# Inch Cape Offshore Wind Farm

New Energy for Scotland

Offshore Environmental Statement:
**VOLUME 2A**
**Appendix 8A: Carbon Balance Review**

REPSOL edp renewables

# Contents

# 8A.1 INTRODUCTION

## 8A.1.1 Scope

This document presents research and calculations relating to the potential energy generated and $CO_2$ emissions savings produced from the Project. The results of the calculations and information provided in this document are presented within the context of electricity consumption within the UK and Scotland, and $CO_2$ emission savings are reported within the context of Scottish $CO_2$ emissions.

The research and calculations presented within this document are based on an assumed export capacity of 1,050MW[1]. Results are generally presented as average annual figures although it is noted that generation output from the Project will vary annually due to wind conditions. Benefits will accrue over the operational life of the Project. It is anticipated that the operational life of the project will be a minimum of 25 years and may be up to 50 years based on the lease period offered by The Crown Estate. Figures are presented in 5 year increments from 25 years to 50 years.

The calculations present $CO_2$ emissions savings from energy generation from the Project. An indicative assessment of $CO_2$ costs arising from construction, operations and decommissioning of the Project is included.

As site-specific data for capacity factor is not currently available, the electricity generated has been calculated using an offshore UK capacity factor derived from the average of the last five years of published figures provided by the Department of Energy and Climate Change (DECC)[2].

The following information is also presented on the basis of the above scope assumptions:

- The potential equivalent number of Scottish and UK households that could be powered by the wind farm.
- The amount of coal, gas and fossil fuels used to produce the equivalent amount of power generated by the wind farm.

[1] Based on the current grid connection secured for the Project.
[2] Digest of UK Energy Statistics 2012 Available online from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx (last accessed 15/01/2013)

- The potential $CO_2$ emissions savings of the wind farm over coal-fired, gas-fired and fossil fuel mix electricity generation.

## 8A.2 Potential Electricity Generation Produced by the Project

The potential electricity generation of a wind farm is calculated using the total capacity of the wind farm, the time over which generation occurs and the predicted capacity factor[3].

Capacity factors for onshore and offshore wind farms show a good correlation with the UK average wind speed[4] and therefore, exhibit considerable annual variation. In the absence of a site-specific capacity factor figure for the Project, an average figure for capacity factor, based on published information, is considered to be more representative than a single annual figure. As such, the annual figures for offshore UK wind capacity factors have been obtained from DECC for years 2007 through to 2011[5] and from these figures, an average figure of 31.96% was calculated. Capacity factor figures for offshore wind for 2012 are not published until September 2013 and therefore were not available for this report.

**Table 8A.1: DECC published offshore UK capacity factors[6] 2007-2011 and calculated average (%)**

| 2007 | 2008 | 2009 | 2010 | 2011 | Average |
|---|---|---|---|---|---|
| 28.3 | 34.9 | 32.1 | 29.5 | 35 | 31.96 |

The following tables provides the potential electricity generation figures for the Project based on the average capacity factor shown in Table 8A.1.

[3] The potential generation figures presented in the calculations undertaken here are based on a commonly used industry formula which multiplies the total MW capacity of the wind farm by the time over which generation occurs and the capacity factor. Methodology also available online from: http://www.renewableuk.com/en/renewable-energy/wind-energy/uk-wind-energy-database/figures-explained.cfm (last accessed 16/01/2013)

[4] UK Onshore Wind Capacity Factors 1998-2004. Energy Trends (March 2006). DECC

[5] Digest of UK Energy Statistics (2012). Available online from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx (last accessed 15/01/2013)

[6] These capacity factors are based on schemes operating on an unchanged configuration basis, i.e. these values are calculated in the same way as other capacity factor values but are restricted to those schemes that have operated continuously throughout the year without a change in capacity. This is considered a more robust figure as it does not recognise those schemes where installed capacity changes within the year e.g. a scheme may be constructed within a particular year but is not generating electricity for the whole of that year.

