AARDVaRC Ltd

Aviation Analysis, Renewables Development & Visualisation, and Radio Communications

Proposed Scheme of Aviation and Maritime Marking and Lighting Scheme for the proposed *Neart na Gaoithe* Offshore Wind Farm

Prepared for Neart na Gaoithe Offshore Wind Limited
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1 Executive Summary

1.1 Background

The Neart na Gaoithe offshore wind farm, currently in planning, is proposed to have a maximum of 90 turbines in the indicative 'Layout C' (note that 'Layout C' gives 95 possible locations) of up to 197m maximum blade tip height allowing a maximum generation capacity of approximately 450MW. The wind farm will be required to have aviation and marine lights and markings and sound signals fitted.

AARDVARC Ltd has been retained to propose a scheme of lighting and marking in order to ensure safety requirements are fully satisfied and to minimise the onshore impact of such equipment as much as possible.

In parallel, AARDVaRC has been requested to provide information on the visibility of such systems onshore. In order to support this, AARDVaRC conducted 4 night-time visits to viewpoints in Suffolk and Essex of offshore wind farms in the North Sea, specifically, Greater Gabbard and Gunfleet Sands.

These works are described in this report.

1.2 Conclusions

Appendix 1 summarised the lighting and sound signal scheme to be applied at each turbine in the wind farm. Appendix 2 shows the same data on a wind farm layout chart (based on the indicative 'Layout C').

A total of 41 turbines locations are proposed to have medium intensity (2000 candela) red aviation lights fitted to the nacelle tops, 33 marking the periphery of the wind farm and 8 inside to give an indication of depth. These lights are to be approved red and infrared combination lights to ensure visibility with pilots' night vision goggles.

All locations are to be fitted with low intensity green lights. It is not proposed to fit low intensity red lights at any turbine location.

The specific turbines locations to be fitted with aviation lights, and light specifications, are given in Appendix 3.

A total of 13 turbines locations on the periphery of the wind farm are identified as Significant Peripheral Structures (SPS), and a further 4 as Intermediate Structures (IS), and are fitted with marine navigation lights and sound signals accordingly.

The specific turbines locations to be fitted with marine lights, and light specifications, are given in Appendix 4.

The specific turbines locations to be fitted with sound signals, and signal specifications, are given in Appendix 5.

Turbine markings for all turbines are described in Appendix 6 with a suggested turbine identifier marking scheme.

All lights and sound signals must be fully controllable from the wind farm control station, and the option of altering the lighting scheme in the future (e.g., introducing or altering flashing patterns) retained.

The onshore effects of marine lights and sound signals will be at most negligible. The onshore effects of aviation lights will be negligible and may be reduced further by dimming the lights in good visibility conditions.

2 Contents

3 Introduction

3.1 Neart na Gaoithe Wind Farm

Neart na Gaoithe Offshore Wind Limited (NNGOWL) has applied for planning permission for the Neart na Gaoithe offshore wind farm in the Firth of Forth with a potential generating capacity of approximately 450MW. The indicative 'Layout C' proposes 90 wind turbines (at 95 possible locations given in 'Layout C') of up to 197m maximum blade tip height.

AARDVaRC Ltd has been retained to prepare an offshore lighting strategy to determine navigation and aviation lighting, marking and audio signal requirements for the Neart na Gaoithe wind farm whilst minimising visibility from shore, and also to provide information on the likely visibility of lighting from varying distances and in varying atmospheric conditions. As part of this work, 4 night visits to viewpoints of North Sea wind farms off the Suffolk coast were conducted to assess the visibility of wind farm lighting – specifically Gunfleet Sands and Greater Gabbard – which are visible at similar distances to the Neart na Gaoithe wind farm from the Scottish coastline.

Considerations in the development of the scheme included (but were not limited to) the following:

- Number of each type of lights;
- Locations;
- Colour;
- Direction of focus;
- Beam width;
- Candela rating requirements;
- Beam description e.g. flashing, constant, flashing in phase;
- Visibility at various distances;
- Thresholds applied to determine visibility;
- Potential for reducing brightness under clear atmospheric conditions.

This report considers marking and lighting for the operational phase of the wind farm. The Northern Lighthouse Board has already stated a requirement for buoys to mark the site during the construction phase, adding that it will specify the location of those buoys when the final design is published. Similarly, a temporary aviation lighting plan should be developed in tandem with a construction plan and agreed with the Civil Aviation Authority (CAA): it is not possible to propose a scheme of aviation lighting for the construction phase at this point. Similarly, further consultation will be required prior to the decommissioning phase.

3.2 *AARDVaRC* Ltd

AARDVaRC Ltd was founded in April 2010 to provide expert aviation, defence and other technical consultancy services to the renewable energy and other industries. These services are particularly focussed on renewable technologies, however, this expertise is equally applied to other industries, e.g., AARDVaRC provided its expert

aviation and defence services for the recently consented Cherry Orchard tower development in south London.

AARDVaRC's expertise lends itself to a wide range of technical issues relating to renewable energy development. For example, the company has developed an analytical model to assess sun glint (reflections) from large-scale solar farm developments, particularly for aviation impact assessment.

3.3 The Author

Charles Morelli holds a BEng degree in Aeronautical Engineering from Bath University. He was commissioned into the Royal Regiment of Artillery, serving as a Forward Observation Officer managing battlefield indirect fire and electronic warfare assets for the local commander before taking helicopter flying duties in the Army Air Corps. Here he served as second-in-command of an anti-tank helicopter squadron, and was the Army Aviation subject matter expert and project manager compiling flying regulations for the newly formed Joint Helicopter Command (JHC). Since leaving the Army in 2004, he has focussed on technical and specialist aviation analysis for renewable energy developments working in 2 consultancy companies until founding AARDVaRC in 2010.

The author has an in-depth knowledge of the aviation industry, electromagnetic propagation – including reflections of light (i.e., glint and glare), wave theory, and of communications, navigation and surveillance (CNS) equipment. He has conducted detailed assessments of aviation and electromagnetic issues, and mitigation studies for many renewable energy and other developments including for Clyde, Fallago Rigg, Middlemoor, Stoke Heights and many other wind farms.

Charles is also a glider pilot and holds a Private Pilot's Licence (PPL) for light single-engined aeroplanes. Other interests and hobbies include amateur astronomy, renewable energy technologies and cycling.

