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Title: **Offshore Wind Generation Cost Variations Review**

Client: **DECC**

Report Nº: **8442-01-R5**

Date: **20 June 2013**

Part of the Petrofac group

## DOCUMENT HISTORY AND STATUS

| CONFIDENTIALITY (Confidential or not confidential): Not Confidential | |
|---|---|
| **Project No.:** | 8442 |
| **Project Name:** | Offshore Wind Generation Cost Variations Review |
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| **Issued by:** | TNEI Services Ltd |

| Revision | Date issued | Reviewed by | Approved by | Date Approved | Revision Type |
|---|---|---|---|---|---|
| R5 | 20/06/2013 | Clive Poole | Clive Poole | 20/06/2013 | Final Issue |

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# 1 Introduction

In the May 2012 draft Energy Bill the Government set out its requirement that National Grid Electricity Transmission (National Grid), as proposed delivery agent for components of the Electricity Market Reform (EMR) programme, would conduct analysis to support the development of feed in tariffs with contracts for difference (CfD) for low carbon technologies. In October 2012 National Grid therefore launched a "*Call for Evidence to support the development of strike prices under Feed in Tariffs with Contracts for Difference (CfD) for Renewable Technologies*".[1]

The Call for Evidence (CfE) was issued to provide confidence that the most recent and relevant technology costs are reflected in subsequent analysis by the Department of Energy and Climate Change (DECC) and National Grid to inform Government's decision-making under EMR and in particular, the setting of CfD strike prices. The data gathered through the CfE was to be considered alongside the information used in the Renewable Obligation Banding Review (ROBR) published in July 2012.

DECC has now compared the CfE data with the earlier ROBR data for offshore windfarms and noted differences in the quoted capital and operational costs and also in the generation load factors.

TNEI was commissioned by DECC to provide advice as to how the variation from ROBR might be attributed to specific elements of the wind generation projects, given that the two sets of cost analysis were both carried out relatively recently and that very little discrepancy between the two sets of figures was therefore anticipated. The brief given by TNEI for this commission invited us to offer views on how any cost differences might have arisen; it did not require TNEI to provide a detailed critique of either of the two input reference reports.

[1] Call for Evidence to support the development of strike prices under Feed in Tariffs with Contracts for Difference (CfD) for Renewable Technologies, National Grid, 9th Oct 2012 http://www.nationalgrid.com/uk/Electricity/Electricity+Market+Reform/

# 2 Background Information

## 2.1 Reference Information

DECC have provided the following information, relating to the National Grid 2012 Call for Evidence, for use within this report

- *National Grid - Electricity Market reform – Call for evidence to support the development of strike prices under feed in tariffs with contracts for difference (CfD) for Renewable Technologies – October 09, 2012.*
- *Anonymized CFE database.*
- *Baringa*[2] *- Electricity Market Reform Contract for Difference Call for Evidence Data Validation – February 25, 2013.*

In addition reference has been made to the following publication relating to ROBR data

- *ARUP – Review of generation costs and deployment potential of renewable electricity technologies in the UK – October, 2011.*

## 2.2 Overview

### 2.2.1 National Grid Call for Evidence (CfE)

National Grid issued a CfE request in October 2012 in order to inform their analysis required to support DECC's process for the setting of CfD strike prices for renewable electricity technologies. The intention of the CfE was to supplement the ROBR (Renewable Obligation Banding Review) data.

The National Grid CfE request covered multiple renewable generation technologies (the 27 defined in the ROBR exercise, but excluding anaerobic digestion, hydro, wind and solar PV installations of less than 5MW) of which responses were received across 10 of the technologies and of which onshore and offshore wind formed the majority.

Of the 59 quantitative responses the majority (43) were associated with wind generation; 29 of which were onshore, 7 "Offshore (A)" and 7 "Offshore (B)" where:

- Offshore (A) – relates to "near shore" offshore wind generation projects
- Offshore (B) – relates to "far shore" (defined as >50km from shore and/or over 45m depth) offshore wind generation projects

The CfE took the form of two questionnaires; the first covering technology costs and maximum build rates, and the second, investment decisions under CfD.

The CfE response data does not directly correlate with ROBR data making direct comparison difficult. The costs appear to relate to individual project delivery dates that have not been adjusted to a common date (2012). Subsequent correspondence between DECC and Baringa

[2] Baringa have been engaged by National Grid to assess and interpret the CfE replies

has confirmed that *"the project costs generally relate to projects commissioning in or after 2016/17, as requested by the Call for Evidence. There were 2 which explicitly stated that they related to projects beginning operation before 2016, but the respondents adjusted the data so they were equivalent to post 2016 projects, or stated that they did not believe costs would change. Where respondents said costs related to an earlier year, this meant that this is when the costs were incurred (especially for pre-development, when a project commissioning in 2016/17 would incur these costs much earlier) or it referred to the price base costs were in."*

The summarised cost data provided in the Baringa report is expressed in the form of Low, Medium and High, which refer to 10, 50 and 90 percentiles respectively for comparison with ROBR data.

