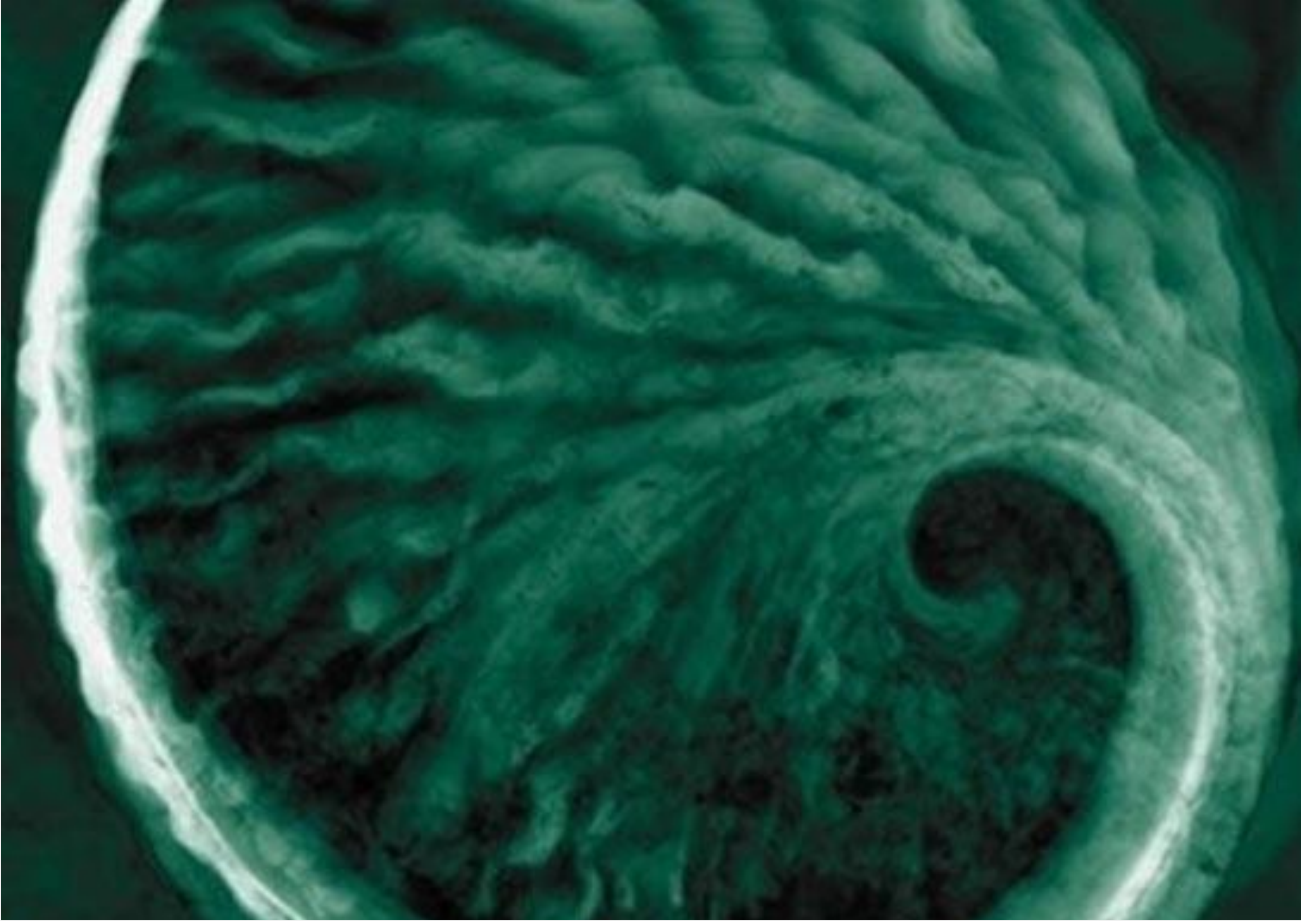


Owenreagh/Craignagapple Wind Farm

Ørsted Onshore Ireland Midco Limited

Environmental Statement - Technical Appendix A15.1 Shadow Flicker Assessment

06 September 2023

Project No.: 0696177

The business of sustainability

Signature Page

06 September 2023

Owenreagh/Craignagapple Wind Farm

Environmental Statement - Technical Appendix A15.1 Shadow Flicker Assessment

Bilal Ahmed
Senior Noise Consultant

Ian S Grant

Ian Grant
Senior Consultant

Peter Rodgers
Partner

Environmental Resources Management Ireland Limited

D5 Nutgrove Office Park

Dublin 14

D14 X343

Ireland

CONTENTS

List of Tables

1. INTRODUCTION AND BACKGROUND

1.1 Overview

This Technical Appendix evaluates the effects of shadow flicker from the proposed new turbines that comprise the Owenreagh / Craignagapple Wind Farm (the Development) on nearby receptors. **Chapter 3: Development Description** of the Environmental Statement (ES) accompanying the application for the Development provides more detail on the proposals.

Under certain combinations of geographical position and time of day and year, the sun may pass behind the rotors of a wind turbine and cast a shadow over neighbouring properties. Shadow flicker is an effect that can occur when the shadow of a blade passes over a small opening (such as a window), briefly reducing the intensity of light within the room, and causing flickering to be perceived. The likelihood and duration of the effects depend on a range of factors, discussed in detail in Section 4 of this Technical Appendix.

This Technical Appendix includes the following elements:

- Legislation, Policy, and Guidance;
- Methodology;
- Scoping Responses and Consultation;
- Baseline Conditions;
- Assessment of Likely Significant Effects;
- Assessment of Cumulative Effects;
- Mitigation Measures
- Residual Effects; and,
- Summary.

This Technical Appendix is supported by the following Figures presented in **Volume 4**:

- **Figure A15.1.1: Shadow Flicker Study Area.**

1.2 Legislation, Policy and Guidance

The following guidance and information sources have been considered in carrying out the shadow flicker assessment:

- Planning Policy Statement (PPS) 18 'Renewable Energy'[1];
- Update on UK Shadow Flicker evidence base[2]; and,
- Wind Energy Development Guidelines[3].

1.2.1 Planning Policy Statement 18 'Renewable Energy

No formal guidance is available regarding what levels of shadow flicker may be considered acceptable across the UK. The Northern Ireland Department of the Environment published the Best Practice Guidance to Northern Ireland Planning Policy Statement (PPS) 18: Renewable Energy which states:

[1] Department for Infrastructure. (2019). Best Practice Guidance to PPS 18 'Renewable Energy'. Available at: https://www.infrastructure-ni.gov.uk/publications/best-practice-guidance-pps-18-renewable-energy. Accessed on: 24 February 2023.

[2] Parsons Brinckerhoff, on behalf of the Department of Energy and Climate Change (2011) Update of UK Shadow Flicker Evidence Base. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/48052/1416-update-uk-shadow-flicker-evidence-base.pdf Accessed on: 24 February 2023.

[3] 'Wind Energy Development Guidelines' published by the Northern Ireland Department of the Environment, Heritage and Local Government (2006) – Revision draft (2019) currently in consultations, available online at gov.ie - Draft Revised Wind Energy Development Guidelines December 2019 (www.gov.ie) Accessed on: 24 February 2023.

"Problems caused by shadow flicker are rare. At distances greater than 10 rotor diameters from a turbine, the potential for shadow flicker is very low. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the site. Where shadow flicker could be a problem, developers should provide calculations to quantify the effect and where appropriate take measures to prevent or ameliorate the potential effect, such as by turning off a particular turbine at certain times.

Careful site selection, design and planning, and good use of relevant software can help avoid the possibility of shadow flicker in the first instance. It is recommended that shadow flicker at neighbouring offices and dwellings within 500 m should not exceed 30 hours per year or 30 minutes per day."

1.2.2 Update of UK Shadow Flicker evidence base

A review of shadow flicker effects from wind turbines was commissioned by The Department of Energy and Climate Change (DECC) in 2011 and carried out by Parsons Brinckerhoff. The document included a review of current guidance, literature and evidence on shadow flicker effects, making reference to both national and international guidance.

The review identifies reoccurring guidance in the context of shadow flicker. These include:

- Guidance suggested that "*only properties within 130 degrees either side of the north of a particular turbine can be affected by shadows*", this was uncontested in any literature or guidance;
- A majority of reviewed guidance suggested that ten times the rotor diameter from turbines was a suitable search area, with some making reference to the possibility of shadows exceeding this distance being extremely low; and,
- There is no standard methodology to measure shadow flicker effects, but a key finding of the report suggests that "*in the UK there have not been extensive issues with shadow flicker and the results of a questionnaire survey to the industry and planning authorities have yielded few complaints*." This suggests that at the time of the study (2011) the current guidance was sufficient.

It should be noted that since the publication of this review (2011), shadow flicker guidance has since been released from the UK Government; however, this is relatively brief and doesn't provide detail or guidance on a suitable rotor diameter distance.