4 Proposed Neart na Gaoithe Wind Farm

4.1 Overview

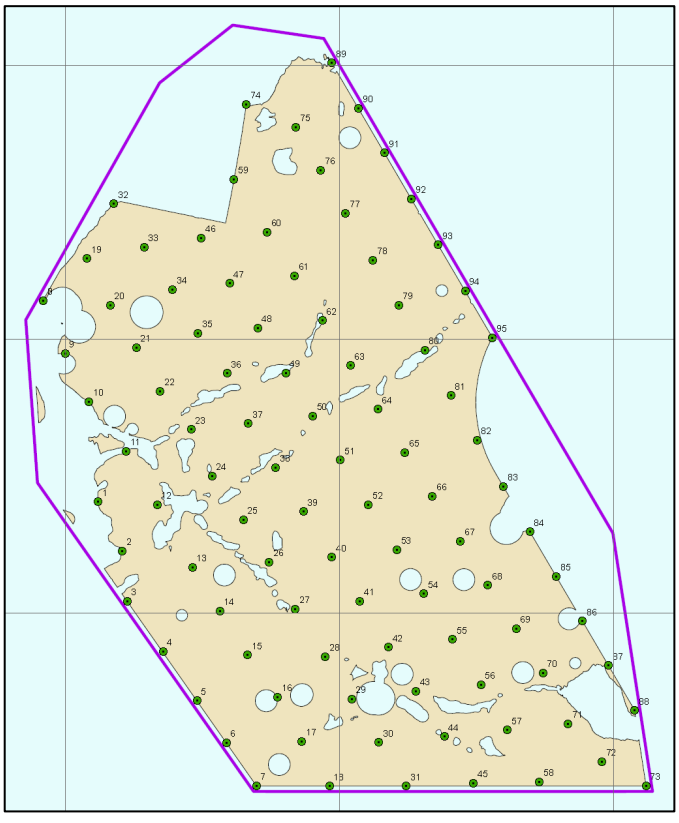
The closest point of the proposed Neart na Gaoithe wind farm is approximately 15.5km east of Fife Ness (the nearest landfall). The site boundary point coordinates are shown in the table at Paragraph 4.2 below, and the 95 possible locations (for up to 90 turbines) in 'Layout C' are shown on the chart at Paragraph 4.3 below. The turbines are of up to 197m maximum blade tip height to give a maximum generation capacity of approximately 450MW.

4.2 Wind Farm Site

The site boundary coordinates are shown in the following table (WGS84 latitude-longitude data).

Boundary Point	West	North
1	2.164969° W	56.254514° N
2	2.154251° W	56.212024° N
3	2.233308° W	56.212526° N
4	2.271549° W	56.212768° N
5	2.327131° W	56.257986° N
6	2.334248° W	56.263775° N
7	2.337206° W	56.290508° N
8	2.297092° W	56.329192° N
9	2.275308° W	56.338526° N
10	2.248497° W	56.336184° N

4.3 Layout Chart



The chart to the left shows the 95 possible locations for 90 turbines in the indicative 'Layout C'.

Chart reproduced from Turbine Layout chart, dated 19 March 2013, with permission from Mainstream Renewable Power. Copyright © Mainstream Renewable Power Limited, 2012.

4.4 Location Chart

The following chart shows the turbine positions overlaid as numbered, red dots on a 1:500,000 scale OS background map, orientated with British National Grid North at the top. The viewpoints considered in the Environmental Statement are also marked as green diamond shapes.

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5 Guidance for Offshore Wind Turbine Marking and Lighting

5.1 Introduction

Aviation and maritime navigation stakeholders have replied to planning consultations giving advice regarding the marking, lighting and audio warning equipment that should be fitted to the wind turbines. This advice is summarised in this section, and the source documents behind the advice.

AARDVaRC Ltd has considered the advice and guidance and here to propose a scheme for the marking, lighting and sound signal equipment it recommends to be fitted to some or all turbines within the wind farm.

5.2 Advice from Consultees

5.2.1 Aviation Stakeholders

5.2.1.1 Civil Aviation Authority

The CAA has advised that significant turbines on the periphery should have steady red 2000 candela (cd) lights fitted. In the future, a request may be made to change to flashing lights signalling Morse code 'W' (▪ ▬ ▬) to avoid confusion with marine lights which would be likely to gain CAA approval. If the 2000cd lights are set to flash, they should be synchronised across the whole wind farm to flash on a 5 second cycle.

All other structures more than 60m tall should be fitted with 2000 candela red lights.

5.2.1.2 Ministry of Defence

The MoD has stated that all turbines should be fitted with either '200 cd red or 2000 cd IR [infrared] combination lights (omni-directional)' at the highest practicable point. AARDVaRC has sought clarification of this statement, but this had not been received at the time of writing. However, it is understood that modern red lights do not emit sufficient energy in the IR spectrum (necessary for pilots' night vision goggles to work), so the lights chosen must have adequate emissions at both red and IR frequencies.

It is noted that the MoD is still awaiting its physical safeguarding assessment for offshore defence interests. It is considered unlikely that the results of the assessment will affect the scheme as proposed, but this will be confirmed later.

5.2.2 Maritime Stakeholders

5.2.2.1 Marine and Coastguard Agency

The MCA made no specific requests for lighting or marking of the turbines but referred to Marine Guidance Notice (MGN) 371.

5.2.2.2 Northern Lighthouse Board

The Northern Lighthouse Board (NLB) gave the following advice for each of the phases of construction, operation and decommissioning.

Construction Phase:

7 standard Cardinal Buoys are required: 1 North buoy, 2 West, 2 South and 2 East buoys (one of the Eastern ones to be fitted with X/S band radar beacon (RACON)).

Buoys are to have a minimum diameter of 3m at their waterline, and focal plane (of the flashing white light – in accordance with the system for Cardinal markers with 5 nautical mile range) at least 3 metres above the waterline.

NLB will advise of locations when it receives confirmation of the final wind farm design.

Buoys are to be in place until the construction phase is complete.

Operational Phase:

The tower of every wind generator should be painted yellow all round from the level of Highest Astronomical Tide (HAT) to 15 metres or the height of the Aid to Navigation, if fitted, whichever is greater.

The structures designated as Significant Peripheral Structures (SPS) shall have lights visible from all directions in the horizontal plane. These lights should be synchronised to display a character of one yellow flash every 5 seconds, with a range of not less than 5 nautical miles.

Selected Intermediate Structures (IS) on the periphery of the wind farm should be marked with lights visible from all directions in the horizontal plane. These lights should be synchronised to display a character of one yellow flash every 2.5 seconds, with a range of not less than 2 nautical miles.

All lights shall be placed not less than 6 metres and not more than 30 metres above Mean High Water Springs (MHWS).

A sound signal shall be attached to each SPS and IS as to be audible upon approaching the wind farm from any direction. The sound signal should be placed not less than 6 metres and not more than 30 metres above MHWS and should have a range of at least 2 nautical miles. The character shall be rhythmic blasts corresponding to Morse letter 'U' (▪ ▪ ▬) every 30 seconds. The minimum duration of the short blast shall be 0.75 seconds. The sound signal shall be operated when the meteorological visibility is two nautical miles or less. All sound signals should be synchronised.

