East Anglia Hub Wind Farms ACP-2022-079 Design Options

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1 Introduction

1.1 Project Overview

Scottish Power Renewables (SPR), the CS, are proposing three wind farm sites in the South North Sea, East of the Norfolk Coastline. The three sites are East Anglia 1N (EA1N), East Anglia 2 (EA2), and East Anglia 3 (EA3). These wind farms have the collective potential to deliver up to 3.1 GW of generating capacity, which makes this one of the largest offshore generating developments in the world. The EA Hub also consists of East Anglia 1 Wind Farm, which is currently operational, but will have no further bearing or reference in this ACP Process unless specifically highlighted. Collectively the EA Hub will consist of up to 242 wind turbines with a maximum blade tip height of 300 metres (m) above lowest astronomical tide (LAT) for EA1 and EA2, 196m above LAT for EA3. Figure 1 below provides the location of the proposed EA Hub Wind Farm sites.

The purpose of this document is to inform the general public and key stakeholders on the development of the design options (DO) that address the requirements of the East Anglia Hub Wind Farm Airspace Change Proposal (ACP). Following the CAA Assessment Meeting[1] this ACP has been pre-scaled at level 3. A Pre-scaled Level 3 ACP has been assigned because the CAA agree that the proposed changes will have a low impact on both aviation and non-aviation stakeholders[2]. The Change Sponsor (CS) is seeking to establish a Transponder Mandatory Zone (TMZ)[3] airspace solution to mitigate the impact of the Wind Farm on the Cromer Primary Surveillance Radar and the provision of air traffic control (ATC) serviced in the vicinity of the proposed development. This ACP will follow the CAA guidance provided in CAP 1616H-Appendix B[4].

In CAP 1616H, it is recognised that ‘there are a very limited number of design options that a CS could develop for a TMZ and that for this reason, ‘there is no requirement for CS’s to develop a list of design options beyond what is practically achievable’[5]. In this ACP, the CS has explored all the DOs which are feasible for latter stage evaluation. As stated in CAP 1616H, as this is a pre-scaled level 3 ACP there will be no stakeholder engagement on the DOs at stage 2. Instead, a qualitative assessment of the DO’s has been provided as part of this document. All proposed DOs will be included in the relevant engagement material as part of stage 3.

[1] ACP-2023-079-CAA Assessment Meeting Minutes (Redacted).
[2] CAP 1616 – Airspace Change Process (v5) - Pg 24 para-2.30.
[3] CAA DAP 1916 Statement of Need (SoN): SPR EA Hub ACP (14 November 2023).
[4] CAP 1616H – Guidance on Airspace Change Process for Level 3 and Pre-Scaled Airspace Change Proposals (v1).
[5] CAP 1616H, Pg35, para B9.

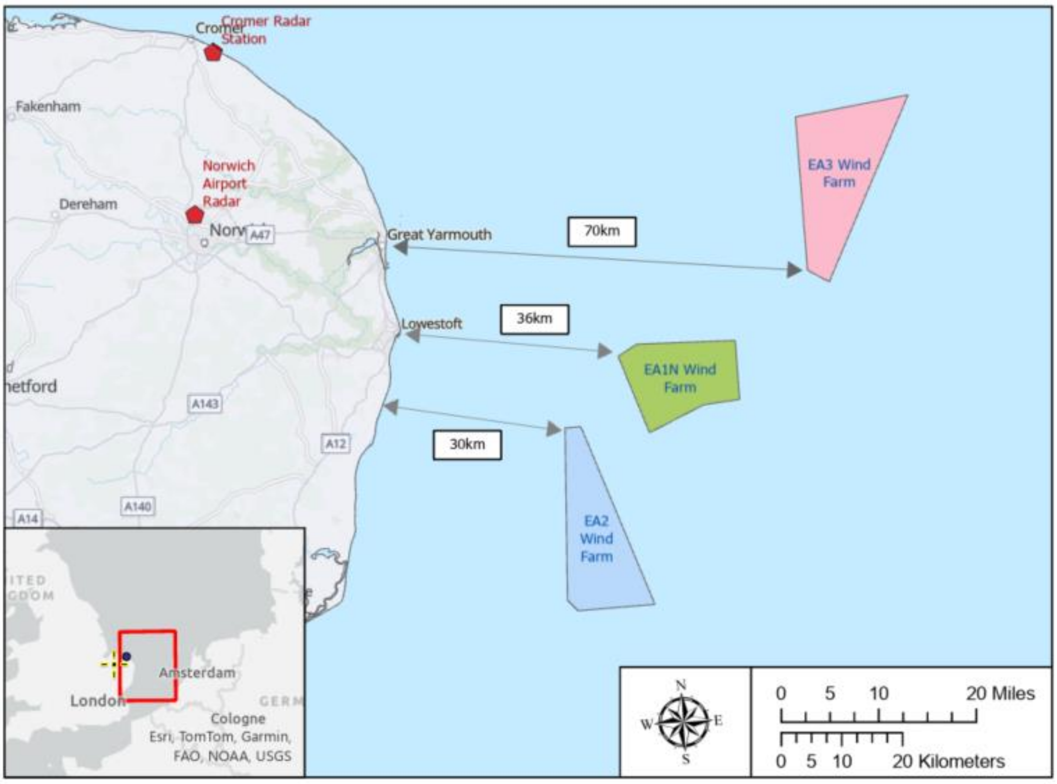

Figure 1 - EA Hub OSWF's Proximity to UK Coastline.