2. METHODOLOGY

2.1 Scope of Assessment

The Development involves the removal of existing turbines from the operational Owenreagh I and II Wind Farms. As these have been consented and operational for well over 10 years, no new shadow flicker effects will arise from these turbines, and they are not assessed further in this Technical Appendix.

2.2 Study Area

The Study Area considers a maximum distance of ten times the rotor diameter from the turbines, in line with current guidance; however, shadows will not be cast over this entire area. At the latitude of the Development, the relative path of the sun through the sky throughout the year means that shadows are cast predominantly to the west and east, with shadows to the south and (to a lesser extent) the north being reduced in comparison.

To ensure that this assessment considers only receptors which may experience shadow flicker effects, the Study Area is defined as the calculated area over which shadows from the wind turbines may be cast, limited to 1,360 m (ten times the rotor diameter of 136 m, which is the maximum of the two candidate turbines) from the wind turbines. The shadow flicker Study Area is shown in **Figure A15.1.1: Shadow Flicker Study Area**.

2.3 Survey Methodology

The assessment of shadow flicker is a desk-based assessment, and as such, no onsite survey specific to shadow flicker has been undertaken.

The desk-based assessment was undertaken using a Geographic Information System (ArcGIS Pro), with input from Ordnance Survey AddressBase Plus data, verified against freely available online aerial imagery, to confirm the locations and names of permanent dwellings within the study area.

2.4 Assessment Methodology

A recognised computer software package[4] was used to calculate theoretical times and durations of shadow flicker effects for each receptor within a distance of 1,360 m from the turbines. This software creates a mathematical model of the proposed turbines of the Development and its surroundings, based on:

- Turbine locations, hub height and rotor diameter;
- Topography (using Ordnance Survey Terrain 5 elevation data); and,
- Latitude and longitude of the Development (used in calculating the position of the sun in relation to the time of day and year).

A cut-off distance of 1,360 m (ten times the maximum rotor diameter of 136 m) from each turbine was employed during this calculation.

Certain worst-case assumptions are made in the calculation, including:

- All receptors have windows facing towards the turbines;
- All windows have been assumed to measure 1 m by 1 m and to be situated at a height of 2 m above ground level, to the window's centre;
- Windows facing towards each of the cardinal compass point directions (north, south, east, and west) have been modelled in order to identify effects from all possible directions. In practice, not all of these directions face the Development, and the buildings may not have windows on each façade;
- There will be no intervening structures or vegetation (other than topography) that may restrict the visibility of a turbine, preventing or reducing the effect;

[4] Resoft WindFarm 4.2.1.7

- Weather conditions are such that strong shadows are always cast during times when shadow flicker may occur;
- The wind direction will be such that the turbine rotor will always be facing directly towards each property, maximising the size of the shadow and hence the frequency and duration of the effect; and,
- The wind speed will be such that the turbine blades will always be rotating.

The shadow flicker calculations are intended to indicate a theoretical maximum potential duration of effects and to provide an approximation of the times of day and year that these would occur, rather than provide a prediction of the level of effects that is likely to occur.

In reality, varying weather conditions (including wind speed, wind direction, and cloud cover) would result in worst-case conditions occurring less frequently than the modelling assumes, and as a result of this precise predictions of actual shadow flicker occurrence are not possible to make in advance. However, a correction to the theoretical maximum potential effects based on measured average weather conditions can provide a more realistic prediction of the level of shadow flicker effects which may occur in practice.

At the Castlederg climate station[5] (the nearest Met Office long-term climate station to the Development), average recorded sunshine levels for the period 1991 – 2020 totalled 1,255.56 hours per year. This figure represents approximately 28% of the total daylight hours experienced per year, based on a total of 4,491 annual daylight hours[6] experienced at the location of the Development.

This assessment, therefore, considers a predicted annual shadow flicker duration based on 28% of the theoretical maximum potential annual effects at each receptor. However, predicted maximum daily levels have not been corrected in order to ensure a worst-case scenario. In practice, for shadow flicker to occur, periods of bright sunshine would have to coincide with the calculated times when shadow flicker may occur, so it is likely that shadow flicker will occur less frequently than the predicted levels indicate.

The likelihood of shadow flicker occurrence is also likely to be further reduced as a result of other factors, such as wind speed, wind direction, screening (from buildings or vegetation) and the actual locations and orientation of windows at the receptors.

2.5 Significance Criteria

The thresholds suggested in the Northern Irish guidance document PPS18 and Wind Energy Development guidelines (i.e., a maximum of 30 minutes / 0.5 hours per day and 30 hours per year) have been adopted for this assessment.

2.6 Assessment Limitations

As outlined in this Chapter, the assumptions made in the assessment process are considered to be conservative and likely to overestimate the effect of shadow flicker in practice.

2.7 Scoping Responses and Consultation

Throughout the scoping exercises, and subsequently, during the ongoing EIA process, relevant organisations were contacted with regards to the Development. Table A15.1.1 outlines the consultation responses received in relation to shadow flicker.

Table A15.1. 1 Consultation Responses

Consultee	Details	Response
Department of Infrastructure	EIA Scoping Response	*'Q15.3 Should no residential properties fall within 10 times the rotor diameter distance of any of the turbines*

[5] Met Office. (2022). Castlederg (county Tyrone) long-term climate averages 1991 – 2020. Available at: [Castlederg (County Tyrone) UK climate averages - Met Office](). Accessed on: 24 February 2023.

[6] Timeanddate.com. (2022). Sunrise, Sunset, and Daylength at 55°52'01.1"N, 3°45'24.2"W. Available at: https://www.timeanddate.com/sun/@55.86700,-3.75674. Accessed 30 November 2022.

		and within 130 degrees either side of north, relative to each of the turbines then the effects of shadow flicker can be scoped out of the assessment. However, this information should be presented in the ES for the final design and layout of the development.'

3. BASELINE CRITERIA

The Study Area is based on the calculated area over which shadows may be cast to ensure that this assessment considers only receptors where shadow flicker effects may occur. There are 20 receptors located within the Study Area. These properties are shown in Figure A15.1.1, and a full list of these receptors is presented in Table A15.1.2 below.

Table A15.1. 2. Receptors with Shadow Flicker Study Area

Receptor ID	Receptor Address	Spatial Coordinates (Meters)	
		Easting	Northing
1	101 Hollyhill Road, Knocklnarvoer, Strabane	242635	398227
2	28 Koram Road, Owenreagh, Strabane (FI)*	240780	397122
3	51 Napple Road, Ballykeery, Dunnamanagh	245122	396215
4	20 Ballykeery Road, Ballykeery, Dunnamanagh	244898	395648
5	33 Koram Road, Owenreagh, Strabane (FI)*	240867	397471
6	105 Hollyhill Road, Knocklnarvoer, Artigarvan	242776	398246
7	109 Hollyhill Road, Knocklnarvoer, Artigarvan (FI)*	242988	398424
8	113 Hollyhill Road, Knocklnarvoer, Artigarvan	243054	398435
9	35 Koram Road, Owenreagh, Strabane (FI)*	240855	397514
10	9 Balbane Road, Meendamph, Dunnamanagh	245451	396366
11	34 Koram Road, Owenreagh, Strabane	240754	397896
12	111 Hollyhill Road, Knocklnarvoer, Artigarvan (FI)*	243037	398390
13	106 Hollyhill Road, Knocklnarvoer, Artigarvan	242692	398319
14	21 Ballykeery Road, Ballykeery,	245007	395703
15	19 Koram Road, Owenreagh, Strabane	241568	395171
16	31 Koram Road, Owenreagh, Strabane	240821	397550
17	Balleykeery Road (Resi_83: LA11/2018/0124/RM)	244844	395550
18	Koram Road (Resi_67: no address) (FI)*	240895	397441
19	Crockan Road (Res-_73: no address)	242705	398335
20	Crockan Road (Resi_64: LA11/2019/0065/RM)	242714	398359

***** FI indicates that the listed receptor has a financial interest in the Development.

It should be noted that additional evaluation of the shadow flicker receptors identified in Table A15.1.2 above indicated that several of these receptors are classified as uninhabitable and as such were not assessed further for potential shadow flicker effects. These included the following:

- 28 Koram Road;
- 19 Koram Road; and,
- 31 Koram Road.

4. ASSESSMENT OF POTENTIAL EFFECTS

4.1 Decommissioning and Construction Phase and Final Decommissioning Phase

Shadow flicker is a phenomenon that only occurs once the turbines are installed and operational, and thus no shadow flicker effects are anticipated during the construction or decommissioning phases of the Development.

4.2 Operational Phase

Table A15.1.3 below presents the calculated shadow flicker levels at the affected receptors detailing exceedances to the daily and annual threshold levels as outlined in 'PPS18' (described in Section 2.4), considering both the theoretical maximum hours of shadow flicker per annum and the predicted number of hours of shadow flicker per annum, based on the worst-case assumptions discussed in Section 2.4.