The National Grid CfE study is therefore based on the responses to questionnaires with a basic degree of due diligence carried out by Baringa to correct for errors and ensure consistency of approach and commonality of units across all responses. For reasons of confidentiality, the identity of the stakeholders has been removed and thus the level of diversity in the data provided is unknown. Specifically, the risk that, and the extent to which the data set is skewed by the thinking and experiences of a single developer cannot be determined.

### 2.2.2 ROBR

No raw source data has been made available for the ROBR results but as the data gathering process was independent of the National Grid CfE it would be reasonable to conclude that both studies have used different data sets to develop their conclusion.

The ROBR technology costs, parameters and maximum build rates are based on both publicly-available and in-house data supplemented by stakeholder input, spanning manufacturers, developers and utilities, updated with the latest evidence in response to the ROBR consultation.

Assuming the methodology adopted by Arup[3] has been followed through to the ROBR data tables provided for comparison in this study[4] [5] then the data has been both normalised and then modified to reflect expected future costs. Stakeholder project cost data has, according to the Arup report, been adjusted to 2010 prices with future costs projected for each of the main cost drivers (steel, labour industrial commodities, etc) and also adjusted

[3] ARUP – Review of generation costs and deployment potential of renewable electricity technologies in the UK – October, 2011

[4] National Grid - Electricity Market reform – Call for evidence to support the development of strike prices under feed in tariffs with contracts for difference (CfD) for Renewable Technologies – October 09, 2012

[5] Baringa - Electricity Market Reform Contract for Difference Call for Evidence Data Validation – February 25, 2013

for "learning rates". The derivation of these cost drivers was informed by historic trend data.

In all cases the ROBR analysis assumes these future costs will be lower than current costs as any future material cost increase will be more than offset by cost reductions gained through delivery experience. Exchange rates are ignored in the analysis.

The ROBR data used in this comparison of CfE and ROBR has been inflated to 2012 prices and is based on years 2016/17 and 2017/18 which, for the purposes of this analysis based on feedback from Baringa, is considered to be on the same base as the CfE data and therefore comparable.

## 2.3 Comparison

The comparative results for offshore wind, taken from Baringa's draft report[6], are shown in Table 1 for near shore and Table 2 for far shore. These show in all cases that the CfE costs are higher than the ROBR costs.

In addition to the cost information, for completeness, the tables also include:

- Variable operating and maintenance costs (VOM). The data is often limited and thus total OPEX cost is considered a better relative comparison.
- Load factor. The ROBR studies are understood to be based on developer expectations rather than any design experience whilst the CfE bases the results on feedback from current project experience. It is therefore not clear whether there is a like-for-like comparison to be drawn as load factor is dependent on wind distribution, wake effects, electrical losses and availability. Offshore ROBR values are lower, though not significantly, than CfE, which appear optimistic at the top end of the range.

As mentioned above, of the 59 quantitative responses from the National Grid CfE the majority (43) were associated with wind; 29 onshore, 7 offshore (A), 7 offshore (B). The breakdown for the ROBR assessment has not been provided but the Arup report states there were approximately 200 responses spread over all renewable technologies.

[6] *Baringa - Electricity Market Reform Contract for Difference Call for Evidence Data Validation - February 25, 2013.*

## Table 1 – Comparison of ROBR and National Grid Data (Offshore A)

| | | ROBR | CfE | Diff | %Diff |
|---|---|---|---|---|---|
| Construction Costs (£/kW) | H | 2700 | 3226 | 526 | 19.5% |
| | M | 2300 | 3046 | 746 | 32.4 |
| | L | 2000 | 2689 | 689 | 34.5% |
| Pre development costs (£/kW) | H | 120 | 161 | 41 | 34.2% |
| | M | 70 | 100 | 30 | 42.9% |
| | L | 46 | 70 | 24 | 52.2% |
| Total Opex (£/kW/year) | H | | 225 | | |
| | M | 126 | 143 | 17 | 13.5% |
| | L | | 103 | | |
| VOM (£/MWh) | H | | 13.3 | | |
| | M | 1.5 | 5.2 | 3.7 | 246.7% |
| | L | | 1.8 | | |
| **Load factor (%)** | H | | 47 | | |
| | M | 38 | 44 | 6 | 15.8% |
| | L | | 39 | | |

