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TECHNICAL NOTE 02

Client:	BERR
Project:	2116 validation of Relative Economics of Wind Farm Projects in the Scottish Islands' study
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1 Executive summary

- It is Econnect Consulting's opinion that IPA's assumptions are reasonable
- It is Econnect Consulting's view that capacity factor values provided in the IPA study are higher than expected for the Scottish mainland and Orkney. It is recommended that the sensitivity of this information is tested
- Costs are broadly similar however there are some differences in relation to the values of individual variables such as concrete and other civils
- Based upon information provided by project developers, some have indicated higher capital costs per kW, especially for distant islands. It is recommended that these sensitivities are tested

2 Introduction

The Department for Business, Enterprise and Regulatory Reform (BERR) has commissioned Econnect Consulting (ECgL) to perform a validation review of a study on the economics of Scottish wind farms carried out by IPA Consulting ("the IPA study"). The aim of this review is to inform the debate as to whether, in the absence of a transmission charges modification scheme under section 185 of the Energy Act 2004, transmission charges would be likely to deter, or otherwise hinder in a material respect, development of renewable generation on the Scottish islands.

ECgL's comments are based on primary data obtained from in-house knowledge, developers, consultants and suppliers, as well as secondary data obtained from published documents. The main body of this document takes the form of a table laid out into two columns with the left hand column containing relevant sections of the IPA study, and the right hand column containing ECgL's comments and findings on that section.

Costs given as £/kW are based on 150MW wind farm, to maintain consistency with an equivalent assumption used in the IPA study as advised by BERR [1]. For the purposes of this report, such a wind farm is assumed to be composed of 75 wind turbine generators (WTGs) each rated at 2.0MW. The hub height is assumed to be 90m and is taken as the height for which wind speeds would be measured.

3 Assessment of the information contained in "Relative Economics of Wind Farm Projects in the Scottish Islands'" study

<table>
<tr><th>Relative Economics of Wind Farm Projects in the Scottish Islands' study – 'IPA study'</th><th>Econnect Consulting's Comments</th></tr>
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2 WIND FARM ECONOMICS

This section discusses the factors that affect the economics of a potential wind farm and identifies the components which are expected to vary between the projects under consideration. All numbers quoted are for a 150MW farm.

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- It is recognised that the proposed projects under development are large and 150MW is likely to be a reasonable comparator
- The definition of mainland needs to be clarified

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2.1 Wind Resource

A major parameter in the economics of a potential wind farm is the expected Capacity Factor, or Load Factor of the project, which dictates the amount of electricity that can be produced.
The capacity factor of a wind farm is a function of the wind speed in the area of development and the power curve of the particular wind turbines employed. The wind resource varies throughout the UK, with evidence that the Islands of Shetland and Orkney have one of the highest wind resources in the UK. This would suggest that the capacity factors on the Islands of Shetland and Orkney would be higher than elsewhere in the UK. In addition, the potential capacity factors will also be affected by the availability of the turbines and array and site losses, which serve to reduce the actual amount of electricity for sale into the grid.
We have taken data from a number of sources to build up a picture of expected load factors for the areas under consideration. These are discussed below.
Table 1: Representative Load Factors

	Mainland	Orkney	Shetland	W. Isles
IPA / Used in Analysis	30%	49%	49%	35%

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- The methods of obtaining the loading factor are appropriate; however, the underlying assumptions made would need to be explicitly stated. The areas in which ECgL would expect more detail are set out in the relevant sections below
- ECgL believes that the ranges of capacity factors provided below are more appropriate as the variation of capacity factors are large even within a small geographic region
- It should be noted that the values provided in the IPA study all lie within ECgL's suggested ranges
- Broadly speaking, ECgL considers that the capacity factors quoted in the IPA study are on the high side of the suggested range

	Mainland*	Orkney	Shetland	W. Isles
ECgL	24-31%	40-45%	45-48%	35-45%

*Mainland was taken for the Scottish Mainland as advised by BERR [2]

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NOABL Database:

Data from the Numerical Objective Analysis of Boundary Layer (NOABL) database, combined with typical power curves for wind turbines was used to provide a wind power output profile for each area under consideration. This data indicated a range of expected load factors for the area under consideration.