Table A15.1. 3. Shadow Flicker Maximum and Average Levels

ID	Receptors	Days per Year on which Shadow Flicker may occur	Maximum Daily Duration of Shadow Flicker Effects	Theoretical Maximum Shadow Flicker Effects per Year	Predicted Shadow Flicker Effects Per Year[7]
		Days	Hours	Hours	Hours
1	**101 Hollyhill Road**	**66**	**1.2**	**79.2**	**22**
6	**105 Hollyhill Road**	**58**	**1**	**55.7**	**16**
13	**106 Hollyhill Road**	**50**	**0.9**	**44.5**	**12**
5	**33 Koram Road**	**101**	**0.6**	**58.6**	**16**
9	**35 Koram Road**	**102**	**0.6**	**57.1**	**16**
18	**Koram Road (Resi_67)**	**105**	**0.6**	**63**	**18**
10	9 Balbane Road	44	0.5	19.8	6
11	34 Koram Road	40	0.5	18.4	5
3	51 Napple Road	18	0.1	0.9	0
4	20 Ballykeery Road	0	0	0	0
7	109 Hollyhill Road	0	0	0	0
8	113 Hollyhill Road	0	0	0	0
12	111 Hollyhill Road	0	0	0	0
14	21 Ballykeery Road	0	0	0	0
17	Ballykeery Road (Resi_83)	0	0	0	0
19	Crockan Road (Res-_73)	48	0.5	21.6	6
20	Crockan Road (Resi_64)	44	0.4	18.9	5

[7] Considering average annual hours of sunshine (required for shadow flicker to occur) of approximately 28%.

As previously discussed in Section 2.4, this assessment includes a number of worst-case assumptions in terms of environmental factors (such as wind conditions and screening), and the context of receptors themselves (in terms of window locations) could reduce or eliminate shadow flicker in practice.

As can be seen from Table A15.1.3, the predicted levels of shadow flicker at the most-affected receptor, 101 Hollyhill Road, are 22 hours per year with a maximum of 1.2 hours in any one day. Predicted shadow flicker hours per year do not exceed 30 hours at any receptors. However, the following receptors exceed the 30 minutes (0.5 hours) per day limit for theoretical maximum shadow flicker, listed in the magnitude of exceedance (highest to lowest):

- 101 Hollyhill Road;
- 105 Hollyhill Road;
- 106 Hollyhill Road;
- 33 Koram Road; and note this property has a financial interest in the Development;
- 35 Koram Road note this property has a financial interest in the Development; and,
- Koram Road (no address, note property has a financial interest in the Development).

Exceedances are seen at these six receptors along Hollyhill Road (directly north) and Koram Road (northwest) only.

As some receptors are calculated, as a theoretical maximum, to experience levels of shadow flicker above the thresholds of 30 minutes (0.5 hours) per day; shadow flicker due to the Development, without appropriate mitigation, is **significant** as per the EIA Regulations.

4.3 Assessment of Cumulative Effects

In order for cumulative shadow flicker effects to occur, shadow flicker sensitive receptors must receive shadow flicker from more than one wind farm/turbine development (including the Development)

A screening exercise was undertaken to identify any cumulative developments which have the potential to result in cumulative shadow flicker effects. No cumulative developments (either operational, consented or in planning) were found to be located within the ten-rotor diameters[8] Study Area. Cumulative developments located more than ten rotor diameters from the Study Area have no prospect of causing cumulative shadow flicker effects and have not been considered.

Therefore, cumulative shadow flicker effects are **not significant** for this Development.

4.4 Mitigation Measures

Whether shadow flicker impacts a person in a property depends on the specifics of the building itself (which affects whether shadow flicker would actually occur), the usage of that room (i.e., the purpose and timing of usage, relative to the shadow flicker effect) and their attitude to the effect should they observe it.

If the shadow flicker does not occur in practice or does occur but does not present an annoyance to residents, there is no reason to put mitigation in place.

If shadow flicker is, in practice, not acceptable to a resident, a range of mitigation measures are available to control the effects, including:

- Control at Property: the provision of blinds, shutters, or curtains to affected properties;
- Control on Pathway: for example, screening via planting close to an affected property; and,
- Control at Source: for example, a shutdown of turbines at times when effects occur.

Control at the property and control on pathway mitigation measures can be limited in effectiveness (as they mask rather than remove the effects) and can take time to become effective (as in the case of screening through planting).

Control at source is the most immediate and effective method for mitigating shadow flicker effects. This involves shutting turbines down during specific times when shadow flicker is likely to occur; the

[8] Rotor diameters are specific to the turbines used for each cumulative development.

times are pre-calculated and programmed into the shutdown calendar of the Development's SCADA system (Supervisory Control and Data Acquisition system), which is the central computerised monitoring system. This does not take account of weather conditions occurring at specific times, which can result in excessive shutdowns. Photocells can be installed that determine whether ambient light levels are sufficient for distinct shadows (and therefore shadow flicker) to be generated to prevent unnecessary shutdowns.

Alternatively, a shadow flicker protection system can be incorporated into the SCADA system. This calculates the locations of shadows in real-time, determines whether these coincide with the pre-programmed locations and considers ambient lighting before triggering shutdowns. These systems provide greater flexibility than shutdown calendars as it allows for new receptor locations to be programmed, for example, if complaints are received from a property not already included in an existing mitigation scheme.

Shadow flicker can be controlled at source using one of the systems outlined above, in order to ensure that the operation of the Development does not directly result in shadow flicker levels exceeding 30 minutes per day at the six properties mentioned in Section 4.2.

Shadow flicker effects are typically controlled through the use of a planning condition. The following is an example of a typical shadow flicker planning condition:

'Prior to operation of the development hereby approved, a scheme detailing the protocol for the assessment of any complaints of shadow flicker resulting from the development on residential properties existing at the date of the grant of planning permission, including remedial measures, should be submitted to and approved in writing by the Planning Authority. Operation of the turbines shall take place in accordance with the approved protocol.'

4.5 Residual Effects

Shadow flicker is a phenomenon that only occurs once the turbines are installed and operational, therefore there will be no effects as a result of shadow flicker during the decommissioning and construction or the final decommissioning phase of the Development.

With appropriate mitigation applied, operational residual effects from shadow flicker would be negligible and **not significant** as per the EIA Regulations, either due to the Development in isolation, or cumulatively.

5. SUMMARY

An assessment of potential shadow flicker effects associated with the Development has been carried out in line with guidance and best practice used in the UK.

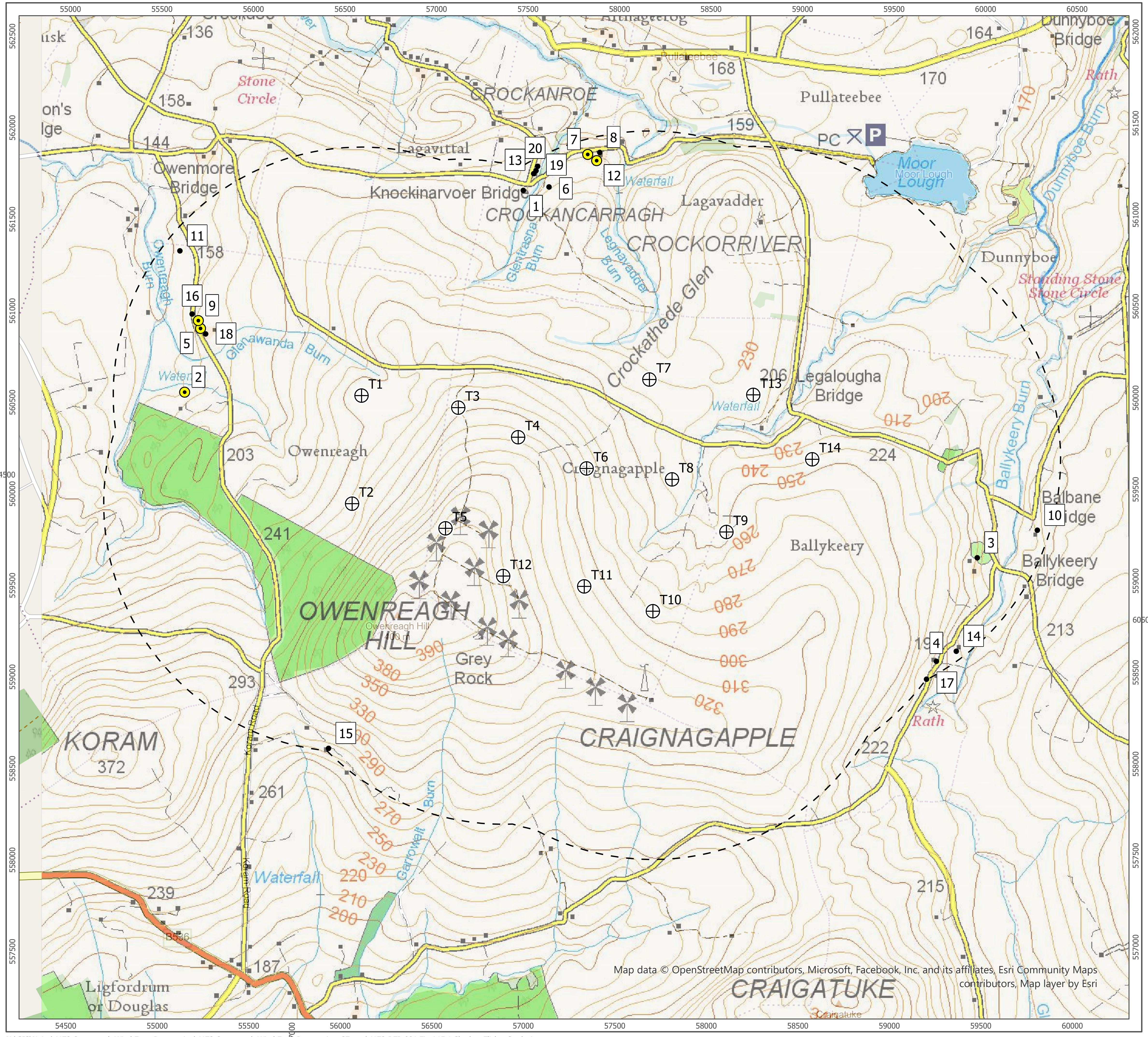
Predictions of shadow flicker have been calculated for receptors located within a Study Area based on the calculated area over which shadows from the turbines may be cast, limited to 1,360 m (ten times the rotor diameter) from each turbine. It has been found that there are 20 receptors within the shadow flicker study area with the potential to experience shadow flicker.