**Table 8A.2: Potential electricity generation produced by the Project - Annual**

| Capacity Factor (%) | Export Capacity (MW) |
|---|---|
| 31.96 | 1050 |
| **Potential Electricity Generated (MWh/year)** | |
| 2,939,680 | |

**Table 8A.3: Potential electricity generation produced by the Project - Lifetime**

| Operational Life | Potential electricity generated in operational period (GWh) |
|---|---|
| 25 years | 73,492 |
| 30 years | 88,190 |
| 35 years | 102,889 |
| 40 years | 117,587 |
| 45 years | 132,286 |
| 50 years | 146,984 |

### 8A.2.1 Potential Electricity Generation Produced by the Project in the Context of Offshore Renewables

In relation to the Project contribution to electricity generated by offshore renewables in general; in 2011 offshore renewables generated a total of 5,126 GWh[7] of electricity in the UK. In the context of this, the potential annual electricity generation produced by the Project (2.94 GWh) would be equivalent to 57.3% of the 2011 total offshore renewables generation in the UK.

[7] Digest of UK Energy Statistics (2012). Available online from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx (last accessed 15/01/2013)

### 8A.2.2 Potential Electricity Generation Produced by the Project in the Context of Scottish and UK Electricity Consumption

The Department for Energy and Climate Change (DECC) produces a range of statistics detailing electricity consumption across the UK. The average domestic electricity consumption in Scotland, based on sales per household, was 4,709 kWh[8] in 2011, compared to a UK average figure of 4,266 kWh in 2011. The electricity generated by the Project will enter the National Grid network, and therefore cannot be tracked to the individual consumer, but the electricity is going to supply demand for the UK and has a grid connection point in East Lothian.

According to the calculated potential generation figures provided in Table 8A.2, the table below provides the equivalent number of household that may be powered per year by the Project.

**Table 8A.4: Potential number of households equivalent powered by Inch Cape Offshore Wind Farm**

| Capacity Factor (%) | Potential Electricity Generated (MWh/year) | 2011 Average Domestic Consumption per household (kWh) Scotland | 2011 Average Domestic Consumption per household (kWh) UK | Potential number of households equivalent powered per year (based on average Scottish consumption) | Potential number of households equivalent powered per year (based on average UK consumption) |
|---|---|---|---|---|---|
| 31.96 | 2,939,680 | 4,709 | 4,266 | 624,268 | 689,095 |

Based on these calculations, the potential electricity generated by the Project will be equivalent to the domestic electricity demand of approximately 625,000 and 690,000 households based on Scottish and UK domestic consumption respectively, assuming a capacity factor of 31.96% and that the average consumption per household has not changed since 2011.

Within Scotland, the number of domestic meter point administration numbers (MPANs) in 2011 was 2,746,968. The figures for Scotland provided in Table 8A.4 reveal that the proposed development could provide the equivalent of 22.7% of households in Scotland, assuming the housing level has remained constant.

[8] Regional and Local electricity consumption statistics 2005-2011, DECC. Available online from: http://www.decc.gov.uk/en/content/cms/statistics/energy_stats/regional/electricity/electricity.aspx (last accessed 16/01/2013)

Within the UK, the number of domestic MPANs in 2011 was 27,301,241[9]. The figures for the UK, provided in Table 8A.4, reveal that the Project could provide the equivalent of 2.5% of households in the UK, assuming the housing level has remained constant.

## 8A.3 Equivalent Fuel Use

Every unit of electricity produced by a wind farm development displaces a unit of electricity which would otherwise have been produced by a conventional (coal or gas) power station and therefore, presents carbon savings. It is the output from coal-fired and gas-fired plant that is adjusted to meet the electricity demand on the system; therefore, wind power replaces the output of these power stations as these are the most flexible plant on the system (wind-generated electricity does not replace electricity from other renewables sources or nuclear power stations). The calculations below use a historical series of published figures from DECC for annual fuel used and electricity generated for 2007 through to 2011[10]. They also use a conversion factor of 0.085985 which converts alternative units (e.g. GWh) into the common unit of energy for comparing and aggregating fuels, i.e. tonne of oil equivalent (toe).