1.2 Wind Turbine Effects to Aviation Radar

Radar detectable wind turbines are a significant cause of radar false plots, or clutter, as the rotating blades can trigger the Doppler threshold (e.g., minimum shift in signal frequency) of the Radar Data Processor (RDP). This clutter generates a received radar return that may be interpreted as a legitimate radar return signal from an aircraft. Significant effects have been observed on radar sensitivity caused by the substantial Radar Cross Section (RCS) of the wind turbines structural components (blades, tower, and nacelle) which can exceed that of a large aircraft; the effect 'blinds' the radar (or the operator) from real aircraft returns in the immediate vicinity of the wind turbine. False plots and reduced radar sensitivity may also reduce the effectiveness of RDP tracking algorithms to an unacceptable level. These effects can compromise the provision of a safe radar service by ATC to participating aircraft.

Stationary objects do not have a significant effect on air traffic radar systems as radar processing techniques remove stationary or slow-moving objects from the radar display. Radar detectable wind turbines only have an effect on radar performance once the turbine blades are rotating. This issue can be further compounded by a large number of wind turbines located together which cause a cumulative effect over a greater volume with higher densities of clutter produced.

Generally, the larger a WTG is, the larger its RCS will appear to a radar system. This results in more energy being reflected and an increased chance of that return signal creating unwanted returns (clutter). This clutter will be processed by the radar and presented to the air traffic controller on their Radar Data Display Screens (RDDS).

The generalised effects wind turbines have on radar systems are as follows:

- Twinkling appearance/blade flash effect which can distract a controller.
- Masking of true aircraft targets by increased clutter on an RDDS.
- Increase in unwanted targets or false aircraft tracks.
- Receiver saturation.
- Target desensitisation causing loss of valid targets that are of a small RCS.
- Shadowing behind the wind turbines caused by physical obstruction (blocking of radar transmitted signal).
- Degradation of tracking capabilities including track seduction.
- Degradation of target processing capability and processing overload.

Radar detectability of wind turbines does not automatically provide justification for an objection from radar stakeholders. Other factors will determine the nature and severity of the operational impact on the receptor e.g.:

- The consideration of airspace structure and classification in the wind turbine vicinity.
- The operational significance of the airspace to the operator.
- The range of the development from the radar source.
- Aircraft traffic patterns and procedures.
- The type of radar service provided to air traffic using the airspace.

When providing a safe Air Traffic Service (ATS), an air traffic controller must maintain standard separation distances between aircraft that are under their control. In many cases, the controller will need to provide a minimum of 5nm radar separation between an aircraft receiving a radar derived ATS and any unwanted radar returns that have the potential to obscure unknown aircraft targets. The radar clutter presented on radar displays that would be associated with radar detectability of the development would require aircraft to be manoeuvred away from desired aircraft track to achieve the appropriate lateral separation criteria. Without specific wind turbine mitigation processing capabilities, radars cannot distinguish between returns from wind turbines (false returns, or 'clutter') and those from aircraft. Air traffic controllers are required to assume that actual aircraft returns might be lost over the location of a windfarm. Furthermore, the identification of aircraft under control could be lost or interrupted.

As part of the development consent process for the EA Hub Wind Farms, the CS has engaged with relevant aviation stakeholders to determine the impact of EA Hub operational wind turbines on local aviation radar systems and operations. National Air Traffic Service (NATS) confirmed that the wind farm development will generate interference (radar clutter) on the primary Cromer radar (Figure 1), caused by its detection of the operational wind turbines. This clutter will have an adverse impact on the ability of NATS to provide an ATS utilising the Cromer radar.

2 Design Options

2.1 Overview

The CS conducted an internal design options workshop on the 12th March 2024. The aim of this workshop was to identify and consider a number of DOs that sought to provide at least partial mitigation against the operational effects the wind turbines could have on Cromer PSR. All DOs which will be carried forward as part of this ACP must allow for operation of all 3 OSWF sites whilst concurrently providing technical mitigation for the impacted Cromer PSR.

The following options have been developed in alignment with the design principles (DPs) developed at an earlier stage of the ACP process. The list of finalised DPs for this ACP are listed in Annex 2.

The following range of mitigation DOs were considered:

- Do nothing.
- A procedure to temporarily close down operation of the WTGs.
- Secondary Surveillance Radar (SSR) only operations.
- The use of In-fill radar.
- Establishment of Controlled Airspace.
- Establishment of a Radio Mandatory Zone (RMZ).
- Introduction of Range Azimuth Gating (RAG) blanking and a Transponder Mandatory Zone (TMZ).

2.2 Option 0: Baseline Do Nothing

This Option provides no mitigation against the impacts of radar clutter. In the event that no mitigating actions are implemented for EA Hub, the clutter created by the radar detecting the operational wind turbines will have a subsequent effect on the safe and effective provision of a radar based ATS using the Cromer radar (Section 1.2).

These anticipated effects will reduce the overall effectiveness of the radar when detecting targets; can result in the misidentification of aircraft; may cause a loss of track position; and prevent track identification because aircraft symbols and track history may be obscured. This would in turn can affect the accuracy and timeliness of air traffic controller instructions, leading to potential serious safety issues for ATC and the flying community operating within the area of wind turbine induced radar clutter.