An assessment of effects from the Development alone has found that six receptors are calculated, as a theoretical maximum, to experience a maximum daily level of shadow flicker in excess of 30 minutes per day and no receptors are predicted to experience in excess of 30 hours of shadow flicker per year based on a likely worst-case scenario. If required, implementation of appropriate mitigation will ensure that shadow flicker levels remain below the recommended threshold at all neighbouring properties, such that shadow flicker effects due to the operation of the Development are **not significant** as per the EIA Regulations.

No cumulative development is within the study area, as such cumulative shadow flicker effects are **not significant** as per the EIA Regulations.

APPENDIX A FIGURES

06 September 2023



N:\GIS\Noise\4172 Owenreagh Wind Farm Repowering\4172 Owenreagh Wind Farm Repowering_SF.aprx\4172-REP-081 Fig A15.1 Shadow Flicker Study Area

Ørsted

ERM

⊕ Turbine Locations

Study Area 1,360m (10x rotor diameter)

• Potential Shadow Flicker Sensitive Receptors

Financially Involved Receptors

1:20,000 Scale @ A3

0 0.35 0.7 km

NORTH

Produced By: BA	Ref: 4172-REP-081
Checked By: KR	Date: 15/08/2023

Shadow Flicker Study Area
Figure No. A15.1.1

Owenreagh Wind Farm
Shadow Flicker Assessment

The Netherlands
New Zealand
Norway
Panama
Peru
Poland
Portugal
Puerto Rico
Romania
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Tanzania
Thailand
UK
US
Vietnam