Table 1: Representative Load Factors

	Mainland	Orkney	Shetland	W. Isles
NOABL	32.9%	41.8%	49.7%	40.1%

- The BERR website describes the NOABL database as follows; "The data is the result of an air flow model that estimates the effect of topography on wind speed. There is no allowance for the effect of local thermally driven winds such as sea breezes or mountain/valley breezes. The model was applied with 1km square resolution and takes no account of topography on a small scale or local surface roughness (such as tall crops, stone walls or trees), both of which may have a considerable effect on the wind speed. The data can only be used as a guide and should be followed by on-site measurements for a proper assessment." [3]
- The height at which wind speed is estimated by NOABL within its model is 45m above ground level, which is approximately half the hub height of modern wind turbine structures. Therefore, if this database were used directly for the calculation of capacity factor it is likely to result in an underestimation of the values
- The quoted values in the report seem reasonable; however, ECgL has used the NOABL database and combined it with the power curves of nine wind turbines (2MW-3MW) considered representative of the wind turbine types used in recent years for a 150MW wind farm. ECgL's findings are set out in the following table

	Mainland*	Orkney	Shetland	W. Isles
NOABL	28%	39%	51%	39%

*Mainland was taken for the Scottish Mainland as advised by BERR [2]

- The Impact of GB Transmission Charging on Renewable Electricity Generation [4] report gives the capacity factor for the UK at 30%; this is in line with published values. However, it is higher than the value obtained from the NOABL database by ECgL for 23% of the UK mainland

ROC Register:

Over the last few years, experience of operating wind farms on the Islands and the mainland has been gained and, from examination of data from Ofgem's ROC Register, capacity factors for the areas under consideration can be estimated. This data indicates that there are differences between the wind resource on the Islands and the Northern Highlands.

Table 1: Representative Load Factors

	Mainland	Orkney	Shetland	W. Isles
ROC Register	Data from 8 wind farms ranging in size from small to 92MW. Little difference between Northern and Western areas, excepting the Forss scheme which has an average capacity factor of 45%. Average of projects (excluding Forss) is 29.3%.	Very patchy data for 6 small wind farms - can achieve similar LFs to Shetland.	Data from Burradale 1 & 2 gives averages of 51% - 47%.	No Data

- ROCs are issued for each MWh produced. The following equation was used to estimate the capacity factor for each site: Capacity factor = average number of ROCs issued in month / (number of hours in month * Installed Capacity)
- **Mainland**

  The ROC register gives an average capacity factor of approximately 26% for all UK onshore wind farms. The average produced in the IPA study is higher than those provided in the ROC register, even for all wind farms on the Scottish mainland
- **Orkney**

  Data was taken from 6 wind farms giving an average capacity factor of approximately 35%
- **Shetland**

  Average obtained from Burradale 1 is slightly higher than that quoted in the IPA study at 52.4%
- **Western Isles**

  The IPA study provided no data for the Western Isles, the ROC register gives information for Arnish Moor wind farm located on the Isle of Lewis. The calculated capacity factor for 2007 is only 15.5%; however, the last 3 months of the year gives an average of 31%

  Further information would be needed to provide an informed opinion on a typical capacity factor for the Western Isles

Other:

	Shetland	W. Isles
Other	Viking project website suggests 50%	Lewis Wind Farm web site suggests 35%

- In addition to the information in the IPA study, the Viking Energy website quotes an estimated capacity of 45% for the proposed Lewis wind farm [5] No evidence is provided for this estimation or for the estimate on the Lewis Wind Farm website for the estimated capacity of 35%.

REGO Database:

Implemented in 2003, the Renewable Energy Guarantee of Origin (REGO) electronic certificate system enables producers of renewable-sourced electricity that is eligible under the EU Renewables Directive to be issued with evidence (guarantees) that their electricity is indeed renewable. Examination of this data provides an estimation of achieved load factors for wind farms throughout the UK. Again, this data indicates that there are differences between the wind resource on the Islands and the Northern Highlands.

Table 1: Representative Load Factors

	Mainland	Orkney	Shetland	W. Isles
REGO Register	Forss scheme, 47.5% Average of projects (excluding Forss) is 30.4%	Patchy data but capacity factors of 43.8% and 48.5% achieved.	Data from Burradale 1 gives 53.7%.	No Data

- The calculation of the capacity factor follows the same method described above for the ROCs register
- **Mainland**

  Forss scheme had an average capacity factor of 44.1%

  Timeframes of this project do not permit the calculation of an average wind farm capacity factor based on a wide range of sample date. However, the average for three large Scottish mainland wind farms was found to be approximately 24%, which is lower than the expected average for Scotland
- **Orkney**

  Burgar Hill; 44.1%
  Burray; 28.9%
  Bu Farm; 32.7%
  Thornfinn A; 20.4%
  Spurness; 23.6%
  Average = 29.9%

  This is significantly less than the information provided in the IPA study
- **Shetland**

  Burradale; 53.7%
- **Western Isles**

  No data for Arnish Moor wind farm was available

Consultation:

Consultation responses also which suggested that island projects are generally expected to have higher load factors than mainland projects.