A lack of mitigation may cause a suspension of ATC radar services to those aircraft operating within the vicinity of the EA Hub complex. Furthermore, dependent on the radar service being provided, it may be necessary for controllers to vector aircraft around the area of wind turbine induced radar clutter. Aircraft would therefore fly greater track distances, increasing fuel burn and nitrogen dioxide (NO2) and carbon dioxide (CO2) emissions, as well as increasing both pilot and controller workloads.

The Do-Nothing option is therefore **not considered to be a viable option**. The Do-Nothing scenario would not address the issues described above and the Sponsor would be unable to progress the wind farm development.

2.3 Option 1: Temporary Wind Turbine Suspension of Operation

A temporary suspension of wind farm operations was considered as an option. Suspending the rotating wind turbine blades would prevent radar clutter appearing on ATC radar displays and the air traffic control service could be provided unhindered. However, there are significant technical and commercial complexities associated with this option, as listed below:

- Frequency and duration of switch offs.
- Time taken to turn off the wind turbines.
- Cromer would effectively require the rights to turn off the wind turbines at any point in time for any duration.

Individual wind turbines are routinely turned off for maintenance. However, any increase in the activation and deactivation of the wind turbines would lead to excessive wear and tear.

Any instruction to turn off the wind turbines unlikely to elicit an immediate response. There is also uncertainty over the time it would take for the wind turbine blades to stop; this would not be compatible with a dynamic air traffic environment. Additionally, electrical generators have a ramp down rate: this is the limit at which the machine can safely reduce its power output to zero without causing significant aging and/or damage to equipment. The electrical machines and mechanical equipment need to brake and reduce speed in a controlled manner. Emergency stop procedures should only be implemented in emergency situations and not as routine practice.

Consideration was given to introducing a process that would stop the rotating wind turbine blades, perhaps via a telephone call to the EA Hub operations room (control of the wind turbines must remain the responsibility of the developer). However, due to the unpredictable nature of operations within uncontrolled airspace this would not be sufficiently robust to satisfy a dynamic ATC operational environment and would introduce delay and increased ATC workloads.

For the reasons stated above this option **not considered to be a viable option** by the Sponsor and considered to be operationally unmanageable and unacceptable to Cromer Radar and NATS.

2.4 Option 2: Secondary Surveillance Radar (SSR) Only Operations

SSR is a co-operative surveillance technique that relies on aircraft being equipped with a transponder. The aircraft's transponder responds to interrogation from a ground station by transmitting a coded reply signal. This reply typically provides an air traffic controller with:

- Squawk Code
- Altitude
- Identification
- Position
- Ground Speed
- Heading
- Other Data

The sole reliance and use of this surveillance technique, without appropriate airspace use rules in place, is not totally approved in the UK due to the complex nature of ATC environments. It should be noted that the situations in the UK where SSR alone may be used to provide an ATS are very limited.

The Military Aviation Authority (MAA) provide Regulatory Articles (RA) to provide a framework of policy, rules, directives, standards, processes and associated direction, advice, and guidance which governs military aviation activity. These RAs are used as the basis against which military air safety is assessed. RA 3241[6] covers contingency arrangements for the continued provision of ATS utilising SSR alone. Military airfield ATC radar controllers may provide an ATS using SSR alone, but only where its use is properly defined in unit orders.

Military controllers are encouraged (in accordance with local orders) to hand-over control of aircraft to adjacent units within overlapping radar coverage (subject to the adjacent unit's radar serviceability) at the earliest opportunity when experiencing radar clutter, and when other mitigation methods are not available. However, this is impracticable within the vicinity of the EA Hub complex as there are limited adjacent radar equipped ATC units capable of providing uncluttered and overlapping radar cover in the region of the EA Hub complex.

With SSR only operations, the PSR would be deselected to remove wind turbine induced clutter. Since it is not possible to deselect PSR for only a specific area (without RAG blanking), deselecting the PSR would remove all primary radar cover across the entire area of operations. In this situation it would not be possible to detect any aircraft entering the airspace above the EA Hub complex unless it was transponder equipped, leading to an unacceptable loss of situational awareness for the controller. This action would also remove a potential barrier that assists with the prevention of a loss of safe separation between aircraft.

This option is therefore **not considered to be a viable option** on safety grounds.

2.5 Option 3: In Fill Radar Solution

The principle of infill radar is to use an existing radar, or position a new radar, in an area unaffected by the WTG induced radar clutter. Such a system would be able to provide primary radar coverage at low enough levels to provide an operationally acceptable solution.

Recently, a number of radar systems have also been developed which have successfully mitigated the impact created by the detection of operational wind farms by PSR systems.

This option requires a suitable site where the infill radar may be positioned with the provision of power and suitable telecommunications links. A new radar will itself require planning consent and attract significant upfront costs (at least £10.5m not including any land lease or utilities).

It is considered that this option is **not considered to be a viable option** on the grounds of cost.

2.6 Option 4: Introduction of Class D or E Controlled Airspace

The EA Hub complex would sit within uncontrolled Class G airspace which is established above the development sites up to FL85 for EA2, and beyond FL100 for EA1N and EA3. Of note is that there are various airways above EA2 which are as low as FL85. Further to this, as shown in the CDS, the Lakenheath Aerial Tactics Areas North and South which, whilst also Class G airspace, do occupy the same airspace

[6] RA 3241 – Secondary Surveillance Radar Alone Operations – Issue 3

volume down to FL60 across all three sites. Lastly, there is an Air-to-Air Refuelling Area which extends from 2000ft to FL 50 above EA1N and EA3.