ERM's Dublin Office

D5 Nutgrove Office Park

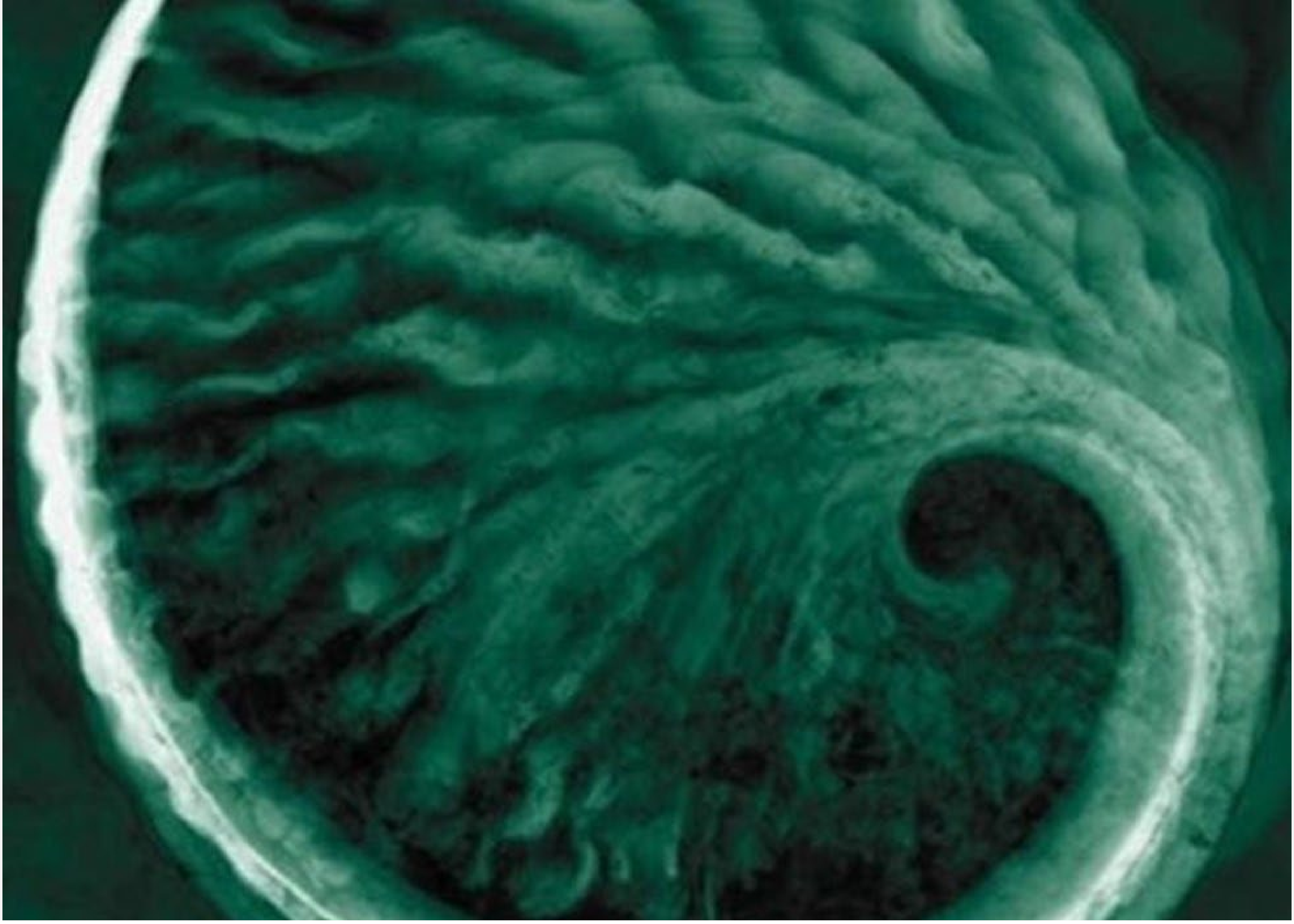
Dublin 14

D14 X343

Ireland

T: +353 (01) 653 2151

www.erm.com



Owenreagh/Craignagapple Wind Farm

Environmental Statement: Technical Appendix A15.2: Carbon Balance Assessment

6 September 2023

Project No.: 0696177

The business of sustainability

Contents

1. TECHNICAL APPENDIX A15.2 CARBON BALANCE ASSESSMENT

1.1 Development Introduction Payback Time and CO2 Emissions

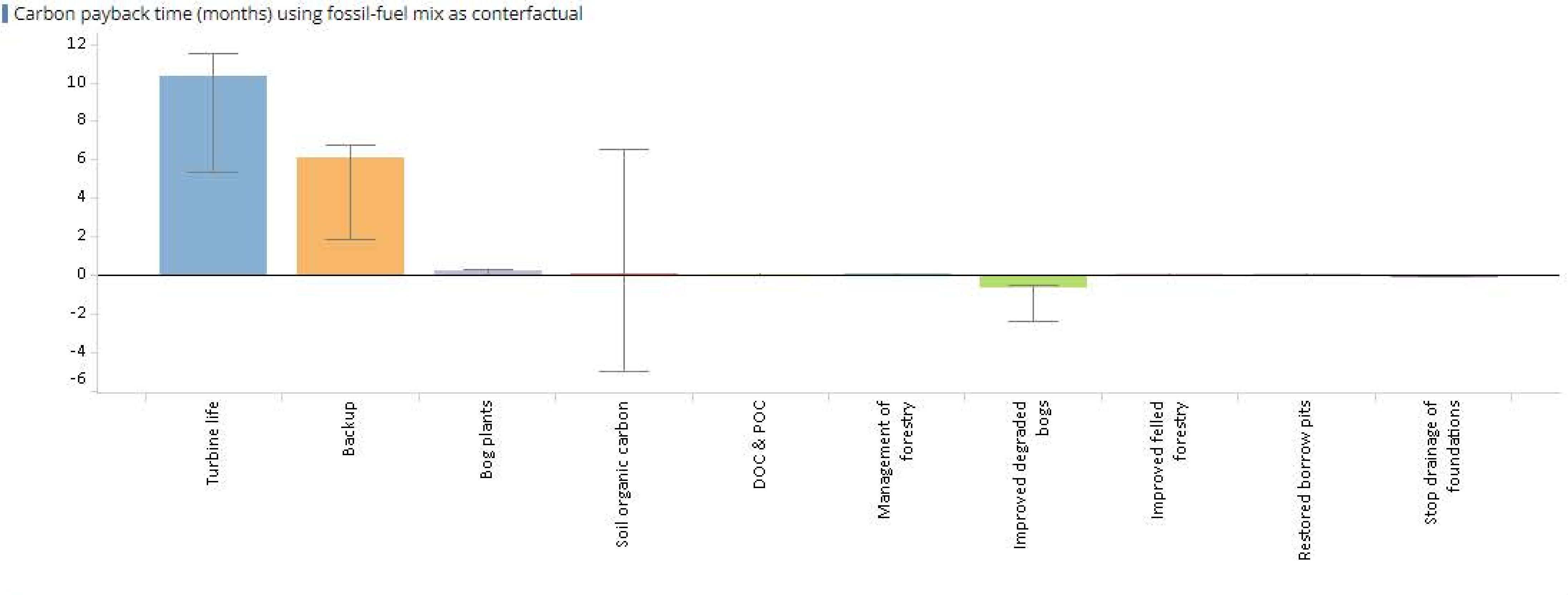
1. Windfarm CO_2 emission saving over…	Exp.	Min.	Max.
…Coal-fired electricity Generation (tCO_2 / yr)	156,546	98,357	190,774
...grid-mix of electricity generation (tCO_2 / yr)	30,212	18,982	36,818
...fossil fuel-mix of electricity generation (tCO_2 / yr)	67,493	42,406	82,250
Energy output from windfarm over lifetime (MWh)	6,249,342	3,435,637	7,615,734

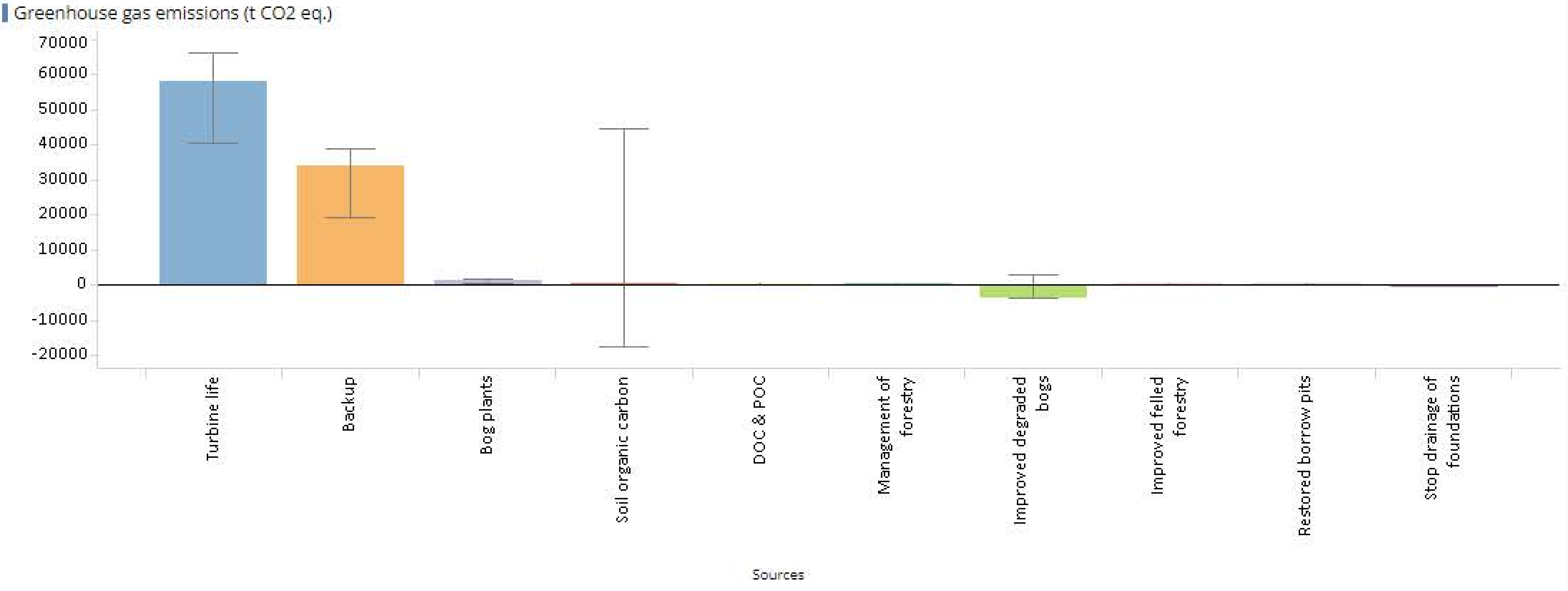
Total CO2 losses due to wind farm (tCO_2 eq.)	Exp.	Min.	Max.
2. Losses due to turbine life (e.g. manufacture, construction, decommissioning)	58,233	40,574	66,268
3. Losses due to backup	34,179	19,256	39,061
4. Losses due to reduced carbon fixing potential	1,296	567	1,850
5. Losses from soil organic matter	144	-17,518	44,592
6. Losses due to DOC & POC leaching	39	29	66
7. Losses due to felling forestry	0	0	0
Total losses of carbon dioxide	93,891	42,907	151,836

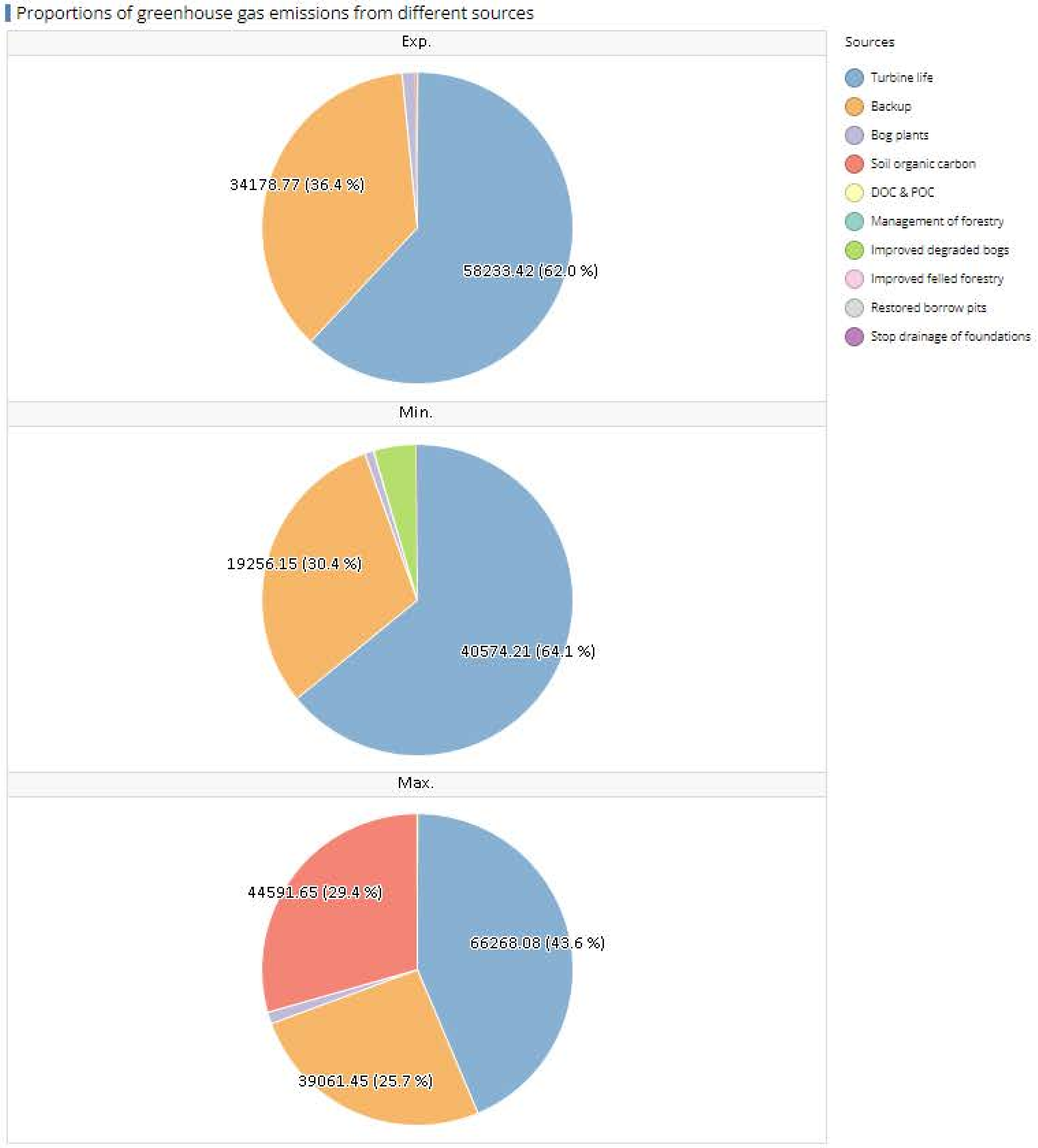
8. Total CO2 gains due to wind farm (tCO_2 eq.)	Exp.	Min.	Max.
8a. Change in emissions due to improvement of degraded bogs	-3,344	2,814	-3,697
8b. Change in emissions due to improvement of felled forestry	0	0	0
8c. Change in emissions due to restoration of peat from borrow pits	0	0	0
8d. Change in emissions due to removal of drainage from foundations & hardstanding	-113	57	-125
Total change in emissions due to improvements	93,891	42,907	151,836