Each tower shall display identification panels with black letters or numbers one metre high on a yellow background visible in all directions. These panels shall be easily visible in daylight as well as at night, by the use of illumination or retro-reflecting material.

All navigation lights should have an availability of not less than 99.8% (IALA Category 1) over a rolling three year period. Sound signals should have an availability of not less than 97% (IALA Category 3) over a rolling three year period.

Appropriate means of ensuring the required IALA Availability target for Category 1 AtoN is achieved through redundancy, monitoring and repair must be in place, and arrangements made to warn the Mariner promptly of any AtoN fault and its subsequent return to fully operational service.

Any existing Meteorological Masts within the site area will have marking and lighting amended to suit the final layout of the wind farm.

The marking and lighting of the wind farm may require to be altered or amended to reflect development of the adjacent Round 3 site in order to form a continuation of suitable marking of the area occupied by turbines and sub-stations. Neart na Gaoithe operator must co-operate fully in this matter.

We also require that once agreed, the final number, layout and positions of each of the wind turbine generators, along with that of any sub-sea infrastructure is communicated to the UKHO in order that all the relevant nautical charts are correctly updated.

Decommissioning Phase: Further consultation will be required.

5.3 Published Guidance

5.3.1 Aviation

5.3.1.1 International Civil Aviation Organisation

Annex 14 to the Chicago Convention, Chapter 6 describes standard 'Type C' medium intensity obstacle lights. However, the requirements of UK law for offshore wind turbines are contained in the Air Navigation Order (ANO) 2009 (reproduced in CAP 393) and do not conform exactly to the ICAO standard lighting.

5.3.1.2 Civil Aviation Authority

Various CAA documents are pertinent as follows.

ANO 2009 (reproduced in CAP 393). The ANO is a legislative document Article 220 is pertinent. This gives the detailed requirement for the aviation lights to be fitted.

The Lighting and Marking of Wind Turbine Generators and Meteorological Masts in United Kingdom Territorial Waters, dated 22 November 2012.

This summarises CAA policy and adds to the ANO information, discussing the option of lights flashing Morse 'W' to distinguish them from other maritime navigation lights, and helicopter operations.

It states the requirement for low intensity green lights in accordance with CAP 437 for helicopter support operations (specifically, hoisting).

It also states that otherwise, there is no requirement for additional lighting (e.g., low intensity red lighting on every turbine) in addition to that required by Article 220 of the ANO.

It refers to various other documents for further information.

CAP 437 *Standards for Offshore Helicopter Landing Areas*, dated February 2013. This gives detailed guidance on the design of nacelle platforms for helicopter support operations in Chapter 10, Section 2.

CAP 764 *CAA Policy and Guidelines on Wind Turbines*, dated January 2012. This refers to Article 220 of the Air Navigation Order and CAP 437.

5.3.2 Marine

5.3.2.1 International Association of Marine Aids to Navigation and Lighthouse Authorities

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) recommendation document O-139 *On The Marking of Man-Made Offshore Structures*, Edition 1 dated December 2008, Section 2.3 *Marking of Offshore Windfarms* is the source of the Northern Lighthouse Board's advice.

6 Proposed Lighting and Marking Scheme

6.1 Overview

Based on the consultation responses given and the published guidance, the wind turbine schedule at Appendix 1 shows the lights and markings proposed to be displayed on, and the sound signals to be broadcast by each wind turbine location in the indicative 'Layout C'. The marking, lighting and sound signal scheme is shown graphically on the chart of turbine locations at Appendix 2.

It should be noted that low intensity red aviation lights are not proposed to be fitted to any turbines since the proposed scheme for medium intensity light s is considered sufficient and because mixing lights of different intensities may be confusing to pilots (e.g., low intensity lights would seem to be further away than medium intensity ones, with potential flight safety implications).

Appendix 3 specifically lists the turbines to display aviation lights and the specifications for the lights. Note that no detailed specification of the angle for low intensity green is given: however, as these need to be seen by helicopters within the wind farm, they need to be visible through all vertical angles and through 360° horizontally.

Appendix 4 specifically lists the turbines selected as significant peripheral structures (SPS) and Intermediate Structures (IS), and hence those required to display maritime navigation lights. Note that SPS should be no more than 3km apart, IS should be no more than 2km apart (this is achieved in the proposed scheme).

Appendix 5 specifically lists the turbines selected as SPS and IS, and hence those required to have sound signals. It also gives the specification for the sound signals.

Appendix 6 describes the markings to be applied to each turbine, and suggests a turbine identifier scheme to be applied to each turbine. It is noted that other than the identifier for each wind turbine, the markings are the same on each turbine. It is also noted that all the wind turbines specified to have maritime navigation lights fitted – and only those – are also specified for audio warning broadcasts.

All lights and sound signals must be controllable from the wind farm control station to allow direct control as required by, say, search and rescue aircraft or vessels, and the option of altering the lighting scheme in the future retained (either to allow for future wind farm development, or to enable – for example – aviation lights to flash Morse 'W' if required for marine navigation purposes).

7 Effects of Wind Turbine Lights and Sound Signals on the Onshore Night-Time Visual Amenity

7.1 Background

AARDVaRC conducted 4 night-time visits to onshore viewpoints of existing offshore wind farms in order to inform the assessment of the effects on the visual amenity. The observations of those visits are given at Appendix 7, with some simple supporting analysis and discussion given here.

Notably, the main lights to consider are the medium intensity (2000 candela) red nacelle-top aviation lights, as these are much brighter than the marine navigation lights mounted much lower (noting that these are only required to be visible to a distance of 5 nautical miles (9.3km), and the nearest onshore point to Neart na Gaoithe is approximately 16km away.

7.2 Comparison with Car Rear Lights

In a letter to the British Wind Energy Association (now RenewableUK) entitled *Lighting of wind turbines*, dated 8 October 2008 (Defence Estate reference: D/DE/JWOC), Julian Chaffer of Defence Estates explains that a 25 candela red light – as often requested by the MoD to be fitted to onshore wind turbines – is equivalent in luminosity to a car brake light. Elsewhere, other military personnel have corrected this statement, saying that it is actually equivalent to a 1960s car rear light (less bright than modern cars), not a brake light; the author is unable to provide a reference for this correction however, so the brake light analogy is used here, but is noted to be 'worst case'.

A 2000 candela light is 80 times as luminous as the 25 candela light in the example. In the absence of atmospheric attenuation (again, 'worst case'), the intensity of lights diminishes proportionally to the distance squared.

The square root of 80 is 8.9 (approximated to 9 for this example).

Therefore, the observed brightness of a 2000 candela light at 16km (the minimum distance for onshore viewing of Neart na Gaoithe) is equivalent to a car brake light viewed at 16 ÷ 8.9 = 1.8km. This is just over 1 statute mile (1 mile = 1.6km).