## Table 2 – Comparison of ROBR and National Grid Data (Offshore B)

| | | ROBR | CfE | Diff | %Diff |
|---|---|---|---|---|---|
| Construction Costs (£/kW) | H | 3500 | 3969 | 469 | 13.4% |
| | M | 2900 | 3258 | 358 | 12.3% |
| | L | 2500 | 2932 | 432 | 17.3% |
| Pre development costs (£/kW) | H | 150 | 182 | 32 | 21.3% |
| | M | 100 | 120 | 20 | 20.0% |
| | L | 49 | 54 | 5 | 10.2% |
| Total Opex (£/kW/year) | H | | 316 | | |
| | M | 165 | 206 | 41 | 24.8% |
| | L | | 170 | | |
| VOM (£/MWh) | H | | 2.2 | | |
| | M | | 1.8 | 1.8 | |
| | L | | 1.4 | | |
| **Load factor (%)** | H | | 48 | | |
| | M | 40 | 44 | 4 | 10.0% |
| | L | | 42 | | |

## 2.4 Commentary

### 2.4.1 Factors Affecting Cost Data

The range of unit costs for project capital and operating expenditure can, it is felt, be explained by a variety of characteristics including: scale effects, differences in the approach to the trade off between capital and operating costs, technology variations and site specific conditions.

Considering each cost element in turn:

Construction costs are driven by site characteristics such as:

- distance to grid
- environmental mitigation
- wind speeds
- sea bed composition
- sea depth

Pre-development costs by outputs from the following activities:

- Pre-licensing
- Technical development
- Bird and marine surveys
- EIA studies
- Public enquiries

Average annual operating costs by:

- O&M strategy
- Vessel hire
- Labour costs
- Insurance
- Grid charges
- Reliability

Wind turbine generator capex costs are the primary driver of installed capacity cost with the onshore grid connection, vessel costs and foundations making up the majority of remainder.

For the purpose of this review OFTO costs have been excluded from Capex costs but included in Opex costs hence, distance from shore impacts only upon the logistics element of the construction cost and on maintenance costs. Wind turbine generator costs are relatively constant but Round 3 sites are more likely to be in deeper water, which tends to increase foundation costs. Offshore wind development constraints associated with noise, radar and mammal, bird and fish habitats can lead to expensive mitigation measures, thereby increasing construction costs.

The ROBR study report noted that the cost differential between projects is not size related but rather, is largely time dependent as costs have increased over recent years. Earlier

smaller projects are cheaper than the later larger ones chiefly, it is felt, due to cost increases driven by supply side constraints.

It should also be borne in mind that both ROBR Round 3 and CfE offshore B are very much estimates at this stage and thus costs are subject to individual stakeholder's views on project risks and uncertainties.

Cost variation is site specific due to local conditions, planning hurdles and appeals, water depth, wind speed, and distance from shore (logistics).

A typical Breakdown of costs[7] for an offshore windfarm is below:

- Pre-development 2%
- Construction 91%
- Non OFTO Grid costs 2%
- Other infrastructure 5%

### 2.4.2 Differences in Approach between the Two Cost Studies

It should be noted that there is fundamental difference between the ROBR offshore categorisation and that of the National Grid CfE. ROBR data tables use Round 2 and 3 (although the original Arup report had 3 categories <100MW, >100MW & round 3) whereas CfE uses "near shore" and "far shore", where the latter is classified as >50km and or a water depth in excess of 45m.

Though the two 2 categorisations are likely to be similar, they are not the same.

Though not a direct cost issue, a difference exists between the load factors in the ROBR and CfE reports. ROBR assumed load factors (net of availability) for Round 2 and 3 reach 38% and 40% respectively; CfE figures are 43% and 44% respectively for Offshore A and Offshore B.

As would be expected, Round 3 sites have a better load factor than near to shore Round 2 projects as the wind distribution and speed are more favourable. Round 3 windfarms are bigger, with higher numbers of turbines, which, though the turbine density may not change, has an increased negative impact on wake effects and thus reduces the load factor. (Essentially only the first row of turbines benefits from the offshore location as subsequent rows suffer, increasingly, from the wake effect). Increasing the spacing between turbines increases the electrical cable cost and associated electrical losses. It also reduces turbine density and thereby, due to the space constraint within the licensed zone, windfarm capacity. The design of the windfarm thus becomes a compromise between increased spacing and lower wake effect against higher electrical capex and electrical losses and higher capacity. Ultimately, the load factors are better further from shore but there is a law of diminishing returns.

[7] *ARUP – Review of generation costs and deployment potential of renewable electricity technologies in the UK – October, 2011*

Ignoring the transmission element, which is assumed to be costed within the OFTO scope, then the load factor is subject to wind distribution, wake effect, electrical losses and availability. Though all figures should be based on net values rather than gross values (i.e. before or after losses and availability) it is not clear if this is the case, which could account for a part of the cost difference.

