figure 2



**Figure 2** Possible capital costs (£m/MW) for on-shore wind farms

These are represented in the levelised cost spreadsheet as a range of likely costs as given in Table 2.

Possible future on-shore wind farm capital costs					
Capex (£m/MW)	£1.05	£1.20	£1.30	£1.40	£1.80
Probability	10 %	10 %	20 %	40 %	20 %

**Table 2** Possible capital costs for on-shore wind farms

The levelised cost spreadsheet contains details of the data sources supporting Figures 1 and 2.

## 2 The affect of ageing upon offshore and onshore wind farms.

Two papers (Gordon Hughes: *The Performance of Wind Farms in the United Kingdom and Denmark*, REF, 2012, and I Staffel and R Green: *How does wind farm performance decline with age?* Renewable Energy 2014) have attempted to detect and quantify the drop of performance of the UK on-shore wind fleet over time. Both agree there is a decline but differ in its magnitude. Staffel and Green report 1.6 +/- 0.2 % per annum, Hughes 5 to 13 % per annum; Staffel and Green also report a doubling of the decline rate after year 16. Either of these rates will increase the levelised cost of these generation methods, but since there is no way at present of separating their likelihood they are both included with equal probability as another sensitivity vector in the calculation. Staffel and Green's acceleration at year 16 is included in both these probabilities. A third scenario, with lower probability, models a much lower ageing effect.

Only Hughes analysed off-shore wind, and was hampered by lack of data. It is likely that the ageing effect off-shore will be worse than on-shore because of poor maintenance access so this is represented as a doubling of the decline rates used for on-shore.

## 3 Levelised costs of solar generation

This is a new worksheet. The levelised cost method is unchanged. Three main sensitivities are considered: capacity factor, capital cost and ageing.

**Capacity factor:** Table 3 shows the likely levels of capacity factor. These are capacity factors seen at the terminals of the local grid transformer (ground-mounted) or the consumers meter terminals (roof-top); further losses in the distribution system will decrease delivery to the transmission system.

	Possible solar capacity factors				
Capacity factor	8 %	8.5 %	9 %	11 %	13 %
Probability	15 %	30 %	40 %	10 %	5 %

**Table 3** Possible capacity factors for solar farms

**Capital cost:** based on figures extracted from the report produced by KPMG *UK Solar beyond subsidy: the transition*, Table 4 shows likely capital cost.

	Possible solar capital costs		
Capex (£m/MW)	£0.91	£0.84	£0.77
Probability	20 %	60 %	20 %

**Table 4** Possible capacity factors for solar farms. See [http://www.kpmg.com/UK/en/IssuesAndInsights/ArticlesPublications/Documents/PDF/Market%20Sector/Power\\_and\\_Utilities/uk-solar-beyond-the-subsidy.pdf](http://www.kpmg.com/UK/en/IssuesAndInsights/ArticlesPublications/Documents/PDF/Market%20Sector/Power_and_Utilities/uk-solar-beyond-the-subsidy.pdf)

**Ageing factor:** based on the comprehensive report *Photovoltaic Degradation Rates-An Analytical Review*, Jordan, D.C and Kurtz, S.R., NREL 2012, Table 5 shows the likely ageing factors per annum for solar generation used in this study.

	Possible solar ageing factors		
Ageing factor (% per annum)	0.5 %	1 %	2 %
Probability	10 %	60 %	30 %

**Table 5** Possible ageing factors for solar farms. See <http://www.nrel.gov/docs/fy12osti/51664.pdf>

#### 4 CCGT levelised costs

Fuel costs are modified to reflect the present fall in gas prices, see Table 6.

	Possible fuel prices		
	£15	£20	£30
Gas price (£/MWh)			
Probability	40 %	50 %	10 %

**Table 6** Expected gas prices (£/MWh) for solar farms.

The station efficiency factors have been modified to reflect the high possibility that for much of the time the CCGT fleet will be operating below full power/maximum efficiency, see Table 7

	Possible efficiency factors		
	40 %	55 %	60 %
Efficiency			
Probability	20 %	60 %	20 %

**Table 7** Possible gas fleet efficiency.

#### 5 Nuclear levelised costs

The sensitivity analysis now reflects likely capital costs seen for the Moorside and Hinckley C projects. Wylfa B cannot be included as no definite project plans exist; see Table 8

	Possible nuclear capital costs	
	£2.94	£5.63
Capex (£/MW)		
Probability	65 %	35 %

**Table 8** Possible nuclear capital costs.

#### 6 Coal with Carbon Capture

The Canadian Boundary Dam project gives us firm figures for capital costs and production levels of the operational carbon capture station. There are also projections for future developments and costs (lower and higher) which can be taken into account, see Table 9.

	Possible future carbon capture capital costs			
	£11.8	£9.45	£12.66	£8
Capex (£m/MW)				
Probability	20 %	30 %	30 %	20 %

**Table 9** Possible carbon capture capital costs.

#### 7 Other generation types and issues.

None of the coal analysis sheets, nor that for the Severn barrage project have been updated since it is likely these will now be of little interest.

The summary charts have been updated.