So, at full brightness, 2000 candela medium intensity lights at Neart na Gaoithe viewed from onshore will be no brighter than a car brake light more than a mile away (it is uncommon to see car lights at such a distance). This does not account for reduced brightness of turbine lights below the horizontal, or for the allowable possibility of dimming the lights in good visibility, nor for attenuation in less than perfect visibility.

This analysis is consistent with the author's experiences during his viewings of wind farm lights.

7.3 Other considerations

During his viewings of wind turbine lights, the author noted that brighter lights (typically – but not necessarily – closer than the wind turbine lights) within the field of view are more eye-catching than the wind turbine lights. Sources of such lights may be marine buoys close to shore, urban lights and associated glare and reflections (even well beyond a wind farm), the moon, or early evening/ morning brightness in the sky.

Bright lights from behind an observer may also reduce the significance of the wind turbine lights, as will flashing lights, or periodic lights (such as lighthouses) which would naturally be more prominent.

Finally, even with lights marine that exceed the minimum standards of brightness required, they will be barely noticeable from shore, and the aviation lights will always be more prominent. Similarly, even using sound signals that exceed the minimum audibility requirements (2 nautical miles or 3.7km), they will not be audible onshore.

8 Conclusions

Appendix 1 summarised the lighting and sound signal scheme to be applied at each turbine in the wind farm. Appendix 2 shows the same data on a wind farm layout chart (based on the indicative 'Layout C').

A total of 41 turbines locations are proposed to have medium intensity (2000 candela) red aviation lights fitted to the nacelle tops, 33 marking the periphery of the wind farm and 8 inside to give an indication of depth. These lights are to be approved red and infrared combination lights to ensure visibility with pilots' night vision goggles.

All locations are to be fitted with low intensity green lights. It is not proposed to fit low intensity red lights at any turbine location.

The specific turbines locations to be fitted with aviation lights, and light specifications, are given in Appendix 3.

A total of 13 turbines locations on the periphery of the wind farm are identified as Significant Peripheral Structures (SPS), and a further 4 as Intermediate Structures (IS), and are fitted with marine navigation lights and sound signals accordingly.

The specific turbines locations to be fitted with marine lights, and light specifications, are given in Appendix 4.

The specific turbines locations to be fitted with sound signals, and signal specifications, are given in Appendix 5.

Turbine markings for all turbines are described in Appendix 6 with a suggested turbine identifier marking scheme.

All lights and sound signals must be fully controllable from the wind farm control station, and the option of altering the lighting scheme in the future (e.g., introducing or altering flashing patterns) retained.

The onshore effects of marine lights and sound signals will be at most negligible. The onshore effects of aviation lights will be negligible and may be reduced further by dimming the lights in good visibility conditions.

Appendix 1 – Schedule of Wind Turbine Markings, Lights and Sound Signals

Met masts should be fitted with medium intensity lights at their highest point due to their relative inconspicuity, and for similar reasons should be fitted with IS marine lights.

Turbine ID	Suggested Identifier	Peripheral Turbine	Nacelle Aviation Lights		Maritime Navigation Aids		
			2000cd Red/IR	Green	SPS Light	IS Light	Audio Signal
1	A09	Yes	Yes	Yes	Yes		Yes
2	A10	Yes	Yes	Yes			
3	A11	Yes	Yes	Yes		Yes	Yes
4	A13	Yes	Yes	Yes	Yes		Yes
5	A14	Yes	Yes	Yes			
6	A15	Yes	Yes	Yes			
7	A16	Yes	Yes	Yes	Yes		Yes
8	B05	Yes	Yes	Yes	Yes		Yes
9	B06	Yes	Yes	Yes			
10	B07	Yes	Yes	Yes		Yes	Yes
11	B08			Yes			
12	B09			Yes			
13	B11			Yes			
14	B12			Yes			
15	B13			Yes			
16	B14			Yes			
17	B15			Yes			
18	B16	Yes	Yes	Yes			
19	C04	Yes	Yes	Yes			
20	C05			Yes			
21	C06			Yes			
22	C07			Yes			
23	C08			Yes			
24	C09			Yes			
25	C10			Yes			
26	C11			Yes			
27	C12		Yes	Yes			
28	C13			Yes			
29	C14		Yes	Yes			
30	C15			Yes			
31	C16	Yes	Yes	Yes		Yes	Yes
32	D03	Yes	Yes	Yes	Yes		Yes
33	D04			Yes			
34	D05			Yes			
35	D06		Yes	Yes			
36	D07			Yes			
37	D08			Yes			
38	D09		Yes	Yes			
39	D10			Yes			
40	D11			Yes			
41	D12			Yes			