In the case of both the Offshore A and B figures, the results are skewed by what would appear to be two optimistic load factor values (50% for Offshore B and 48% for Offshore A). These two results contribute to the higher figures and increase the mean load factor by an average of 1%.

### 2.4.3 Data Sets Used in the Two Cost Studies

For the purposes of this evaluation it is has been accepted that the ROBR cost data and CfE cost data are directly comparable in that, in both cases, the data is based on 2012 costs for projects commissioned in 2016/17.

- ROBR data is based on 2010 costs, which for future years have been projected based on a multitude of factors including: inflation, commodity prices and "learnings". Hence, though there is no clear way of projecting the costs, simply taking 2010 values and adding inflation would not necessarily be valid. (It should, however, be noted that several consultants have suggested using the GDP inflator as an alternative.)
- No information has been provided with regards to the ROBR source data but the Arup publication refers cost to project "Financial Close" as opposed to at the year of commissioning, which could differ by 2 to 3 years or more (for example a CfE commissioning year of 2016 would equate to a ROBR financial close year of 2013/14). It has been assumed that Baringa have taken this into account when the ROBR conversions have been undertaken although this is not clear from the report. The date to which costs are referred is particularly important as cost predictions are very much subjective. The Arup view, as stated in their report, is that prices will fall over time.

On the assumption that a direct cost comparison is however valid then the differences must be attributable to other reasons. TNEI considers that the most probable causes of the apparent differences are:

- The two costing studies should be treated with a degree of caution as they are both based upon limited information in specific areas (the volume of data is largely dependent on the specific renewable generation technology and relates to the size of the industry, level of respondent enthusiasm and diligence, and on the number of stakeholders).
- The source data sets are different. Both are based largely on stakeholder input, but over 2 years apart, and whilst the CfE uses raw unprocessed data, ROBR has, to some degree, been normalised using in house and publicly available data.

- The two year time difference between responses may mean that, internally within the responding stakeholder organisation, the responses to each call for evidence are unconnected and hence, even for two identical questions, the approach to answering may be different.
- It is clear from the differences discussed that the two survey questionnaires were different and thus the responses were unlikely to be the same. How different is unknown and hence the extent to which the questionnaires themselves influenced the responses is unclear. (Should the data capture process be followed in the future then it is recommended that, in order to remove any ambiguity in the answers, a common questionnaire be developed with detailed guidance provided for each question).
- It is also suggested that, if not already the case, the questionnaire should be developed with the involvement of the stakeholders in order to ensure that the population of the answers can be easily drawn from their own cost models thereby increasing confidence in the validity of the numbers.
- Both the CfE offshore A and B data sets are too small (7 results in each) to give high confidence in the results.
- The two CfE offshore data sets and ROBR offshore data sets, though apparently similar, are not equivalent. The latter used Round 2 and Round 3 data whereas the NG CfE uses near shore and far shore/deep water as a means of categorisation.
- The cost data is an estimate in both studies however the CfE input should be better informed due to recent knowledge obtained and would include the latest forecast information on supply chain constraints for materials, manpower and vessels, which is likely to be different to ROBR.
- ROBR results used both stakeholder feedback and publicly available data to project costs for future dates and thus could be considered to be more accurate than stakeholder feedback alone, especially where the provision of higher cost estimates may be seen to be of benefit to the stakeholder concerned.

# 3 Conclusion

Assuming the costs data is directly comparable, there is no evidence to suggest which of either the ROBR or CfE costs is likely to be the more valid. Though the difference between the ROBR and CfE figure for each variable under consideration may appear quite high the range from high to low in each case is actually much larger, which, when combined with such a small data set, makes any result derived very sensitive to small changes. Such a change might result from adding in data from either a single 'good' project or a 'bad' project.

The CfE Data in theory represent the most recent views of the stakeholders, however, as experience offshore is still largely limited and developers are still learning then it might be expected that early projects would be the more problematic. This may influence developers' views on future projects leading to a more pessimistic assessment of costs. Equally it could be argued that knowledge gained in the time interval between the two calls for evidence may give them a more realistic view of cost and risk.

With the CfE relying on stakeholder data, which would, most likely be sourced from developers, then the responses are likely to be sensitive to how they perceive the data will be used. Should there be a difference, perceived or otherwise, in how ROBR data and CfE data was to be utilised then this may impact the responses and lead to different results. If a developer respondent suspects that the cost data he provides will be used to set the CfD strike price then he is incentivised to overstate them. It is also unclear as to the level of challenge which the veracity of the data has been subject to.

# Appendix A - CfE Data

Though the source of the data has been removed for reasons of confidentially the CfE raw data has been provided to TNEI in an anonymous form. Each of the 3 relevant cost comparators, Construction Costs (£/kW), Pre-development Costs (£/kW), and Operating Costs (£/kW), are shown graphically, for each response received, in the figures A1 to A8.