The introduction of Class D airspace would provide a known traffic environment which would allow aircraft to operate under both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR); under IFR, ATC would provide ATS separation. Aircraft operating under Visual Meteorological Conditions (VMC) can request a VFR transit and ATC will pass traffic information to VFR aircraft about IFR aircraft; separation between VFR and IFR traffic is based on the “see and avoid” principle.

Class E airspace enables flight under both IFR and VFR. IFR flights must obtain an ATC clearance before entering Class E airspace and must then comply with ATC instructions. VFR traffic does not require a clearance to enter Class E airspace, but it must also comply with ATC instructions (if an ATS is provided). Class E does not currently extend to the surface in the UK.

Option 4 does not include radar blanking of the Cromer PSR system and wind turbine induced radar clutter would therefore still be an issue. Furthermore, establishing controlled airspace in the region of EA Hub complex may adversely impact those airspace users who are not capable of flying in controlled airspace.

Option 4 is therefore **not considered to be a viable option** because it will not successfully mitigate the operational effects on Cromer caused by wind turbine induced clutter on the PSRs.

2.7 Option 5: Class E + Transponder Mandatory Zone (TMZ) Airspace

A TMZ[7] is an area of defined dimensions within which a pilot must operate a serviceable transponder, prior to entry. Class E Controlled Airspace which also includes a TMZ has already been deployed in the UK (for example to replace Class F airways). There is therefore a precedent for this airspace solution. However, as previously stated, there is currently no provision to deploy Class E down to surface level in the UK. Under this airspace solution, the conspicuity element would be provided by the concept of compliance with a TMZ as described in the Terminology table in Annex 4.

This option does not include radar blanking of the Cromer PSR systems and is therefore **not considered to be a viable option** to successfully mitigate the operational impact created by the radar detectability of the EA Hub complex.

2.8 Option 6: Radio Mandatory Zone (RMZ)

A RMZ is an area of defined dimensions which requires a pilot to be in two-way communication with the airspace owner, prior to entry. Pilots must also provide information pertinent to the flight, for example, route required and altitude/height. A RMZ created in the airspace above the EA Hub complex would provide a degree of situational awareness to the controller about aircraft operating within the defined airspace. Although ATC would be able to provide some level of service to aircraft operating within the airspace, the RMZ solution would not prevent generation and display of false tracks/clutter on PSR systems and could lead to an associated loss of situational awareness by air traffic controllers. Operations within an RMZ carries no requirement to operate a transponder and therefore identification of aircraft could be protracted or potentially impossible due to PSR clutter.

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[7] SARG Policy 123: Policy For Radio Mandatory Zones & Transponder Mandatory Zones (v2 – 13 Jan 2022)

This mitigation option is **not considered to be a viable option** because it fails to eradicate the presence or radar clutter which would limit ATC's ability to provide the prescribed separation between aircraft.

2.9 Multiple Range Azimuth Gating (RAG) Blanking and/or TMZ Options

A TMZ is an area of defined dimensions within which a pilot must operate a serviceable transponder, prior to entry. A TMZ created in the airspace above the EA Hub complex would provide a degree of situational awareness to an air traffic controller about aircraft operating within the vicinity and within the defined TMZ airspace.

RAG blanking involves prevents detected radar clutter it from showing on radar displays by blanking the area at the source of clutter on the RDDS, thus removing it as a distraction from the controller's display. This also means that within the area of the RAG blanking, any primary radar contacts (from wind turbines or aircraft) would also be suppressed and also not appear on a controller's radar display.

Unique to the EA2 OSWF location, is that the TMZ would require division into two sectors (North (N) and South (S)). The southern sector would likely extend from the surface (SFC) to FL85 to accommodate for the existing Clacton CTA Sector 5's lower limit (Class A airspace). The northern sector remains with a standard upper TMZ vertical limit of FL100, as shown in Figure 2.

Figure 2 - Illustration of the Clacton CTA Sector 5 above EA2 OSWF.

There are 11 configuration possibilities for a TMZ/ RAG blanking implementation that fall into the following categories:

- Generalised design options.
- Design options per individual EA OSWF site.
- Design options which look to address a grouping of EA OSWF sites.
- Single design options which address all EA Hub OSWF sites.

A table containing a summarised listing of the design options below can be found in Annex A1, along with their initial viability grading by the CS.

The DPs which will be used to evaluate these options are described in detail in the Design Principles Evaluation (DPE) document, which can be found on the CAA airspace change portal[8], and repeated at Annex A2 within this document.

2.10 Option 7: RAG Blanking Only

Range Azimuth Gating involves blanking the clutter (created by the detection of the EA Hub wind turbines by a PSR) within a specific geographic area. This means that, any primary radar contacts (from wind turbines, aircraft, or other contacts) would also be suppressed and prevented from showing on the controllers' RDDS.

RAG blanking effectively creates a 'black hole' in the radar coverage overhead the EA Hub complex in and around which no primary radar returns would be created. Blanking of the Cromer PSR systems without an associated TMZ would therefore be unsafe and unacceptable to air traffic controllers at the affected units.

For these reasons this option alone is **not considered to offer a viable mitigation**.