### 8A.3.1 Coal

Based on the DECC figures[10] for fuel use 2007-2011, the average amount of coal used to produce a GWh of electricity is 240 toe [i.e. 0.240 thousand toe (ttoe)][11]. Using this average figure and the potential annual generation figures for the Project shown in Table 8A.4, it can be calculated that the Project has the potential to replace approximately 705,523 toe (705.523 ttoe) of coal[12]. To place this into context, in 2011, 26,030 ttoe of coal was used to produce 108,583 GWh of electricity for the UK; the Project, therefore, has the potential to replace the equivalent of approximately 2.7% of this annual coal usage in 2011.

### 8A.3.2 Gas

The historical series of published figures from DECC for 2007-2011 also report on gas used for electricity generation. Using these figures, the average amount of gas used to produce a

[9] As Footnote 8

[10] Digest of UK Energy Statistics (2012) DECC. Available online from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx (last accessed 16/01/2013)

[11] The calculation for this figure was based on dividing the annual amount of fuel used in ttoe (using the conversion factor to convert from GWh to ttoe) by the total annual electricity generation (GWh) of that fuel.

[12] For example, 2,939.68 GWh/year x 0.240 ttoe = 705.523 ttoe or 705,523 toe.

GWh of electricity is 184 toe [i.e. 0.184 ttoe]. Using this average figure and the potential annual generation figure from the Project shown in Table 8A.4, it can be calculated that the Project has the potential to replace the equivalent of approximately 540,901 toe (540.901 ttoe) of gas. Again, to place this into context, in 2011, 26,030 ttoe of gas was used to produce 146,814 GWh of electricity; therefore, the Project has the potential to replace the equivalent of approximately 2.1% of this annual gas usage.

### 8A.3.3 Fossil Fuels

DECC report on the fuel use of coal, gas and oil. All three fuels make up the fossil fuel mix and using the published figures from DECC for 2007-2011, the average amount of fossil fuel used to produce a GWh of electricity is 207 toe [i.e 0.207 ttoe]. Using this average figure and the potential annual generation figure from the Project shown in Table 8A.4, it can be calculated that the Project has the potential to replace the equivalent of approximately 608,514 toe (608.514 ttoe) of fossil fuel usage. To place this into context, in 2011, 52,451 ttoe of fossil fuels (coal, gas and oil) was used to produce 259,062 GWh of electricity; the Project has the potential to replace the equivalent of between 1.2% of this annual fossil fuel mix usage.

## 8A.4 Potential $CO_2$ Emission Savings Produced by the Project

### 8A.4.1 $CO_2$ Savings

The amount of $CO_2$ emissions produced during energy production varies with the type of fuel used; therefore, the potential $CO_2$ savings from the Project depends on the type of fuel it replaces.

The wind farm $CO_2$ emissions savings over other types of generation (i.e. coal-fired, gas-fired, fossil-fuel mix) is calculated by multiplying the energy output of the proposed wind farm by the emissions factor of the other type of generation.

Carbon dioxide emissions from power stations vary by type of fuel used. In addition, the emissions for different types of electricity generation show annual variations. DECC publishes the annual estimated emissions ($tCO_2$/GWh) from electricity generation for different fuel types in their annual Digest of UK Energy Statistics[13]. Although the annual

[13] Digest of UK Energy Statistics (2012) DECC. Available online from: http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx (last accessed 16/01/2013)

variations are fairly small, the average $CO_2$ emissions for gas, coal and the fossil fuel mix for years 2009-2011, sourced from the 2012 Digest, have been calculated. These average emissions figures (0.910 $tCO_2$/MWh, 0.396 $tCO_2$/MWh and 0.596 $tCO_2$/MWh for coal, gas and all fossil fuels respectively) are known as the emissions factor for that fuel type and are used in the following calculations.