Results	Exp.	Min.	Max.
Net emissions of carbon dioxide (tCO_2 eq.)	90,434	39,085	154,707
Carbon Payback Time			
...coal-fired electricity generation (years)	0.6	0.2	1.6
...grid-mix of electricity generation (years)	3.0	1.1	8.2
...fossil fuel-mix of electricity generation (years)	1.3	0.5	3.6
Ratio of soil carbon loss to gain by restoration (not used in Scottish applications)	0.05	-4.58	No gains!
Ratio of CO_2 eq. emissions to power generation (g/kWh) (for info. only)	14.47	5.13	45.03

2. PAYBACK TIME CHARTS


Carbon payback time (months) using fossil-fuel mix as conterfactual
12
10
8
6
4
2
0
-2
-4
-6
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations


Greenhouse gas emissions (t CO2 eq.)
70000
60000
50000
40000
30000
20000
10000
0
-10000
-20000
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations
Sources


Proportions of greenhouse gas emissions from different sources
Exp.
34178.77 (36.4 %)
58233.42 (62.0 %)
Min.
19256.15 (30.4 %)
40574.21 (64.1 %)
Max.
44591.65 (29.4 %)
66268.08 (43.6 %)
39061.45 (25.7 %)
Sources
Turbine life
Backup
Bog plants
Soil organic carbon
DOC & POC
Management of forestry
Improved degraded bogs
Improved felled forestry
Restored borrow pits
Stop drainage of foundations

3. BASELINE REVIEW

Carbon Calculator v1.7.0
Owenreagh Location: 54.81 -7.33
Orstead

Core input data

Input data	Expected value	Minimum value	Maximum value	Source of data
Windfarm characteristics				
Dimensions				
No. of turbines	14	14	16	LA11/2021/0788/PAD; Chapter 3, Section 3.4
Duration of consent (years)	40	35	40	Applicant; Chapter 3, Section 3.6
Performance				
Power rating of 1 turbine (MW)	4.8	3.45	4.8	Source: https://www.nordex-online.com/en/product/n133-4-8/; Chapter 1, Section 1.1
Capacity factor	26.54	23.2	28.3	Dukes (2022) UK Energy Statistics. Average Onshore Wind capacity
Backup				
Fraction of output to backup (%)	3.36	3.01	3.36	https://www.nordex-online.com/en/product/n133-4-8/; Chapter 1, Section 1.1
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10	10	10	Fixed
Total CO2 emission from turbine life ($tCO_2\ MW^{-1}$) (eg. manufacture, construction, decommissioning)	Calculate wrt installed capacity	Calculate wrt installed capacity	Calculate wrt installed capacity	
Characteristics of peatland before windfarm development				
Type of peatland	Acid bog	Acid bog	Acid bog	GSNI GeoIndex (bgs.ac.uk); Chapter 10, Active Peat Assessment
Average annual air temperature at site (°C)	9.1	9	9.2	Strabane climate: Temperature Strabane & Weather By Month - Climate-Data.org
Average depth of peat at site (m)	1.06	0	4.3	Site Survey, Chapter 9, section 9.4.2
C Content of dry peat (% by weight)	19	19	26	Site Survey; Chapter 9, Peat Management Plan. Note: value in PMP is 18%, this cannot be inputted into the carbon calculator so the closest value possible has been used.
Average extent of drainage around drainage features at site (m)	0.3	0.29	0.31	Technical estimation – sensitivity tests in varying the factor to be carried out
Average water table depth at site (m)	0.55	0	1	Dipwell monitoring survey results
Dry soil bulk density ($g\ cm^{-3}$)	0.2	0.19	0.21	National Soil Inventory of Scotland (Lilly et al., 2010)
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	30	30	30	Fernandez et al. (2013). Raised Bog Monitoring and Assessment Survey 2013
Carbon accumulation due to C fixation by bog plants in undrained peats ($tC\ ha^{-1}\ yr^{-1}$)	0.25	0.12	0.31	SNH Guidance - Carbon Payback Calculator: Guidelines on Measurements. Irish guidance suggests fixation could be at 0.7 tC /ha/year, but this value could not be inputted.
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	0	0	No forestry being felled in Proposed Development

Input data	Expected value	Minimum value	Maximum value	Source of data
Average rate of carbon sequestration in timber (tC ha^{-1} yr^{-1})	0	0	0	N/A - No forestry being felled in Proposed Development
Counterfactual emission factors				
Coal-fired plant emission factor (t CO2 MWh^{-1})	1.002	1.002	1.002	
Grid-mix emission factor (t CO2 MWh^{-1})	0.19338	0.19338	0.19338	
Fossil fuel-mix emission factor (t CO2 MWh^{-1})	0.432	0.432	0.432	
Borrow pits				
Number of borrow pits	0	0	0	N/A - No borrow pits in Proposed Development
Average length of pits (m)	0	0	0	N/A - No borrow pits in Proposed Development
Average width of pits (m)	0	0	0	N/A - No borrow pits in Proposed Development
Average depth of peat removed from pit (m)	0	0	0	N/A - No borrow pits in Proposed Development
Foundations and hard-standing area associated with each turbine				
Average length of turbine foundations (m)	20	20	20	EIA Chapter 3
Average width of turbine foundations (m)	20	20	20	EIA Chapter 3
Average depth of peat removed from turbine foundations(m)	1.06	0.51	1.62	EIA Chapter 9, Table 9.6
Average length of hard-standing (m)	173.5	173.5	173.5	EIA Chapter 3
Average width of hard-standing (m)	62.8	62.8	62.8	EIA Chapter 3
Average depth of peat removed from hard-standing (m)	1.05	0.5	1.67	Recorded Peat Data
Volume of concrete used in construction of the ENTIRE windfarm				
Volume of concrete (m^3)	6300	6300	6300	*includes foundations for turbines only
Access tracks				
Total length of access track (m)	6387.3	6386.28	6388.32	EIA Chapter 3
Existing track length (m)	235	235	235	EIA Chapter 3
Length of access track that is floating road (m)	390	389	391	EIA Chapter 3
Floating road width (m)	6	5	8	EIA Chapter 3
Floating road depth (m)	0.45	0.44	0.46	EIA Chapter 3
Length of floating road that is drained (m)	390	389	391	EIA Chapter 3
Average depth of drains associated with floating roads (m)	0.2	0.19	0.21	EIA Chapter 3
Length of access track that is excavated road (m)	2881.15	2881.14	2881.16	EIA Chapter 3
Excavated road width (m)	5.5	5.5	5.5	EIA Chapter 3
Average depth of peat excavated for road (m)	0.97	0	3	Recorded Peat Data from Surveys
Length of access track that is rock filled road (m)	2881.15	2881.14	2881.16	EIA Chapter 3
Rock filled road width (m)	6	5	8	EIA Chapter 3

Input data	Expected value	Minimum value	Maximum value	Source of data
Rock filled road depth (m)	0.45	0.44	0.46	EIA Chapter 3
Length of rock filled road that is drained (m)	2881.15	2881.14	2881.16	EIA Chapter 3
Average depth of drains associated with rock filled roads (m)	0.3	0.29	0.31	EIA Chapter 3
Cable trenches				
Length of any cable trench on peat that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	0	0	0	N/A
Average depth of peat cut for cable trenches (m)	0.97	0	3	Recorded Peat Survey Data
Additional peat excavated (not already accounted for above)				
Volume of additional peat excavated (m^3)	0	0	0	PMP
Area of additional peat excavated (m^2)	0	0	0	PMP
Peat Landslide Hazard				
Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	negligible	negligible	negligible	Fixed
Improvement of C sequestration at site by blocking drains, restoration of habitat etc				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	77.766	77.37	78.1	TA 3.2: draft HMEP
Water table depth in degraded bog before improvement (m)	0.22	0.21	0.23	Technical Estimation
Water table depth in degraded bog after improvement (m)	0.12	0.11	0.13	Note: below ground level in degraded wet modified bog in current conditions.
Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	30	30	30	Fernandez et al. (2013). Raised Bog Monitoring and Assessment Survey 2013.
Period of time when effectiveness of the improvement in degraded bog can be guaranteed (years)	40	35	40	Mackin et al. (2017). Best practice in raised bog restoration in Ireland. Unable to input referenced value (50) so used worst case allowed value
<u>Improvement of felled plantation land</u>				
Area of felled plantation to be improved (ha)	0	0	0	N/A - No forestry being felled in the Proposed Development
Water table depth in felled area before improvement (m)	0	0	0	N/A - No forestry being felled in the Proposed Development
Water table depth in felled area after improvement (m)	0	0	0	N/A - No forestry being felled in the Proposed Development
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	2	2	2	N/A - No forestry being felled in the Proposed Development. Lowest allowed value inputted.