Each cost estimate is plotted next to the corresponding windfarm MW capacity, the X axis showing the project reference numbers (which, in turn, relates to the respondent's ID number)

Where cost data has been provided (a full set of data has not been provided for every windfarm) the graphs show that costs relate to a broad range of windfarm capacities. In all cases there appears to be no obvious correlation between costs and windfarm rating.

Combined with such a small data set, this would tend to suggest that caution be exercised in attempting to draw conclusions as they can be heavily influenced by a single set of data relating to an older, smaller windfarm or newer, larger one skewing the output.

# Offshore A

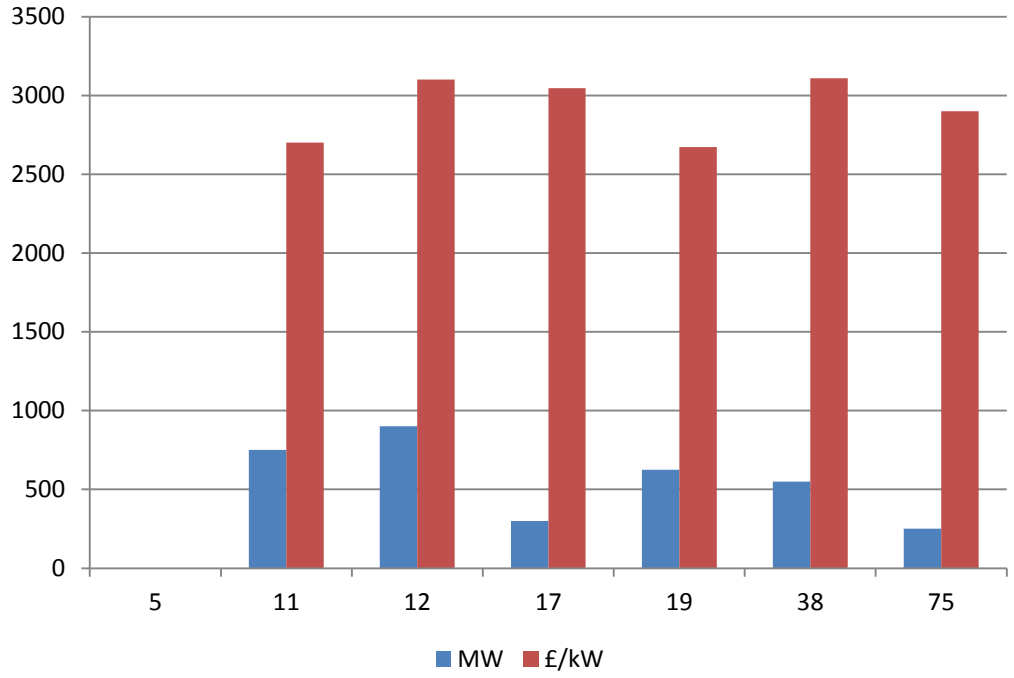


Figure A1 - Offshore A - Construction Costs

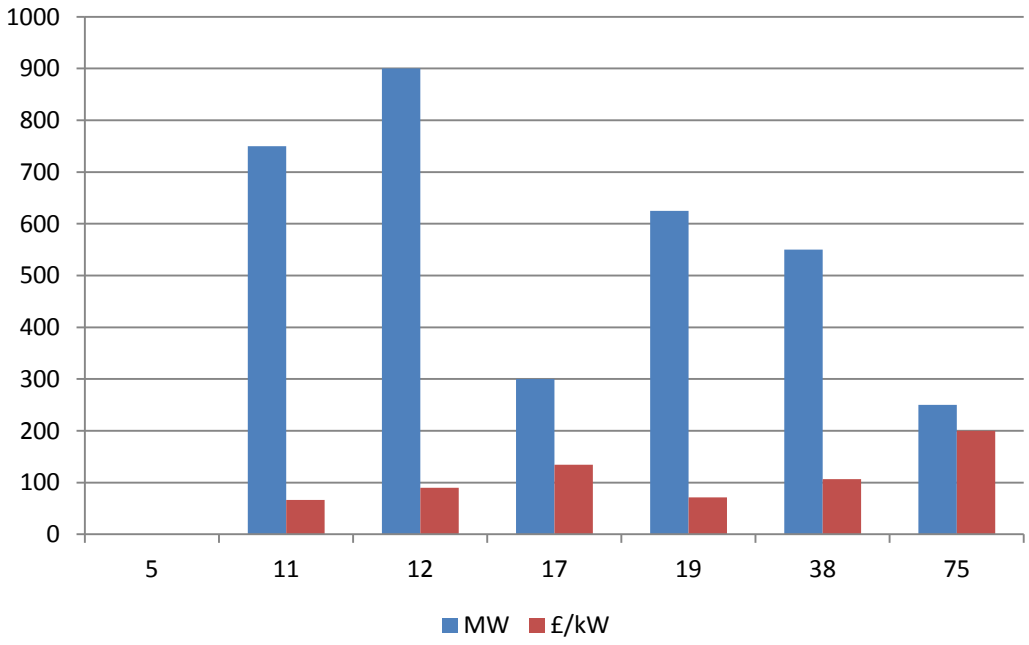


Figure A2 - Offshore A - Development Costs

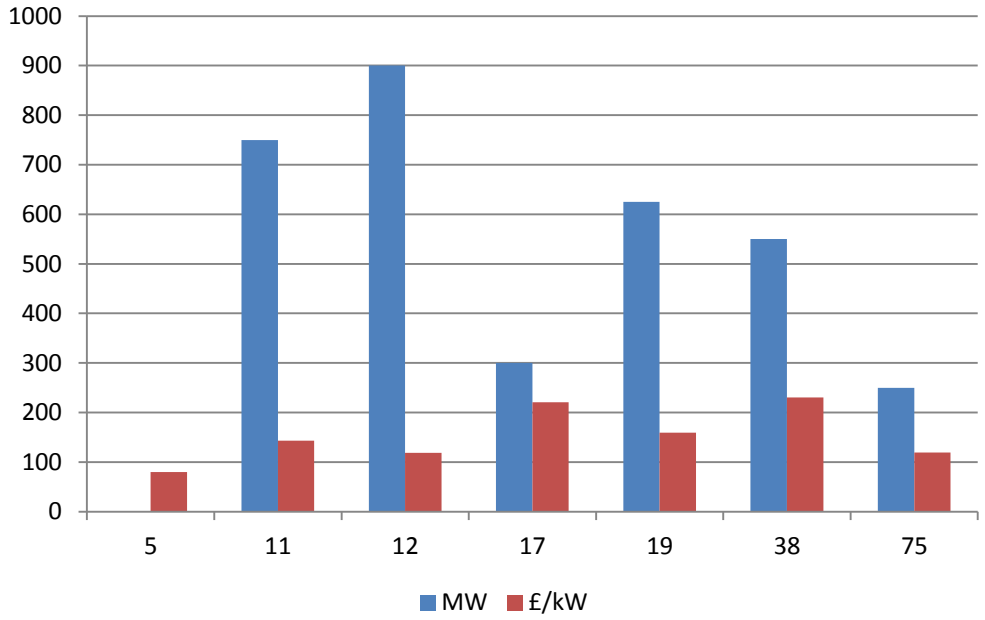


Figure A3 - Offshore A - Operational Costs

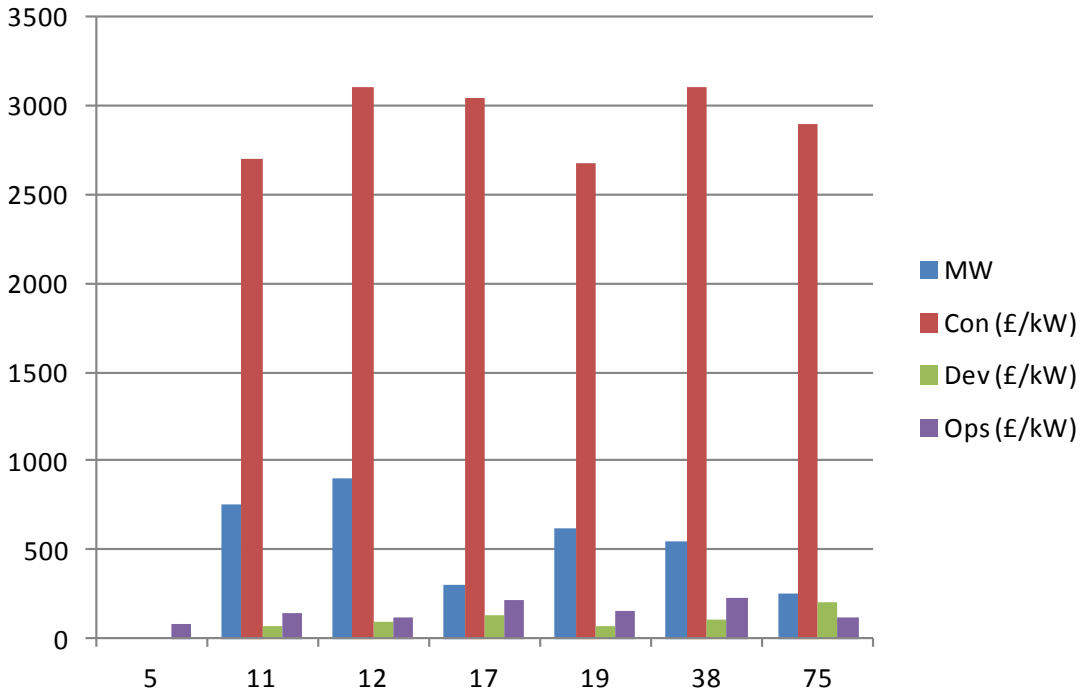


Figure A4 - Offshore A - All Costs