2.11 Option 8: TMZ (3) Only

This option involves establishing a TMZ which covers only the minimum area required. This would ensure the minimum restriction for non-transponder equipped aircraft who would otherwise overflying the EA Hub complex. Transponder equipped aircraft would be able to transmit on SSR frequencies when over, or in the vicinity of, the wind turbines, and would be unaffected from an operational perspective.

The airspace classification allocated to a TMZ would remain the same as that of the surrounding airspace. Consequently, the ATS available within and around the TMZ would continue to be provided in accordance with CAP 774[9] UK Flight Information Services, through the assured provision of SSR data to the controller.

Without the use of RAG blanking also applied to the TMZ area, wind turbine induced primary radar clutter could negatively affect the degree, accuracy and timeliness of the instructions, advice, and information a controller is able to provide to pilots operating within the TMZ, with consequent impacts on safety. There could be an increase in controller workload; the clutter could result in poor radar performance because of processing saturation and desensitisation or shadowing; and there could be a loss of radar detection of aircraft operating within the vicinity of the TMZ.

For the reasons above, the TMZ only option is a sub-optimal solution and is therefore **not considered to offer a viable mitigation** option.

[8] ACP-2023-079: ScottishPower Renewables (UK) Ltd East Anglia Windfarm Mitigation
[9] CAP 774 UK Flight Information Services (v4 – 15 December 2021)

2.12 Option 9: TMZ (3) and RAG Blanking with No Buffers

As illustrated in Figure 3, Option 9 establishes a TMZ over the OSWF locations including the use of RAG blanking to remove associated wind turbine induced radar clutter from the Cromer PSR associated ATC displays, but without a 2nm safety buffer. This option encompasses a total area of 770 km^2.

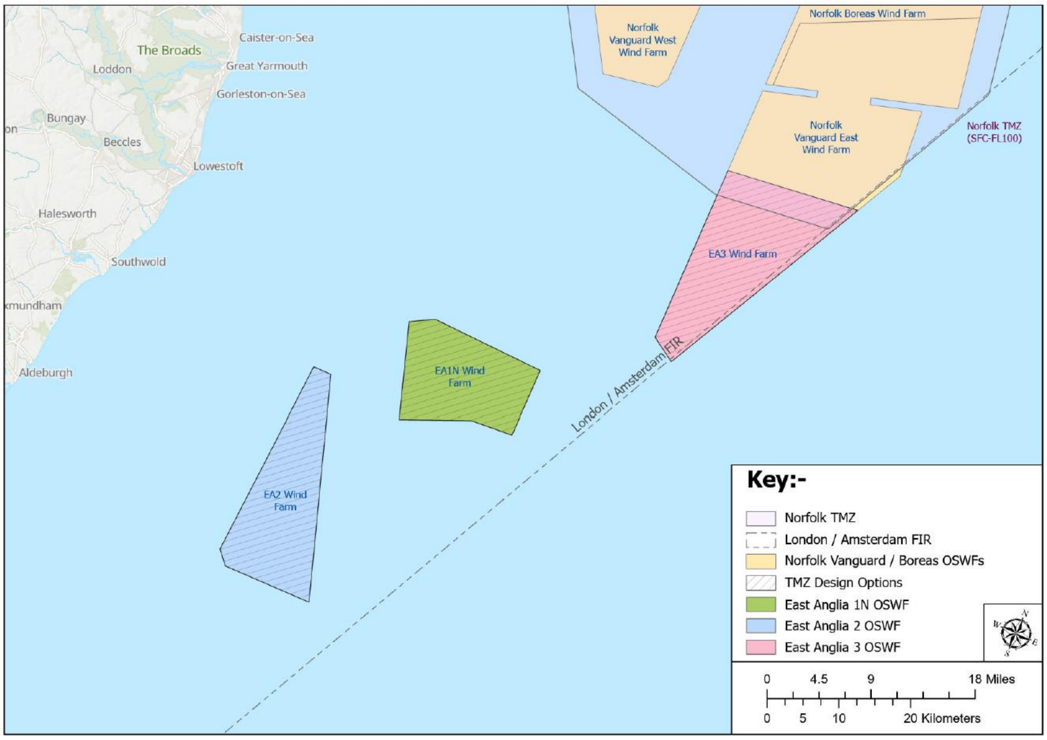

Figure 3 - Option 9 TMZ (3) and RAG Blanking with No Buffers.

This option provides the minimum TMZ airspace cover required to restrict non-transponder aircraft from overflying the associated geographic area where RAG blanking area of the radar system has been introduced. Any aircraft entering the TMZ would be required to be equipped and operate its SSR transponder equipment.

A non-transponder equipped aircraft would disappear from the controller's radar display if it inadvertently crossed into the hashed areas (Figure 3 above) because it would be entering a volume of airspace where RAG blanking had been introduced. Establishing a TMZ without an additional buffer zone on the shadow side removes the indication to a controller that a non-SSR equipped/ operated aircraft is approaching the TMZ boundary.

Option 9 is **considered to offer a viable, but suboptimal solution**.

2.13 Option 10: TMZ (3) and RAG Blanking with Norfolk TMZ Overlap

As illustrated in Figure 4, Option 10 provides three distinct TMZs and a RAG blanking airspace solution. Each TMZs perimeter is extended to include a 2nm buffer within established UK airspace. This option overlaps the Norfolk TMZ perimeter. This option encompasses a total area of 1,575 km^2.