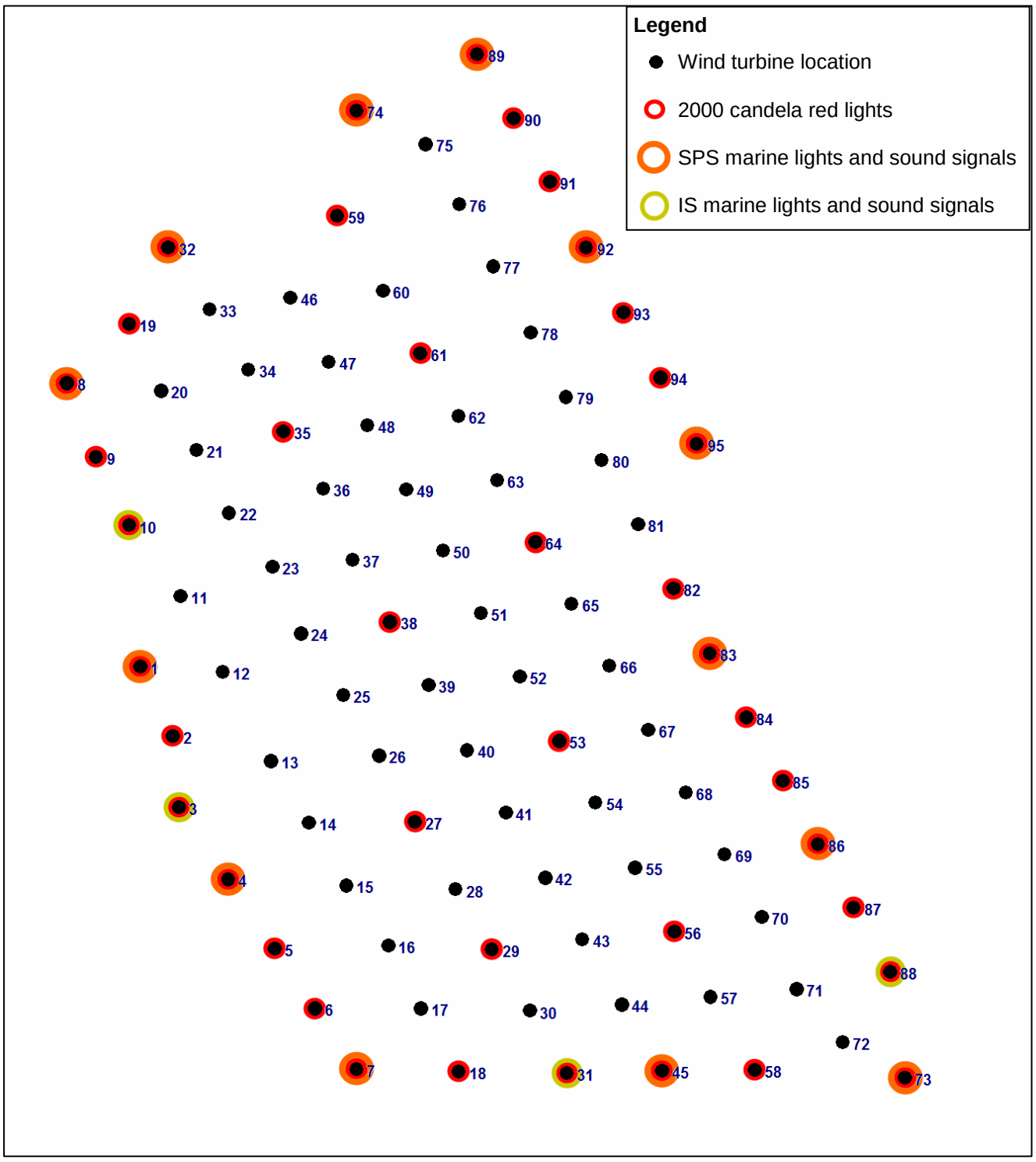
Turbine ID	Suggested Identifier	Peripheral Turbine	Nacelle Aviation Lights		Maritime Navigation Aids		
			2000cd Red/IR	Green	SPS Light	IS Light	Audio Signal
42	D13			Yes			
43	D14			Yes			
44	D15			Yes			
45	D16	Yes	Yes	Yes	Yes		Yes
46	E04			Yes			
47	E05			Yes			
48	E06			Yes			
49	E07			Yes			
50	E08			Yes			
51	E09			Yes			
52	E10			Yes			
53	E11		Yes	Yes			
54	E12			Yes			
55	E13			Yes			
56	E14		Yes	Yes			
57	E15			Yes			
58	E16	Yes	Yes	Yes			
59	F03	Yes	Yes	Yes			
60	F04			Yes			
61	F05		Yes	Yes			
62	F06			Yes			
63	F07			Yes			
64	F08		Yes	Yes			
65	F09			Yes			
66	F10			Yes			
67	F11			Yes			
68	F12			Yes			
69	F13			Yes			
70	F14			Yes			
71	F15			Yes			
72	F16			Yes			
73	F17	Yes	Yes	Yes	Yes		Yes
74	G01	Yes	Yes	Yes	Yes		Yes
75	G02			Yes			
76	G03			Yes			
77	G04			Yes			
78	G05			Yes			
79	G06			Yes			
80	G07			Yes			
81	G08			Yes			
82	G09	Yes	Yes	Yes			
83	G10	Yes	Yes	Yes	Yes		Yes
84	G11	Yes	Yes	Yes			
85	G12	Yes	Yes	Yes			
86	G13	Yes	Yes	Yes	Yes		Yes
87	G14	Yes	Yes	Yes			
88	G15	Yes	Yes	Yes		Yes	Yes
89	H01	Yes	Yes	Yes	Yes		Yes
90	H02	Yes	Yes	Yes			

Turbine ID	Suggested Identifier	Peripheral Turbine	Nacelle Aviation Lights		Maritime Navigation Aids		
			2000cd Red/IR	Green	SPS Light	IS Light	Audio Signal
91	H03	Yes	Yes	Yes			
92	H04	Yes	Yes	Yes	Yes		Yes
93	H05	Yes	Yes	Yes			
94	H06	Yes	Yes	Yes			
95	H07	Yes	Yes	Yes	Yes		Yes
Met-Masts			Yes			Yes	
Sub-Stations							

Substations and other structures less than 60m tall do not need to be fitted with lights of any sort provided that they are situated within the peripheral wind turbines.

Appendix 2 – Wind Turbine Lights Chart

The following chart identifies turbines to be fitted with various lights, markings and sound signals as specified in Appendix 1.



Note that all locations to be fitted with SPS and IS marine lights and sound signals are also to be fitted with aviation lights, whereas not all locations to be fitted with aviation lights are necessarily fitted with marine lights.

Appendix 3 – Schedule of Nacelle Aviation Lights

The following table lists turbines to be fitted with various aviation lights on their nacelle tops.

<table>
<tr><th>Turbine ID</th><th>Lights to be fitted</th></tr>
<tr><td>1 - 10
18
19
27
29
31
32
35
38
45
53
56
58
59
61
64
73
74
82 - 95</td><td>Approved 2000 Candela Combined Red/ Infrared Lights (Medium Intensity)
A single light visible through 360° horizontally, or 2 lights to be fitted on either side of the nacelle top as far from the rotor disc as practicable to minimise obscuration from the turbine blades, is to be provided.
Note that approved lights should emit sufficient infrared (IR) radiation (in addition to 2000 cd red light) to be observed through military night vision goggles (NVG).
Notes:
• The angle of the plane of the beam of peak intensity emitted by the light must be elevated to between three and four degrees above the horizontal plane.
• Not more than 45% or less than 20% of the minimum peak intensity specified for a light of this type is to be visible at the horizontal plane.
• Not more than 10% of the minimum peak intensity specified for a light of this type is to be visible at a depression of 1.5 degrees or more below the horizontal plane.
Low Intensity Green Lights
A single low intensity (16 cd top 60 cd) green light is to be fitted and only switched on to indicate that the turbine rotor is locked in a safe position for helicopter winching and/ or search and rescue operations to the turbine.
Older guidance recommends a flashing green light is used to indicate a turbine is in the process of shutting down to a safe state for helicopter operations, and a steady green light indicates that the rotor is safely locked. Although this may not be current guidance, the green lights should be capable of both flashing and continuous display.</td></tr>
<tr><td>Remainder (i.e.: 11 to 17, 20 to 26, 28, 30, 33, 34, 36, 37, 39 to 44, 46 to 52, 54, 55, 57, 60, 62, 63, 65 to 72, 75 to 81)</td><td>Low Intensity Green Lights
A single low intensity green light is to be fitted and only switched on to indicate that the turbine rotor is locked in a safe position for helicopter winching and/ or search and rescue operations to the turbine.
Older guidance recommends a flashing green light is used to indicate a turbine is in the process of shutting down to a safe state for helicopter operations, and a steady green light indicates that the rotor is safely locked. Although this may not be current guidance, the green lights should be capable of both flashing and continuous display.</td></tr>
</table>

All aviation lights must be omnidirectional in the horizontal plane.