Using the above emissions factors and the potential generation produced by the Project shown in Table 8A.4, the potential $CO_2$ emissions savings from the Project electricity generation are calculated and shown in Figure 8A.5 over a range of operational periods.

**Table 8A.5: Potential $CO_2$ Emissions Savings Produced from the Project**

| Potential Electricity Generated (MWh/year) | Potential annual $CO_2$ emissions savings over coal-fired generation ($tCO_2$/year) | Potential annual $CO_2$ emissions savings over gas-fired generation ($tCO_2$/year) | Potential annual $CO_2$ emissions savings over fossil fuel mix generation ($tCO_2$/year) |
|---|---|---|---|
| 2,939,680 | 2,675,108 | 1,164,113 | 1,752,049 |
| **Operational Life** | **Potential $CO_2$ emissions savings from electricity generation over coal-fired generation ($MtCO_2$)** | **Potential $CO_2$ emissions savings from electricity generation over gas-fired generation ($MtCO_2$)** | **Potential $CO_2$ emissions savings from electricity generation over fossil fuel mix generation ($MtCO_2$)** |
| 25 years | 66.88 | 29.10 | 43.80 |
| 30 years | 80.25 | 34.92 | 52.56 |
| 35 years | 93.63 | 40.74 | 61.32 |
| 40 years | 107.00 | 46.56 | 70.08 |
| 45 years | 120.38 | 52.39 | 78.84 |
| 50 years | 133.76 | 58.21 | 87.60 |

Using the DECC average capacity factor (31.96%), the Project has the potential to produce CO2 emissions savings of 2,675,108 tCO2 per year (i.e. 2.68 MtCO2), 1,164,113 tCO2 per year (i.e. 1.16 MtCO2) and 1,752,049 tCO2 (1.752 Mt CO2) per year over coal-fired, gas-fired and fossil fuel mix electricity generation respectively.

### 8A.4.2 $CO_2$ Costs

CO2 emissions will arise from the manufacture of WTGs and other components, and from construction, operations and decommissioning of the Project. At this stage of the Project, many of the specific elements that will result in emissions are not yet defined. These include WTG make and model, substructure and foundation type and therefore material selection, and installation methods which will affect vessel selection. Operations and maintenance requirements and support locations are also not yet defined. It is only possible at this stage to provide an indicative assessment of CO2 emissions that will arise from construction, operations and decommissioning of the Project based on published data. A recent climate declaration[14] in relation to Vattenfall's Nordic Wind Farms (including Horns Rev and Lillgrund) provides verified results from a life cycle assessment (LCA) performed as basis for

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http://www.vattenfall.com/en/file/Certified_Environmental_Product_Declaration_of_Electricty_from_Vattenfall_s_Windfarms_2010_12180312.pdf

an EPD (Environmental Product Declaration)[15], in accordance with ISO 14025. The declaration shows the emissions of greenhouse gases, expressed as CO2-equivalents as follows;

| | **Grams $CO_2$ equivalent per KWh** |
|---|---|
| *Oils used in plant* | 0.23 |
| *Operations* | 0.16 |
| *Construction, reinvestments and decommissioning* | 13.56 |
| **Total** | **13.95** |

$CO_2$ costs for the Project have been estimated on this basis. Table 8A.6 below summarises the savings, costs and net savings of $CO_2$ over a range of operational periods based on savings from a fossil fuel mix as per Table 8A.5.