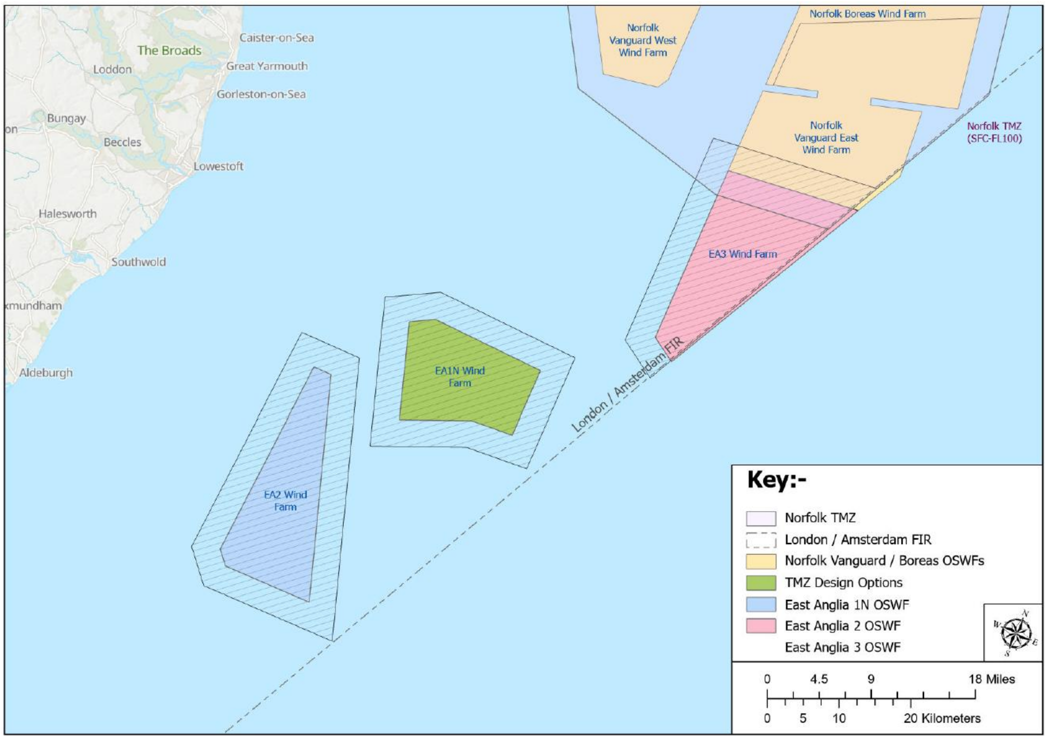

Figure 4 - Option 10 TMZ (3) and RAG Blanking with Norfolk TMZ Overlap.

To ensure safe and efficient ATS provision, a lateral 2nm TMZ buffer has been added. Aircraft entering the TMZ with this extended buffer will be required to be equipped with and operate SSR transponder equipment.

This lateral buffer helps mitigate potential navigation errors that can occur when pilots of non-transponding aircraft approach the blanked area. The 2nm buffer enhances controllers' chances of detecting such aircraft approaching the lateral boundaries of the RAG blanked area, enabling them to provide relevant information to transponding aircraft operating within the RAG blanked area. The 2nm buffer also allows for a non-transponder equipped aircraft to make a track adjustment, in those situations where it realises an infringement is likely to occur and avoid the RAG blanked area.

However, the introduction of buffer areas narrows the available gap between the TMZs of EA1 and EA2 to 1.6nm. This now creates a funnel within which a small navigational error might lead to a TMZ infringement by a non-transponding aircraft. In addition, the TMZ's various shapes would be unsympathetic to controllers and would unnecessarily increase controller workloads.

Option 10 is therefore **considered to offer a viable, but suboptimal solution with safety concerns**.

2.14 Option 11: TMZ (3) and RAG Blanking with Norfolk TMZ Adjoined

As illustrated in Figure 5, Option 11 provides three distinct TMZs and a RAG blanking solution. Each TMZs perimeter is extended to include a 2nm buffer within established UK airspace, with no overlap of the design option into the Norfolk TMZ. This option encompasses a total area of 1,415 km^2.