Appendix 4 – Schedule of Marine Navigation Lights

The following table lists turbines to be fitted with marine navigation lights.

Turbine ID	Lights to be fitted
1	**Significant Peripheral Structures (SPS)** These turbines designated as SPS shall have lights visible from all directions in the horizontal plane (i.e., at least 2 lights are needed, one on either side of the turbine tower). These lights should be synchronised to display a character of one yellow flash every 5 seconds, with a range of not less than 5 nautical miles.
4	
7	
8	
32	
45	
73	
74	
83	
86	
89	
92	
95	
3	**Selected Intermediate Structures (IS)** These turbines designated as IS should be marked with lights visible from all directions in the horizontal plane. These lights should be synchronised to display a character of one yellow flash every 2.5 seconds, with a range of not less than 2 nautical miles.
10	
31	
88	
Remainder (i.e., 2, 5, 6, 9, 11 to 26 to 29, 30, 33 to 44, 46 to 72, 75 to 82, 84, 85, 87, 90, 91, 93 and 94)	**No marine navigation lights required**

Note that these lights shall be placed not less than 6 metres and not more than 30 metres above Mean High Water Springs (MHWS). It is recommended that lights be placed below the rotor disc to avoid possible blade collision and obscuration of lights.

In the absence of other guidance, it is suggested that flashes should be of 1 second duration.

Appendix 5 – Schedule of Sound Signals

The following table lists turbines to be fitted with sound signals.

Turbine ID	Audio Signals to be fitted
1 4 3 7 8 10 31 32 45 73 74 83 86 88 89 92 95	**Significant Peripheral Structures (SPS) and Selected Intermediate Structures (IS)** Sound signals shall be fitted so as to be audible upon approaching the wind farm from any direction. The character shall be rhythmic blasts corresponding to Morse letter 'U' (▪ ▪ ▬) every 30 seconds. The minimum duration of the short blast shall be 0.75 seconds. The sound signal shall be operated when the meteorological visibility is two nautical miles or less. All sound signals should be synchronised.
Remainder (i.e., 2, 5, 6, 9, 11 to 26 to 29, 30, 33 to 44, 46 to 72, 75 to 82, 84, 85, 87, 90, 91, 93 and 94)	**No marine sound signals required**

Note that these sound signals should be placed not less than 6 metres and not more than 30 metres above MHWS and should have a range of at least 2 nautical miles.

Appendix 6 – Wind Turbine Markings

Common Wind Turbine Markings

All wind turbines are to be marked as follows.

Colour scheme RAL 7035 for the turbine structure, except for nacelle top helicopter winch markings (see CAP 437), and as follows.

- Turbine towers should be painted yellow all around from the level of Highest Astronomical Tide (HAT) to 15 metres above it or the height of the marine navigation lights and sound signal equipment, if fitted, whichever is greater.
- Each tower shall display identification panels with black letters or numbers a minimum of one metre high on a yellow background visible in all directions, e.g., facing north, east, south, and west. These panels shall be easily visible in daylight as well as at night, by the use of illumination or retro-reflecting material (illumination should be by an inward and downward facing light). Note that in accordance with CAP 437, the turbine identifier should be displayed on the nacelle top as well in characters in a contrasting colour (preferably black) with a minimum size of 1.2m (and otherwise should be as large as practicable).

Suggested Turbine Identifier Schedule

The suggested turbine identifiers are shown in the following table. This is based on the recommended 'spread sheet method' to simplify navigation to the correct turbine through the wind farm. The MCA should be consulted on the identifier code when the layout is finalised.

The principle for these suggested codes is that rows of turbines (i.e., roughly west to east) have a number identifier, beginning at '01' for the northernmost row, and the columns of turbines (i.e., roughly north-northwest to south-southeast) have a letter identifier beginning at 'A' for the southwesternmost column. This should aid navigation within the wind farm to a specific turbine for a boat or helicopter, and to assist this, some consecutive identifiers are omitted (e.g., the first turbine s 'A09', and there is no 'A12'). This is described as a 'spread sheet system'.

Turbine	Suggested Identifier Code	Turbine	Suggested Identifier Code	Turbine	Suggested Identifier Code	Turbine	Suggested Identifier Code	Turbine	Suggested Identifier Code
1	A09	20	C05	39	D10	58	E16	77	G04
2	A10	21	C06	40	D11	59	F03	78	G05
3	A11	22	C07	41	D12	60	F04	79	G06
4	A13	23	C08	42	D13	61	F05	80	G07
5	A14	24	C09	43	D14	62	F06	81	G08
6	A15	25	C10	44	D15	63	F07	82	G09
7	A16	26	C11	45	D16	64	F08	83	G10
8	B05	27	C12	46	E04	65	F09	84	G11
9	B06	28	C13	47	E05	66	F10	85	G12
10	B07	29	C14	48	E06	67	F11	86	G13
11	B08	30	C15	49	E07	68	F12	87	G14
12	B09	31	C16	50	E08	69	F13	88	G15
13	B11	32	D03	51	E09	70	F14	89	H01
14	B12	33	D04	52	E10	71	F15	90	H02
15	B13	34	D05	53	E11	72	F16	91	H03
16	B14	35	D06	54	E12	73	F17	92	H04
17	B15	36	D07	55	E13	74	G01	93	H05
18	B16	37	D08	56	E14	75	G02	94	H06
19	C04	38	D09	57	E15	76	G03	95	H07

Suggested Turbine Identifier Chart

The wind turbines are shown in the chart below with the suggested identifier code. Note that some codes are missing in order to maintain, so far as possible, the 'spread sheet system' of identifying rows and columns.