## Offshore B

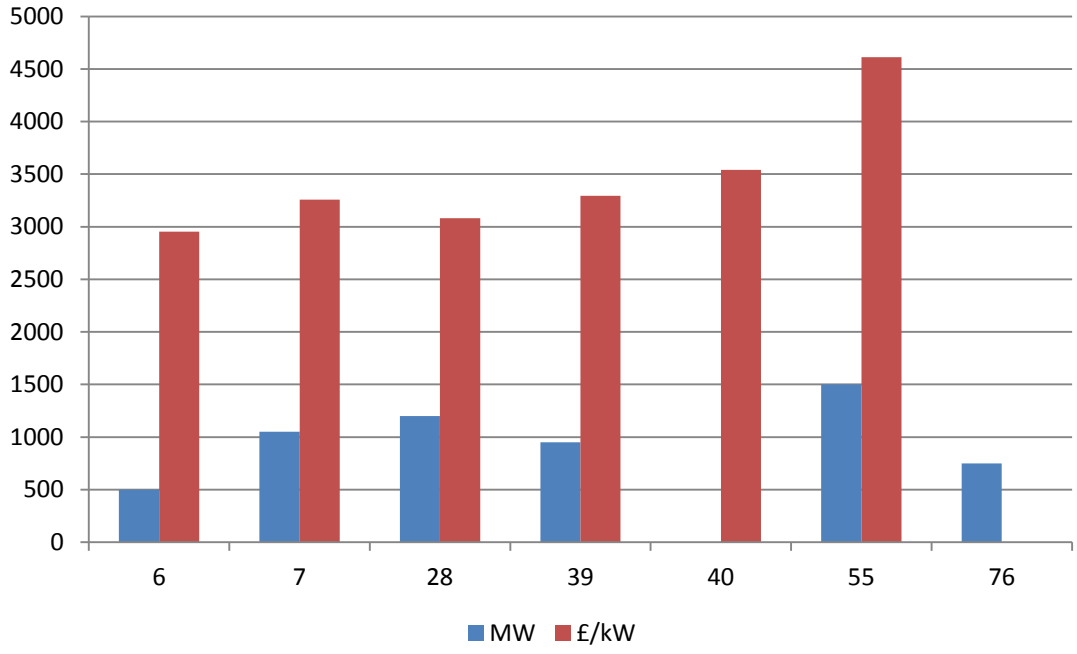


Figure A5 - Offshore B - Construction Costs

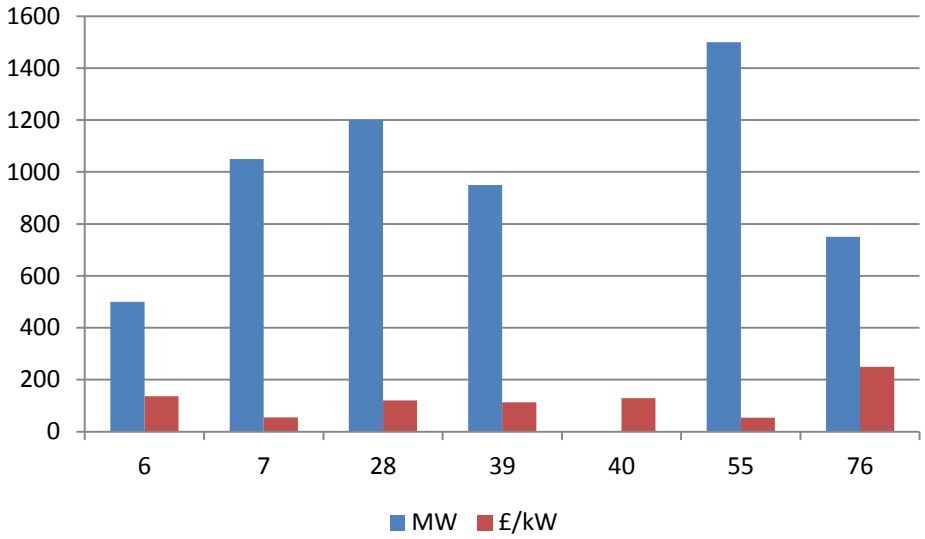


Figure A6 - Offshore B - Development Costs

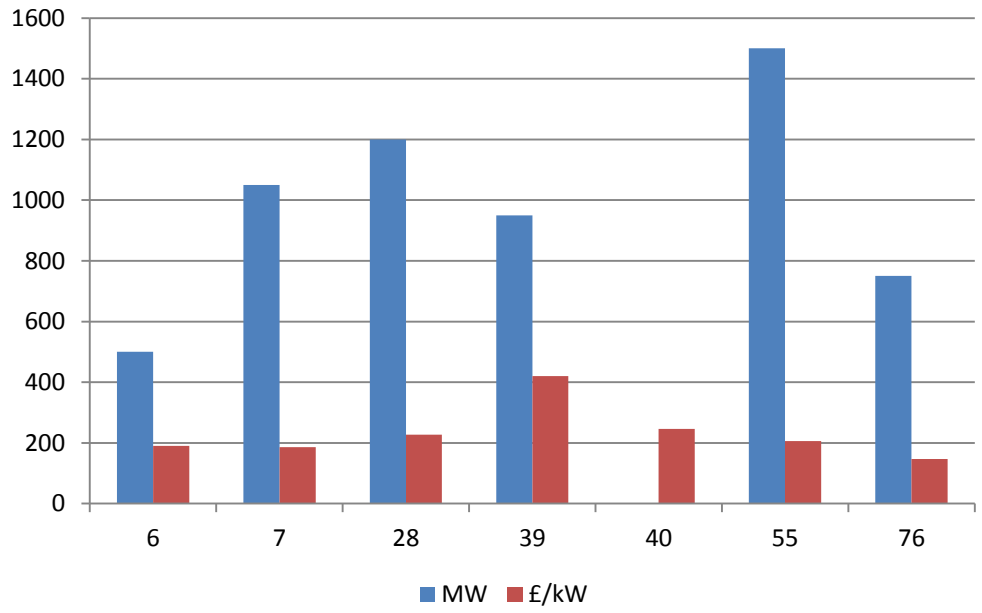


Figure A7 - Offshore B - Operational Costs

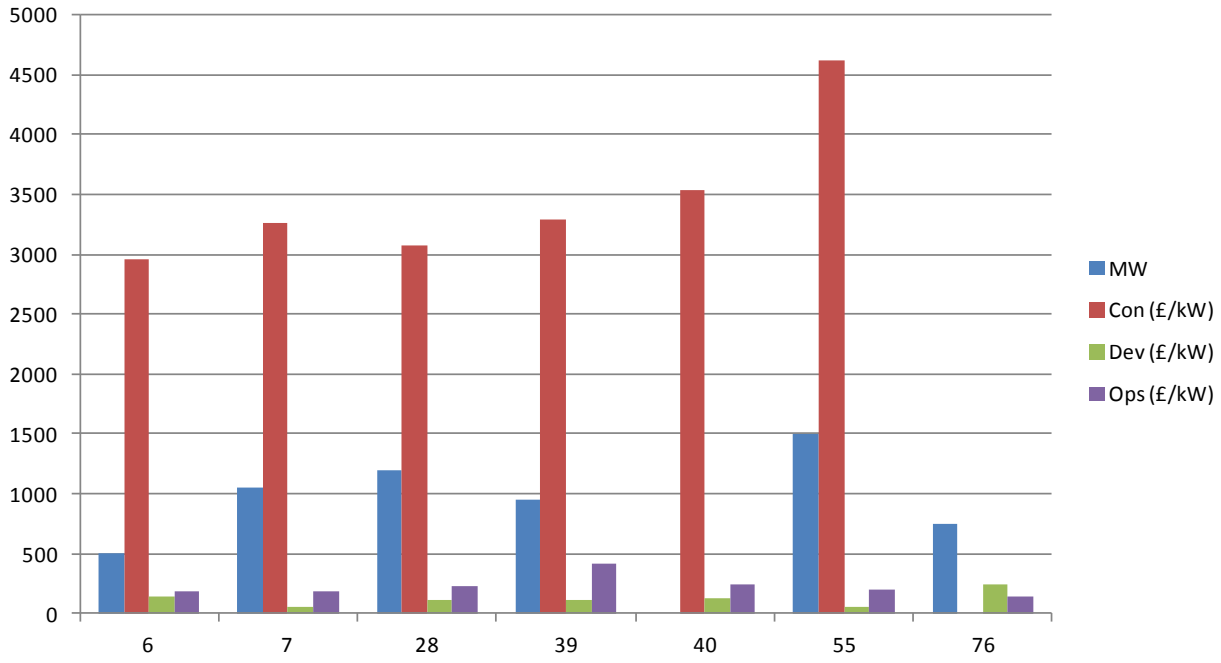


Figure A8 - Offshore B – All Costs