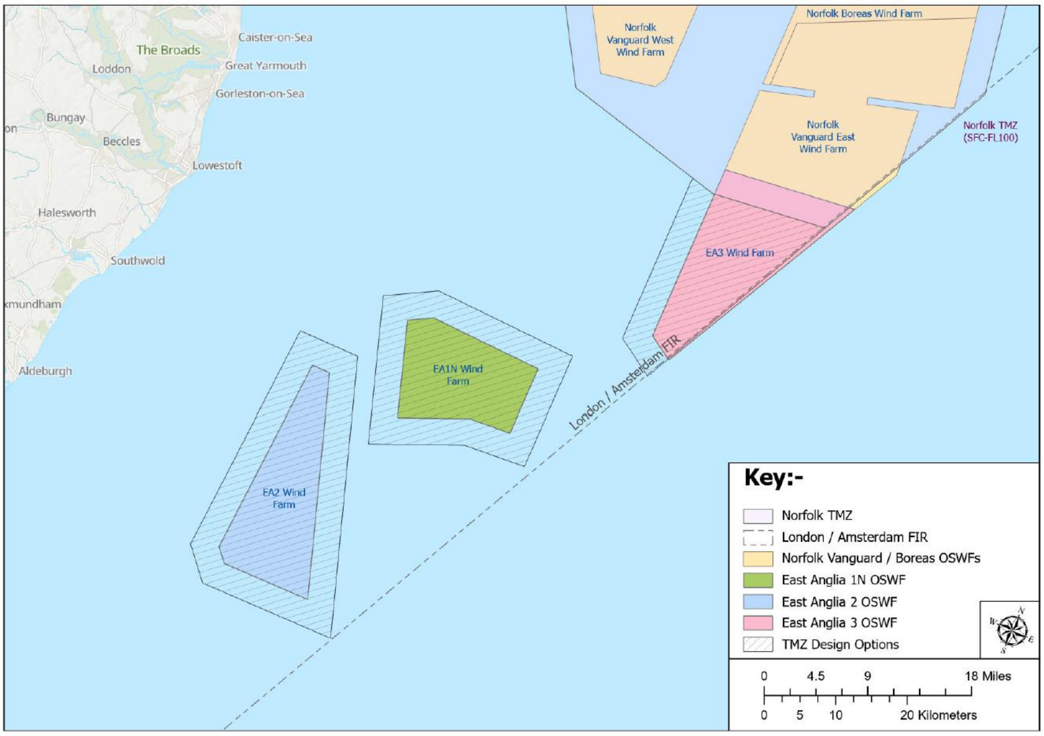

Figure 5 - Option 11 TMZ (3) and RAG Blanking with Norfolk TMZ Adjoined.

Option 11 has the same advantages as those in Option 10. In addition to the disadvantages documented for Option 10, the TMZ does not extend along the northern edge of EA3. This is due to the planned formation of the Norfolk TMZ around the Vanguard and Boreas OSWF's.

However, there is a risk that either the Norfolk TMZ does not get established, or that the Norfolk TMZ is removed whilst the EA Hub area still requires protection. If either of these scenarios materialises, then there may be a requirement for a further TMZ ACP to be conducted to provide a buffer to the North of EA3.

As with Option 10, the introduction of buffer areas narrows the available gap between the TMZs of EA1 and EA2 to 1.6nm. This now creates a funnel within which a small navigational error might lead to a TMZ infringement by a non-transponding aircraft. In addition, the TMZ's various shapes would be unsympathetic to controllers and would unnecessarily increase controller workloads.

Option 11 is therefore **considered to offer a viable solution, but with safety concerns**.

2.15 Option 12: TMZ (3) and RAG Blanking with Extended Norfolk TMZ Boundary

As illustrated in Figure 6, Option 12 provides three distinct TMZs and a RAG blanking solution. The EA1N and EA2 TMZs perimeter is extended to include a 2nm buffer. However, the EA3 TMZ provides an extended shape to simplify the perimeter boundary between the proposed EA3 TMZ and the Norfolk TMZ. This option includes an overlap into the Norfolk TMZ. This option encompasses a total area of 1,881 km^2.

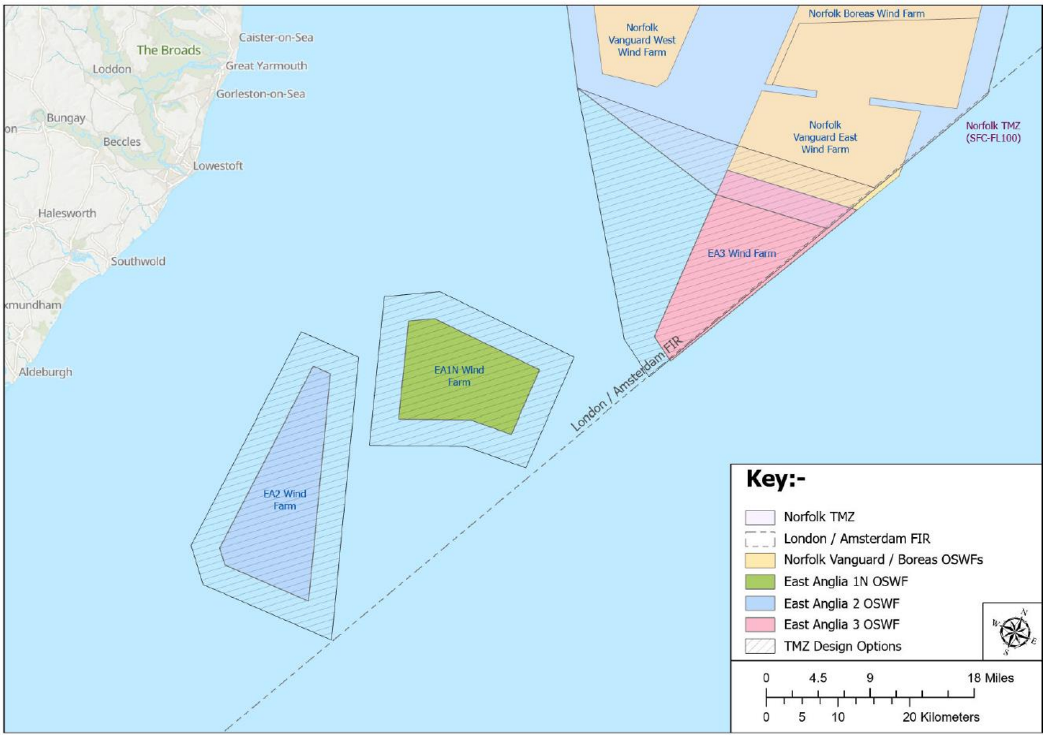

Figure 6 – Option 12 TMZ (3) and RAG Blanking with Extended Norfolk TMZ Boundary .