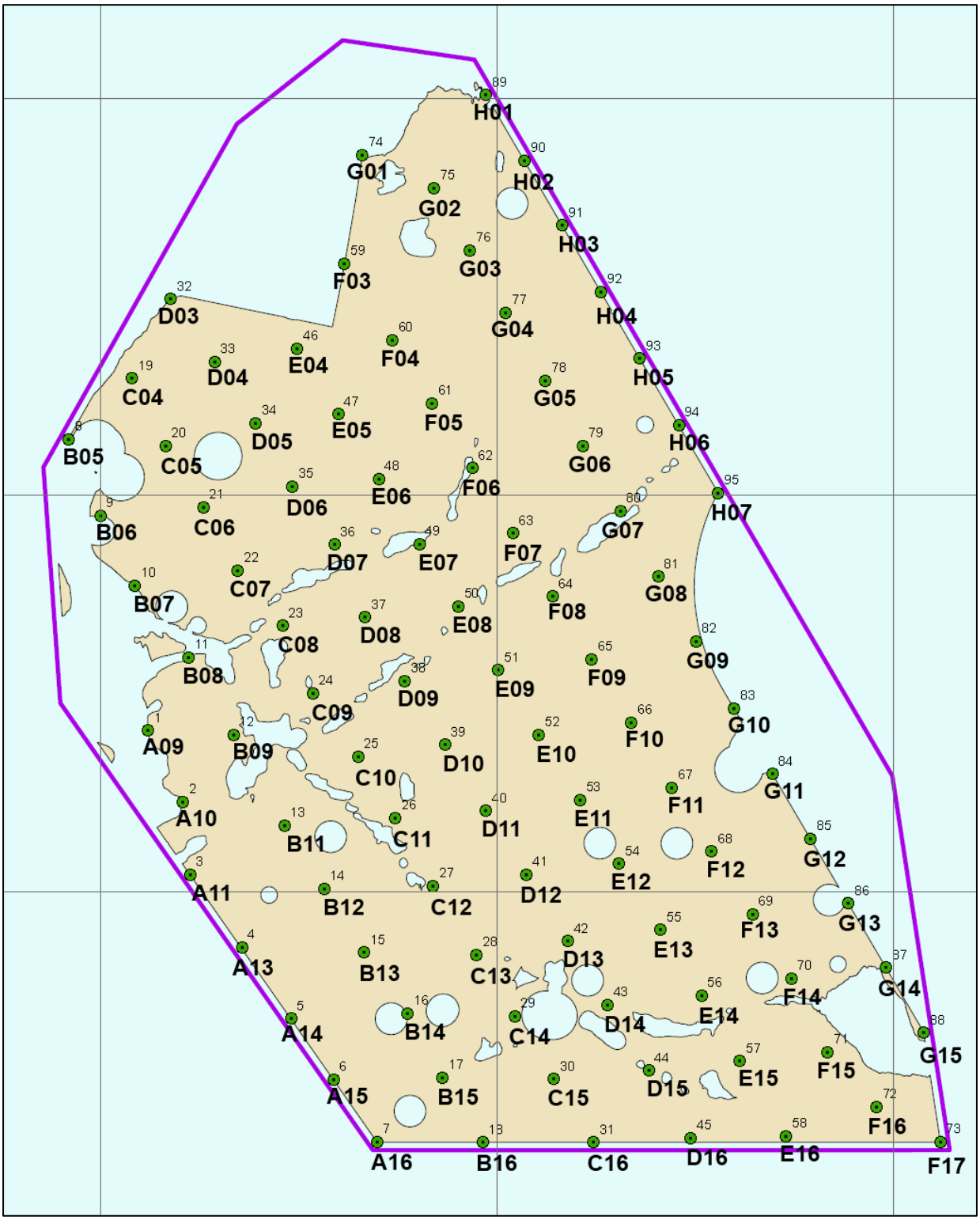


Chart reproduced from Turbine Layout chart, dated 19 March 2013, with permission from Mainstream Renewable Power. Copyright © Mainstream Renewable Power Limited, 2012.

Appendix 7 – Night Viewings of Offshore Wind Farms

Background

In order to understand the effect of offshore wind farm lights on the night-time visual amenity, the author conducted visits to viewpoints of offshore wind farms on the Suffolk and Essex coast on 4 separate nights in March 2013, on 21st, 25th, 26th, and 27th. The visibility on these nights varied between 'good' and 'very good' (as forecast on the BBC website), perhaps even 'excellent' on one night (although this was not forecast by the BBC). Viewing distances were between approximately 5km and nearly 40km.

The nearby wind farms intended for viewing were Greater Gabbard and Gunfleet Sands. The London Array was also seen, although this was not targeted as it was understood to be under construction (the others were operational) and its state of development was not known.

Photographs were taken but are of limited value in a report such as this as the brightness of lights viewed at night depends on the exposure time and the level of 'zoom' used. The main benefit is from comparison with each other and with known light sources (e.g., urban lights and/ or the moon), so unless otherwise stated, exposure and zoom were consistent (maximum x5 zoom and maximum exposure available on a simple hand-held digital camera).

It is not known whether the medium intensity lights were 'powered down' as the Air Navigation Order permits in good visibility conditions: the relative brightness of these compared to other lights (e.g., for marine navigation) suggests that they were at full brightness.

It is worth noting that the author's vision is excellent – and better than average – confirmed by a visit to an optician less than 2 months before these visits.

Wind Farms

Greater Gabbard

The Greater Gabbard wind farm, approximately 25km offshore, consists of 140 wind turbines, although this is understood to be split into 2 sites. There are approximately 100 turbines at the site viewed. Turbines have hub heights of 77.5m and rotor diameters of 107m.

Gunfleet Sands

The Gunfleet Sands wind farm, approximately 5km offshore, consists of 48 wind turbines (phases 1 and 2: phase 3 of this project is understood not to be built yet). Turbines have hub heights of 75m and rotor diameters of 107m.

London Array

The London Array wind farm (Phase 1), approximately 22km offshore, is to consist (when complete) of 175 wind turbines. Its current build state is unknown. Turbines have hub heights of 87m and rotor diameters of 120m.

Chart

The wind turbines locations are shown as red dots in the chart below (turbine locations are taken from the list of tall structures in the UK Aeronautical Information Publication).

21 March Viewing

On this night, the BBC's online weather forecast for Felixstowe was for 'very good' visibility. Southend Airport (just to the southwest of the area of the chart below) reported 'greater than 10km visibility' throughout the visit. The wind was from east-northeast.

Various viewpoints were visited, shown as numbered green diamonds in the following chart.

Only the Gunfleet Sands wind farm was seen on this visit.

Viewing distances to the nearest turbines varied from 5km to approximately 12km. The most distant turbine seen was approximately 18km (note that no turbines from any wind farm were visible from Viewpoint 9 at Harwich: Gunfleet Sands was only seen from viewpoints around Clacton, Frinton and The Naze).

The viewpoints (excepting Viewpoint 9 from which nothing was seen) on this visit were all closer to the wind turbines than any onshore viewpoints of the Neart na Gaoithe wind farm.

It was immediately obvious that the most prominent lights were the medium intensity red aviation lights on the nacelle tops. Other lights, though visible, were almost inconspicuous in comparison.

The following photo (with areas of darkness cropped top and bottom) was taken from St Osyth Beach (Viewpoint 1 on the previous chart) at a distance of approximately 8km to the nearest turbine. It shows the nacelle-top lights with very faint marine navigation lights and possibly buoys lower down.