Input data	Expected value	Minimum value	Maximum value	Source of data
Period of time when effectiveness of the improvement in felled plantation can be guaranteed (years)	2	2	2	N/A - No forestry being felled in the Proposed Development. Lowest allowed value inputted.
Restoration of peat removed from borrow pits				
Area of borrow pits to be restored (ha)	0	0	0	N/A - No borrow pits in the Proposed Development
Depth of water table in borrow pit before restoration with respect to the restored surface (m)	0	0	0	N/A - No borrow pits in the Proposed Development
Depth of water table in borrow pit after restoration with respect to the restored surface (m)	0	0	0	N/A - No borrow pits in the Proposed Development
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	1	1	1	N/A - No borrow pits in the Proposed Development
Period of time when effectiveness of the restoration of peat removed from borrow pits can be guaranteed (years)	2	2	2	N/A - No borrow pits in the Proposed Development. Lowest allowed value inputted.
Early removal of drainage from foundations and hardstanding				
Water table depth around foundations and hardstanding before restoration (m)	0.43	0.43	0.43	Technical Esitmation
Water table depth around foundations and hardstanding after restoration (m)	0.15	0.14	0.16	Technical Estimation. Note: below ground level in degraded wet modified bog in current conditions.
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	2.55	0.1	5	Technical Estimation
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	No	No	No	
Will you attempt to block any gullies that have formed due to the windfarm?	No	No	No	EIA Chapter 8
Will you attempt to block all artificial ditches and facilitate rewetting?	No	No	No	EIA Chapter 8
Will the habitat of the site be restored on decommissioning?	Yes	Yes	Yes	
Will you control grazing on degraded areas?	Yes	Yes	Yes	TA 3.2 draft HMEP

Input data	Expected value	Minimum value	Maximum value	Source of data
Will you manage areas to favour reintroduction of species	Yes	Yes	Yes	TA 3.2 draft HMEP
Methodology				
Choice of methodology for calculating emission factors	Site specific (required for planning applications)			

Forestry input data

N/A

Construction input data

N/A

4. WINDFARM CO2 EMISSION SAVING

Capacity Factor – Direct	Exp.	Min.	Max.
Capacity Factor (%)	26.5	23.2	28.3

Emissions due to turbine life	Exp.	Min.	Max.
Annual energy output from windfarm (MW/yr)			
RESULTS			
Emissions saving over coal-fired electricity generation (tCO_2/yr)	156,546	98,357	190,774
Emissions saving over grid-mix of electricity generation (tCO_2/yr)	30,212	18,982	36,818
Emissions saving over fossil fuel – mix of electricity generation (tCO_2/yr)	67,493	42,406	82,250
Energy output from windfarm over lifetime (MWh)			

5. CO_2 LOSS DUE TO TURBINE LIFE

Emissions due to turbine life	Exp.	Min.	Max.
Emissions due to turbine from energy output (tCO_2)	4017	2756	4017
Emissions due to cement used in construction (tCO_2)	1991	1991	1991
RESULTS			
Losses due to turbine life (manufacture, construction, etc.) (tCO_2)	58,233	40,574	66,268
Additional CO_2 payback time of windfarm due to turbine life			
...coal-fired electricity generation (months)	4	5	4
...grid-mix of electricity generation (months)	23	26	22
...fossil fuel - mix of electricity generation (months)	10	11	10

6. CO_2 LOSS DUE TO BACKUP

Emissions due to backup power generation	Exp.	Min.	Max.
Reserve energy (MWh/yr)	19,779	12,736	22,605
Annual emissions due to back up from fossil fuel-mix of electricity generation (tCO_2/yr)	854	550	977
RESULTS			
Total emissions due to back up from fossil fuel-mix of electricity generation (tCO_2)	34,179	19,256	39,061

7. LOSS OF CO_2 FIXING POTENTIAL

Emissions due to loss of bog plants	Exp.	Min.	Max.
Area where carbon accumulation by bog plants is lost (ha)	20.20	19.81	23.24
Total loss of carbon accumulation up to time of restoration (tCO_2 eq./ha)	64	29	80
RESULTS			
Total loss of carbon fixation by plants at the site (t CO_2)	1,296	567	1,850
Additional CO_2 payback fixation by plants at the site (tCO_2)			
… coal-fired electricity generation (months)	0	0	0
…grid-mix of electricity generation (months)	1	0	1
…fossil fuel – mix of electricity generation (months)	0	0	0

8. LOSS OF SOIL CO_2

5. Loss of Soil CO_2	Exp.	Min.	Max.
CO_2 loss from removed peat (tCO_2 equiv.)	143.96	-17,518.45	44,468.28
CO_2 loss from drained peat (tCO_2 equiv.)	0	0	123.37
RESULTS			
Total CO_2 loss from peat (removed + drained) (tCO_2 equiv.)	143.96	-17,518.45	44,591.65
RESULTS			
Additional CO_2 payback time of windfarm due to loss of soil CO_2			
...coal-fired electricity generation (months)	0.01	-2.14	2.8
...grid-mix of electricity generation (months)	0.06	-11.07	14.53
...fossil fuel - mix of electricity generation (months)	0.03	-4.96	6.51

5a. Volume of peat removed	Exp.	Min.	Max.
Peat removed from borrow pits			
Area of land lost in borrow pits (m^2)	0	0	0
Volume of peat removed from borrow pits (m^3)	0	0	0
Peat removed from turbine foundations			
Area of land lost in foundation (m^2)	5,600	5,600	6,400
Volume of peat removed from foundation area (m^3)	5,936	2,856	10,368
Peat removed from hard-standing			
Area of land lost in hard-standing (m^2)	152,541.2	152,541.2	174,332.8
Volume of peat removed from hard-standing area (m^3)	160,168.26	76,270.6	291,135.78
Peat removed from access tracks			
Area of land lost in floating roads (m^2)	2,340	1,945	3,128
Volume of peat removed from floating roads (m^3)	1,053	855.8	1,438.88
Area of land lost in excavated roads (m^2)	15,846.33	15,846.27	15,846.38
Volume of peat removed from excavated roads (m^3)	15,370.94	0	47,539.14
Area of land lost in rock-filled roads (m^2)	17,286.9	14,405.7	23,049.28
Volume of peat removed from rock-filled roads (m^3)	7,779.11	6,338.51	10,602.67
Total area of land lost in access tracks (m^2)	35,473.23	32,196.97	42,023.66
Total volume of peat removed due to access tracks (m^3)	24,203.04	7,194.31	59,580.69
RESULTS			
Total area of land lost due to windfarm construction (m^2)	193,614.43	190,338.17	222,756.46
Total volume of peat removed due to windfarm construction (m^3)	190,307.3	86,320.91	361,084.46

5b. CO_2 loss from removed peat	Exp.	Min.	Max.
CO_2 loss from removed peat (tCO_2)	26,516.39	11,426.11	72,289.77
CO_2 loss from undrained peat left in situ (tCO_2)	26,372.43	28,944.57	27,821.49
RESULTS			
CO_2 loss attributed to peat removal only (tCO_2)	143.96	-17,517.45	44,468.28

5c. Volume of peat drained	Exp.	Min.	Max.
Total area affected by drainage around borrow pits (m^2)	0	0	0
Total volume affected by drainage around borrow pits (m^3)	0	0	0
Peat affected by drainage around turbine foundation and hardstanding			
Total area affected by drainage of foundation and hardstanding area (m^2)	2,325.96	2,248.27	2,747.05
Total volume affected by drainage of foundation and hardstanding area (m^3)	1,232.76	573.31	2,293.78
Peat affected by drainage of access tracks			
Total area affected by drainage of access track (m^2)	6,031.38	5,512.74	6,943.06
Total volume affected by drainage of access track (m^3)	1,355.12	448.51	3,310.25
Peat affected by drainage of cable trenches			
Total area affected by drainage of cable trenches(m^2)	0	0	0
Total volume affected by drainage of cable trenches(m^3)	0	0	0
Drainage around additional peat excavated			
Total area affected by drainage (m^2)	0	0	0
Total volume affected by drainage (m^3)	0	0	0
RESULTS			
Total area affected by drainage due to windfarm (m^2)	8,357.34	7,761.01	9,690.1
Total volume affected by drainage due to windfarm (m^3)	2,587.88	1,021.82	5,604.04