Table 1: Representative Load Factors

	Mainland	Orkney	Shetland	W. Isles
Consultation	35%	45% - 50%	45% - 50%	35% - 37%

- Consultation section does not mention the references for the material used
- Quoted capacity factors for the mainland and Orkney would appear to be high relative to values arising from ECgL calculations

Used in Analysis:

Mainland

We have used the average of data from the ROC and REGO databases (excluding the Forss project) - 30%

Orkney

As there is evidence to suggest that Orkney can achieve similar load factors to Shetland we have used the same value - 49%

Shetland

We have used the average of the data from the ROC Register - 49%

W.Isles

In the absence of actual data we have used the data from the Lewis Wind Farm website - 35%

Table 1: Representative Load Factors

	Mainland	Orkney	Shetland	W. Isles
Used in Analysis	30%	49%	49%	35%

- **Mainland**

  In ECgL's experience the average capacity factor calculated for UK mainland wind farms is approximately 27% and would be expected to be higher for the Scottish mainland

- **Orkney**

  The value provided for Orkney seems to be too high from the data presented in the IPA study and in light of ECgL calculations. Table 1 in the IPA study claims there is evidence to suggest that Orkney can achieve similar load factors to Shetland; it would be beneficial to the reader to be guided to a reference for this evidence

  A major developer in the region has advised that a range of 40% to 45% would be more reasonable. Client confidentiality prevents us from revealing the source of this information

- **Shetland**

  A major developer in the region has advised that a range of 45% to 48% is appropriate in their experience

- **Western Isles**

  A major developer in the region has advised that the Western Isles are perceived to have a similar potential capacity factor (of 40% to 45%) as that in Orkney. Considering the scarcity of measured data it is ECgL's view that a value of 35% would be prudent. This supports the information provided in the IPA

	study.
2.2 Pre-Construction Costs Pre-construction costs for a wind farm typically comprise a Feasibility Study, an Environmental Impact Assessment and a planning application. These are assumed to total £5/kW.	• Pre-construction costs are assumed to be £5/kW based on a total wind farm capacity of 150MW; this equates to a cost of £750,000 for the whole wind farm. Citing a cost on a per kW basis would seem misleading as these costs are not linear to project size. For example, it may be anticipated that economies of scale can be achieved with larger wind farms with an associated reduction in the costs per kW. An estimated cost range might be more applicable than cost a per kW estimate. Although total pre-connection costs are site specific, for most mainland wind farms an average could be assumed • The IPA study assumes the same cost of Environmental Impact Assessment (EIA) for the Island projects as for mainland projects. This assumption would appear to be flawed in light of the extra studies required to assess subsea cable route and landing points for the islands • Information obtained from a range of consultancies and developers indicate that a typical cost for pre-construction works on the mainland would be in the range of £400,000 to £700,000 per project which is equivalent to approximately £2.7/kW to £4.7/kW. As for the Islands, a range of £500,000 to £900,000, which is equivalent to approximately £3.3/kW to £6/kW, is considered more appropriate • The pre-construction costs suggested in the IPA study fall within the range suggested by ECgL
2.4 Capital Costs The main components of the Capex costs have been identified in the following list, with the main cost differentials being identified as the cost of concrete, the cost of labour and turbine transportation & erection.	• The IPA study identifies the components of the capital cost of wind farm development which are expected to vary between the wind farm projects in different locations (Mainland, Orkney, Shetlands, and Western Isles). It is unclear as to what is covered by each of the components. The list of components

- Concrete;
- Labour;
- Other Civils;
- Turbine Cost;
- Turbine Transportation & Erection; and
- Local Connection Cost;

2.4.7 Capital Costs Summary

Table 9: Capital Costs

£/kW	Mainland	Orkney	Shetland	W. Isles
Total	1,056	1,080	1,088	1,080

These mainland costs are broadly consistent with the DTI's earlier report 'Impact of banding the Renewables Obligation – Costs of electricity production', published in April 2007.
Discussion on each of the components follows.

should either be expanded or more clear definitions provided

- ECgL has reviewed, amongst other sources, a DTI paper on 'The economics of onshore wind energy' Wind Energy Fact Sheet 3 first issued in June 2001. The proportions of capital costs provided seem to be in line with figures published in the paper with regards to turbine costs and local connection costs only [6]
- The breakdown of capital costs in the aforementioned DTI paper provided cost information relating to activities not considered in the IPA Study. These activities included: bank fees, interest accrued during construction, development costs, legal costs, insurance and project management
- The source(s) of the costs quoted should be provided
- In ECgL's experience, the average cost per kW for a development on the mainland of this size is approximately £1,120 per kW. The table below reflects ECgL's views on the estimated cost for the island developments
- Several developers have provided an indicative overall development cost of around £1,200/kW for the mainland. The same sources quoted overall costs of around £1,400/kW for a 'distant development'