There was no glare from the wind farm, nor any visible reflection of light from clouds, both of which are commonly noticed around well-lit urban areas at night.

At Viewpoint 8 (The Naze), the nearest turbine was approximately 12km away, and there was a noticeable reduction in brightness of the nacelle top lights compared to the 5km viewing distance at Clacton.

Some flickering of more distant nacelle-top lights was observed. The wind direction – and presumably turbine rotor direction – was such that it would be unlikely for rotor blades to pass in front of the lights on the same turbine, but the unseen blades might obscure lights from the more distant turbines. The flickering was barely noticeable, and at most appeared to be similar to a slightly exaggerated flickering of stars.

The brightness of the red nacelle-top aviation lights at Clacton (5km to the nearest light) was judged to be similar to rear car lights some distance ahead on a straight road. It was also noticed that these lights seemed comparable to lights on tall onshore masts (thought to be TV masts) in the vicinity, contributing to the author's assumption that the wind turbine lights weren't dimmed.

There was no 'light pollution' from the lights, even when viewed at 5km. They were not bright enough to be detrimental to any other night-time activity, e.g., star gazing.

25 March Viewing

On this night, the BBC's online weather forecast for Felixstowe was 'very good' visibility, reducing to 'good' at times. Southend Airport again reported 'greater than 10km visibility' throughout the visit. The wind was from east-northeast. The waxing gibbous moon was noticeably brighter – through cloud – than the previous visit, giving more ambient brightness away from artificial lights.

Viewpoints visited are shown on the chart below. The main difference from the previous visit was the viewpoint to the south of West Mersea (Viewpoint 1), approximately 16km from the nearest turbine (i.e., a similar distance to that for the nearest onshore viewpoint of Neart na Gaoithe), and a viewpoint at Aldeburgh (Viewpoint 5) approximately 28km from the Greater Gabbard wind farm.

There was no significant difference in observations made from the vicinity of Clacton, Frinton and The Naze from the previous visit, although more distant lights, assumed to be from the London Array wind turbines, were noticed for the first time.

However, the view from Viewpoint 1 – a dark site (other than the ambient brightness from the moon) with no nearby light pollution (although lights and associated glare from around Clacton were visible just to the left of the wind farm) was noticeably different. The turbine lights were markedly less prominent than at the closer viewpoints, and the brighter lights of the coastal towns were much more eye-catching and made the wind turbine lights even less prominent. This can be seen from the following photos. Marine navigation lights were almost invisible.

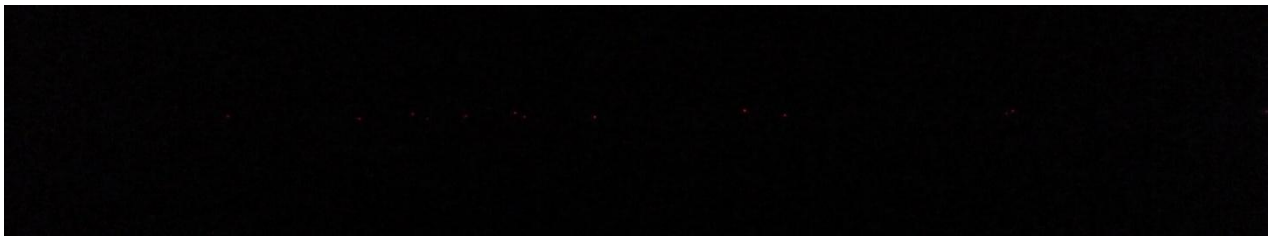


Photo from Viewpoint 1 at the same exposure and zoom settings as for the photo from St Osyth beach on the previous visit. The turbines lights are barely visible here (although they were more visible to the naked eye).

Photo from Viewpoint 1 (zoomed out – unlike other photos – to show the effect of brighter lights): lights from around Clacton are to the left of the photo; wind farm lights are barely visible in the centre (although they were more visible to the naked eye).

At Viewpoint 5, it was difficult to identify the more distant (28km) lights of Greater Gabbard, and took some time searching before they were seen. The lights were noticeably lower than previously seen when closer to the turbines at Gunfleet Sands and were only faintly visible. The lights were not visible in the photographs so none are shown. The only lights discernible were the red lights assumed to be on the nacelle-tops (lower marine navigation lights were presumed to be below the horizon).

26 March Viewing

On this night, the BBC's online weather forecast for Felixstowe was again for 'very good' visibility. Southend Airport again reported 'greater than 10km visibility' throughout the visit. However, the night was very clear with a very bright moon with no cloud (mostly) and the visibility was markedly better than the previous night: in the author's opinion, it warranted an 'excellent' in the BBC's reporting system. The wind was from the east.

This visit focussed on Greater Gabbard from a number of viewpoints, starting with Aldeburgh as visited on the previous night, as seen from the chart below.

At Viewpoint 1 (Aldeburgh), lights at Greater Gabbard were readily identifiable, partly perhaps due to knowing exactly where to look after the previous visit, but in the clear night it seemed more prominent, although the lights were very close to the horizon. The turbine lights are just discernible on a photograph viewed on a bright, high definition screen, but are unlikely to be visible when printed. Nevertheless, a photo is shown below (zoom and exposure are as for the first photo shown from St Osyth). The turbine lights are central, right of the reflected moonlight.

There was little noticeable variation from this at other viewpoints.

However, Harwich was revisited as the conditions were such that the lights should have been visible from there: they were not, so the author concludes that at that distance (39km), the nacelle-top lights were below the horizon (the lights are estimated to be about 80m high, the viewpoint was very close to sea level).

27 March Viewing

On this night, the BBC's online weather forecast for Felixstowe was for 'very good' visibility reducing to 'good'. Southend Airport again reported 'greater than 10km visibility' throughout the visit. Again, the moon was very bright with little cloud, although visibility certainly seemed less than the previous night. The wind was from the northeast.

This visit considered the views of Gunfleet Sands again at the viewpoints shown in the following chart.

It was noticed that the visibility seemed to be less than on previous visits: the turbines lights from Viewpoint 1 (at 16km) seemed to be noticeably dimmer than two nights before (the previous visit to this viewpoint), although no noticeable difference was observed from near Clacton. This is to be expected: a slightly reduced visibility would have little effect at short distances, but over longer distances, haze has more chance to attenuate the lights.

The moon was bright and relatively low in the sky (approaching full moon, and rising in the east close to sunset) which may have affected the apparent brightness of the lights – although the experience at Aldeburgh on the previous night suggests to the author that this factor is of low significance.

The following zoomed out photo was taken from viewpoint 1. Although the turbines lights are more prominent in the photo than previously (to the left of the picture), this does not correspond to the author's experience, and many factors (including automatic camera settings) may be relevant. Notably, in the moonlight, a low level haze is apparent (this was not visible on the previous night).