**Table 8A.6: Potential $CO_2$ Emissions Savings Produced from the Project**

| Operational Life | Potential $CO_2$ emissions savings from electricity generation over fossil fuel mix generation ($MtCO_2$) | Potential $CO_2$ costs from Project ($MtCO_2$) | Net $CO_2$ emissions savings from Project based on fossil fuel mix ($MtCO_2$) |
|---|---|---|---|
| 25 years | 43.80 | 1.03 | 42.78 |
| 30 years | 52.56 | 1.08 | 51.48 |
| 35 years | 61.32 | 1.14 | 60.19 |
| 40 years | 70.08 | 1.19 | 68.89 |
| 45 years | 78.84 | 1.25 | 77.59 |
| 50 years | 87.60 | 1.30 | 86.30 |

Based on this scenario the time taken to payback the $CO_2$ costs of the Project through offsetting emissions from a fossil fuel mixed generation would be slightly less than 12 months.

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http://gryphon.environdec.com/data/files/6/9020/cd183_Climate_Declaration_Vattenfall_Nordic_Wind_2013.pdf

### 8A.4.3 Backup Generation

Wind generated electricity is inherently variable and may require backup power from other forms of generation in order to manage the supply to the consumer. The extra capacity needed for backup power generation is estimated at 5% of the rated wind farm capacity if all the wind power schemes within the UK contribute more than 20% of the total supply to the National Grid (Dale *et al.* 2004 cited in Nayak *et al.* 2010[16]). If fossil fuel provides the backup, there will be carbon emissions associated with this back up.

It is likely that the contribution from UK wind energy sources will increase to more than 20% of the total supply of the National Grid during the assumed lifetime of the Project. As such, backup power generation may be required at some point in the future depending on how and when this Project and other projects progress to construction and operation. The emissions associated with backup have not been taken into consideration within the calculations made above.

### 8A.4.4 Potential $CO_2$ Emissions Savings Produced by the Project in the Context of Scottish Emissions

To place the above $CO_2$ emissions savings calculations into context, the potential $CO_2$ emissions savings produced by the Project and presented in Table 8A.5 can be compared to the latest published figures for $CO_2$ emissions at a Scottish national level. These published estimates reveal that the total $CO_2$ emissions estimate for Scotland in 2010 was 39.85 million $tCO_2$ [$MtCO_2$][17].

As such, based on the annual generation figures using the average DECC capacity factor, the expected annual $CO_2$ emission savings from the Project could account for the equivalent of between approximately 2.9% (over gas-fired generation), 4.4% (over fossil fuel mix generation) to 6.7% (over coal-fired generation) of the total $CO_2$ emissions estimate for Scotland in 2010, assuming that gas-fired, coal-fired and fossil fuel mix generation are replaced alone.

Furthermore, as the Scotland figure of 39.85 $MtCO_2$ includes transport, industrial and commercial, as well as agricultural $CO_2$ emissions; when examining the $CO_2$ emissions

[16] Nayak D. R., Miller, D., Nolan, A., Smith, P. and Smith, J. U. (2010) Calculating carbon budgets of wind farms on Scottish peatlands. Mires and Peat, Vol. 4, Article 9.

[17] Based on estimates produced by AEA for the Department of Energy and Climate Change (DECC). Available online from: http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx (last accessed 16/01/2013). 2011 $CO_2$ emissions figures not yet available.

estimates for domestic electricity usage for Scotland in 2010 (6.542 $MtCO_2$[18]), the expected annual $CO_2$ emission savings from the Project could account for the equivalent of between approximately 17.8% (over gas-fired generation), 26.8% (over fossil fuel mix generation) to 40.9% (over coal-fired generation) of the total $CO_2$ emissions estimate for Scotland in 2010, assuming that gas-fired, coal-fired or fossil fuel mix generation are replaced alone.

[18] The emissions associated with domestic electricity consumption have been estimated using an average UK factor for the relevant year in terms of kt $CO_2$ per GWh. This average allocates equal shares of coal, gas, oil and renewable powered generation to all the domestic electricity consumers and is derived from the UK inventory for 2010. AEA. Local and Regional Carbon Dioxide Emissions Estimates for 2005-2010 for the UK Technical Report. Available online from: http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/gg_emissions/laco2/laco2.aspx (last accessed 16/01/2013)