£/kW	Mainland	Orkney	Shetland	W. Isles
Total	1,120	1,300	1,400	1,300

- It is ECgL's view that the overall costs expressed by IPA are lower than may be expected

2.4.1 Concrete

Table 6: Concrete costs

	Mainland	Orkney	Shetland	W. Isles

- Information provided by Econnect Construction to ECgL indicates a cost of concrete on the Mainland at £62/kW; this is approximately £22/kW less than that quoted in the IPA study

Concrete	Cost, £/kW	84	+15%	+20%	+15%	• The basis for the percentage increase in costs for the Scottish islands needs to be explained clearly. If shipping costs are included it is suggested that these are provided separately

2.4.2 Labour

Table 7: Labour costs

	Mainland	Orkney	Shetland	W. Isles
Labour Cost, £/kW	20	+10%	+15%	+10%

- It is not clear whether the labour costs includes the costs associated with labour requirements for turbine erection or whether it is separate. In addition, it is not clear if the cost of labour includes project development
- The basis for the percentage difference in the cost of labour on the Scottish Island needs to be explained. Clarification is also needed as to whether the percentage differences between the investigated areas take into account labour transportation and accommodation
- Without clarification of assumptions, a meaningful validation cannot be made.

2.4.3 Other Civils

Other civils, including the cost of constructing access roads, are likely to utilise locally quarried aggregates as much as possible and so unlikely to vary between the areas under consideration. We have assumed that they remain constant between the comparator projects, at £81/kW.

- The definition of what is included in these costs is unclear. See comments raised against Table entry 2.2
- Information provided to ECgL by a range of developers indicate that civil infrastructure work would be in the range of £100/kW to £180/kW
- These sources also indicated that civil works costs may be expected to be some 30% to 50% higher on the islands than on the mainland
- Other civils costs would be expected to include those associated with subsea crossing. This should be clarified

2.4.4 Turbine Costs

The costs are assumed to remain constant irrespective of the location of the development, at £661/kW. Note that this is excluding the cost of transportation & erection.

- The assumed turbine type used in the IPA study needs to be identified as the price varies greatly between generation capacities, suppliers, and hub heights. Additionally, a breakdown of the supplier costs would also be useful
- Data provided to ECgL by a range of developers suggests that a range of costs between £500/kW to 720/kW. In light of this information, the quoted value of £661/kW would seem to be appropriate

2.4.5 Turbine Transportation & Erection

Table 8: Turbine Transportation & Erection costs

	Mainland	Orkney	Shetland	W. Isles
Turbine Transportation & Erection Cost, £/kW	58	+15%	+20%	+15%

- Assumptions made in obtaining the figures in Table 8 of the IPA study need to be clarified; particularly those relating to the Scottish islands in light of likely soil conditions and consequential impact on erection costs
- In ECgL's experience, turbine transportation and erection costs add between 8% and 10% to total turbine costs for projects on the Scottish mainland. The costs provided in the report represent 8.7% of the turbine cost and is, therefore, considered appropriate
- The "Renewable Energy Resource Assessment for Orkney & Shetland" published in July 2005 [7] gives indicative costs of erection and transportation of wind turbines. The costs quoted are significantly higher than those in the IPA study. For the Shetlands, the cost is expected to be 150% more than that of the mainland costs, while for the Orkneys and the Western Isles it is expected to be more than 100% more than the mainland cost

2.4.6 Local Connection Costs

In addition to the Island transmission development costs A wind farm

- The definition of what is covered in local connection cost,

developers will have to pay for their own assets which are necessary to connect to the Transmission system. These are termed 'local connection costs' and have been assumed to remain constant between the areas under consideration at a cost of £152/kW.	particularly in light of costs considered under Table 3 and Table 5 of the IPA study, requires clarification • In ECgL's experience the cost of grid connection (i.e. solely taking into account electrical balance of plant between wind farm substation and the grid) on the mainland can be anticipated to be approximately £100/kW and up to £175/kW for the Shetland Islands

4 Conclusion

Due to the lack of detail provided in relation to research background or assumptions made in the IPA study it is difficult to validate all information presented. ECgL has compared the figures to anticipated ranges of the various costs based upon experience, primary data and research.

Based on publicly quoted wind farm data, the capacity factor figures in section 2.1 of the IPA study appear, largely, slightly higher than may be expected.

Developers consulted by ECgL have indicated that the overall capital expenditure is estimated to be around £1,200/kW for wind farms on the Scottish mainland. The overall cost provided in section 2.4.7 of the IPA study appears to be lower than that estimated by ECgL. It should be noted that the outcome will vary greatly on site specific basis.

Based on ECgL's experience, the overall results seem reasonable with load factors generally, slightly high while capital costs are slightly understated. However, it is recommended that the sensitivities of these results are tested.

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