5d. CO_2 loss from drained peat	Exp.	Min.	Max.
Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning			
Total GHG emissions from Drained Land (tCO_2 equiv.)	360.58	135.26	1,121.94
Total GHG emissions from Undrained Land (tCO_2 equiv.)	360.58	135.26	998.57
Calculations of C Loss from Drained Land if Site Is Restored after Decommissioning			
Losses if Land is Drained			
CH_4 emissions from drained land (tCO_2 equiv.)	-7.16	-7.59	-7.92
CO_2 emissions from drained land (tCO_2)	1,145.52	1,187.8	1,367.7
Total GHG emissions from Drained Land (tCO_2 equiv.)	360.58	135.26	1,121.94

5d. CO_2 loss from drained peat	Exp.	Min.	Max.
Losses if Land is Undrained			
CH_4 emissions from undrained land (tCO_2 equiv.)	-7.16	-7.59	498.89
CO_2 emissions from undrained land (tCO_2)	1,145.52	1,187.8	711.37
Total GHG emissions from Undrained Land (tCO_2 equiv.)	360.58	135.26	998.57
RESULTS			
Total GHG emissions due to drainage (tCO_2 equiv.)	0	0	123.37

5e. Emission rates from soils	Exp.	Min.	Max.
Calculations following IPCC default methodology			
Flooded period (days/year)	178	178	178
Annual rate of methane emission (tCH_4-C/ha year)	0.04	0.04	0.04
Annual rate of carbon dioxide emission (tCO_2/ha year)	35.2	35.2	35.2
Calculations following ECOSSE based methodology			
Total area affected by drainage due to wind farm construction (ha)	0.84	0.78	0.97
Average water table depth of drained land (m)	0.55	1	0.58
Selected emission characteristics following site specific methodology			
Rate of carbon dioxide emission in drained soil (tCO_2/ha year)	19.58	23.55	20.16
Rate of carbon dioxide emission in undrained soil (tCO_2/ha year)	19.58	23.55	0.32
Rate of methane emission in drained soil (tCH_4-C/ha year)	0	0	0
Rate of methane emission in undrained soil (tCH_4-C/ha year)	0	0	0.5
RESULTS			
Selected rate of carbon dioxide emission in drained soil (tCO_2/ha year)	19.58	23.55	20.16
Selected rate of carbon dioxide emission in undrained soil (tCO_2/ha year)	19.58	23.55	0.32
Selected rate of methane emission in drained soil (tCH_4-C/ha year)	0	0	0
Selected rate of methane emission in undrained soil (tCH_4-C/ha year)	0	0	0.5

9. CO_2 LOSS BY DOC AND POC LOSS

Emissions due to loss of DOC and POC	Exp.	Min.	Max.
Gross CO_2 loss from restored drained land (tCO_2)	0	0	0
Gross CH_4 loss from restored drained land (tCO_2 equiv.)	0	0	0
Gross CO_2 loss from improved land (tCO_2)	0	0	0
Gross CH_4 loss from improved land (tCO_2 equiv.)	1,279.32	2,922.59	1,465.85
Total gaseous loss of C (tC)	31.29	71.48	35.85
Total C loss as DOC (tC)	8.13	5	14.34
Total C loss as POC (tC)	2.5	2.86	3.58
RESULTS			
Total CO_2 loss due to DOC leaching (tCO_2)	29.83	18.35	52.58
Total CO_2 loss due to POC leaching (tCO_2)	9.18	10.48	13.14
Total CO_2 loss due to DOC & POC leaching (tCO_2)	39.01	28.83	65.72
Additional CO_2 payback time of windfarm due to DOC & POC			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

10. FORESTRY CO_2 LOSS

Emissions due to loss of DOC and POC	Exp.	Min.	Max.
Area of forestry plantation to be felled (ha)	0	0	0
Carbon sequestered (tC ha-1 yr-1)	0	0	0
Lifetime of windfarm (years)	40	35	40
Carbon sequestered over the lifetime of the windfarm (tC ha-1)	0	0	0
RESULTS			
Total carbon loss due to felling of forestry (tCO_2)	0	0	0
Additional CO_2 payback time of windfarm due to management of forestry			
...coal-fired electricity generation (months)	0	0	0
...grid-mix of electricity generation (months)	0	0	0
...fossil fuel - mix of electricity generation (months)	0	0	0

11. CO_2 GAIN – SITE IMPROVEMENT

Degraded Bog	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	77.766	77.37	78.1
Depth of peat above water table before improvement (m)	0.22	0	0.23
Depth of peat above water table after improvement (m)	0.12	0	0.11
2. Losses with improvement			
Improved period (years)	10	10	5
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.109	0.495	0.124
CH4 emissions from improved land (tCO_2 equiv.)	1,269.68	2,864.322	1,453.716
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	3.388	0.269	3.053
CO_2 emissions from improved land (tCO_2 equiv.)	1,349.67	53.284	1,221.466
Total GHG emissions from improved land (tCO_2 eqiv.)	2,619.349	2,917.606	2,675.182
3. Losses without improvement			
Improved period (years)	10	10	5
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.029	0.495	0.025
CH_4 emissions from improved land (tCO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	7.668	0.269	8.159
CO_2 emissions from unimproved land (tCO_2 equiv.)	5,963.206	104.003	6,372.167
Total GHG emissions from unimproved land (tCO_2 eqiv.)	5,963.206	104.003	6,372.167
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (tCO_2 equiv.)	3,343.856	-2,813.603	3,696.985

Felled Forestry	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.495	0.495	0.496
CH_4 emissions from improved land (tCO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	0.295	0.269	0.322
CO_2 emissions from improved land (tCO_2 equiv.)	0	0	0

Felled Forestry	Exp.	Min.	Max.
Total GHG emissions from improved land (tCO_2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	0	0	0
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.495	0.495	0.496
CH_4 emissions from improved land (tCO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	0.295	0.269	0.322
CO_2 emissions from unimproved land (tCO_2 equiv.)	0	0	0
Total GHG emissions from unimproved land (tCO_2 eqiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (tCO_2 equiv.)	0	0	0

Borrow Pits	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0	0	0
Depth of peat above water table before improvement (m)	0	0	0
Depth of peat above water table after improvement (m)	0	0	0
2. Losses with improvement			
Improved period (years)	1	1	1
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.495	0.495	0.496
CH_4 emissions from improved land (tCO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	0.295	0.269	0.322
CO2 emissions from improved land (tCO_2 equiv.)	0	0	0
Total GHG emissions from improved land (tCO_2 eqiv.)	0	0	0
3. Losses without improvement			
Improved period (years)	1	1	1
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.495	0.495	0.496
CH_4 emissions from improved land (tCO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	0.295	0.269	0.322
CO_2 emissions from unimproved land (tCO_2 equiv.)	0	0	0
Total GHG emissions from unimproved land (tCO_2 eqiv.)	0	0	0
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (tCO_2 equiv.)	0	0	0

Foundations and Hardstandings	Exp.	Min.	Max.
1. Description of site			
Area to be improved (ha)	0.233	0.225	0.275
Depth of peat above water table before improvement (m)	0.43	0	0.43
Depth of peat above water table after improvement (m)	0.15	0	0.14
2. Losses with improvement			
Improved period (years)	37.5	34.9	35
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	0.074	0.495	0.085
CH4 emissions from improved land (tCO_2 equiv.)	9.638	58.263	12.137
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	4.563	0.269	4.184
CO2 emissions from improved land (tCO_2 equiv.)	20.365	1.084	20.551
Total GHG emissions from improved land (tCO_2 eqiv.)	30.003	59.347	32.588
3. Losses without improvement			
Improved period (years)	37.5	34.9	35
Selected annual rate of methane emissions (tCH_4-C ha-1 yr-1)	-0.002	0.495	-0.002
CH_4 emissions from improved land (tCO_2 equiv.)	0	0	0
Selected annual rate of carbon dioxide emissions (tCO_2 ha-1 yr-1)	16.408	0.269	16.435
CO_2 emissions from unimproved land (tCO_2 equiv.)	142.925	2.116	157.561
Total GHG emissions from unimproved land (tCO_2 eqiv.)	142.925	2.116	157.561
RESULTS			
4. Reduction in GHG emissions due to improvement of site			
Reduction in GHG emissions due to improvement (tCO_2 equiv.)	112.922	-57.232	124.873

The Netherlands
New Zealand
Norway
Panama
Peru
Poland
Portugal
Puerto Rico
Romania
Singapore
South Africa
South Korea
Spain
Sweden
Switzerland
Taiwan
Tanzania
Thailand
UK
US
Vietnam

ERM's Dublin Office
D5 Nutgrove Office Park
Dublin 14
D14 X343
Ireland

T: +353 (01) 653 2151
www.erm.com