In addition to the advantages listed for Option 10, this option generates a simplified EA3 TMZ shape by adjoining with the Norfolk TMZ, whilst remaining independent. The option utilises a large portion of airspace left to the northwest of EA3 which would not be aligned with the requirement for more efficient use of airspace in general. This additional volume of airspace may also be considered surplus to requirements if the Norfolk TMZ was not established as planned.

As with Option 10, the introduction of buffer areas narrows the available gap between the TMZs of EA1 and EA2 to 1.6nm. This now creates a funnel within which a small navigational error might lead to a TMZ infringement by a non-transponding aircraft. In addition, the TMZ's various shapes would be unsympathetic to controllers and would unnecessarily increase controller workloads.

This option is **considered to offer a viable solution, but with safety and efficiency concerns**.

2.16 Option 13: TMZ (2) and with Norfolk TMZ Overlap

As illustrated in Figure 7, Option 13 provides two distinct TMZs and a RAG blanking airspace solution. Each TMZ's perimeter is extended to include a 2nm buffer within established UK airspace. This option overlaps the Norfolk TMZ perimeter. This option encompasses a total area of 1,659 km^2.

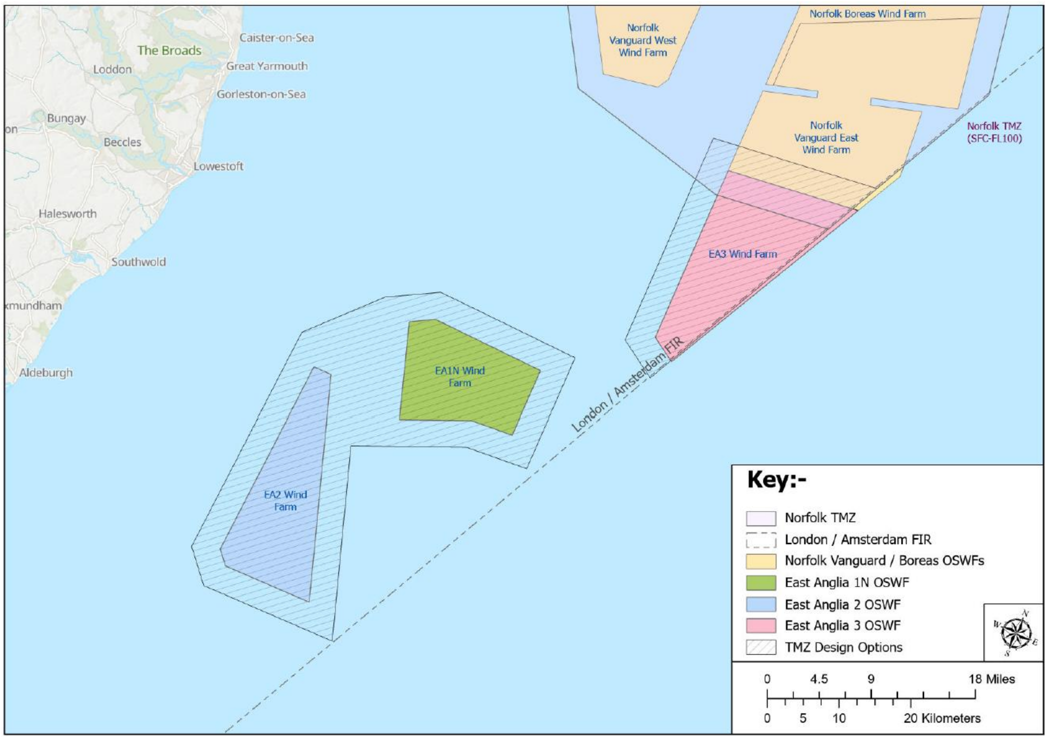

Figure 7 - Option 13 TMZ (2) and with Norfolk TMZ Overlap.

This Option is very similar to Option 10. The only difference is that the gap between the EA1 and EA2's TMZ and RAG blanking areas has been closed. This provides a simpler, joint TMZ and RAG blanking solution to EA1N and EA2 by eliminating the narrow, virtually unusable corridor between the two, whilst maintaining a GA transition corridor between EA1N and EA3. This Option utilises only necessary amounts of airspace, is future proofed against issues with the Norfolk TMZ and has closed the funnel between EA1 and EA2.

The only consideration with this Option is that for non-transponding aircraft, there is now a virtually unusable section of airspace between the London/Amsterdam FIR boundary and EA1 and EA2 joint RAG blanked area with TMZ buffer. However, the impact of this will be minimal as a transponder is required to cross the FIR boundary.

This option is therefore **considered to offer a viable solution**.

2.17 Option 14: TMZ (2) and RAG Blanking with Norfolk TMZ Adjoined.

As illustrated in Figure 8, Option 14 provides two distinct TMZs and RAG blanking solution. Each TMZs perimeter is extended to include a 2nm buffer within established UK airspace, with no overlap of the design option into the Norfolk TMZ. This option encompasses a total area of 1,498 km^2.

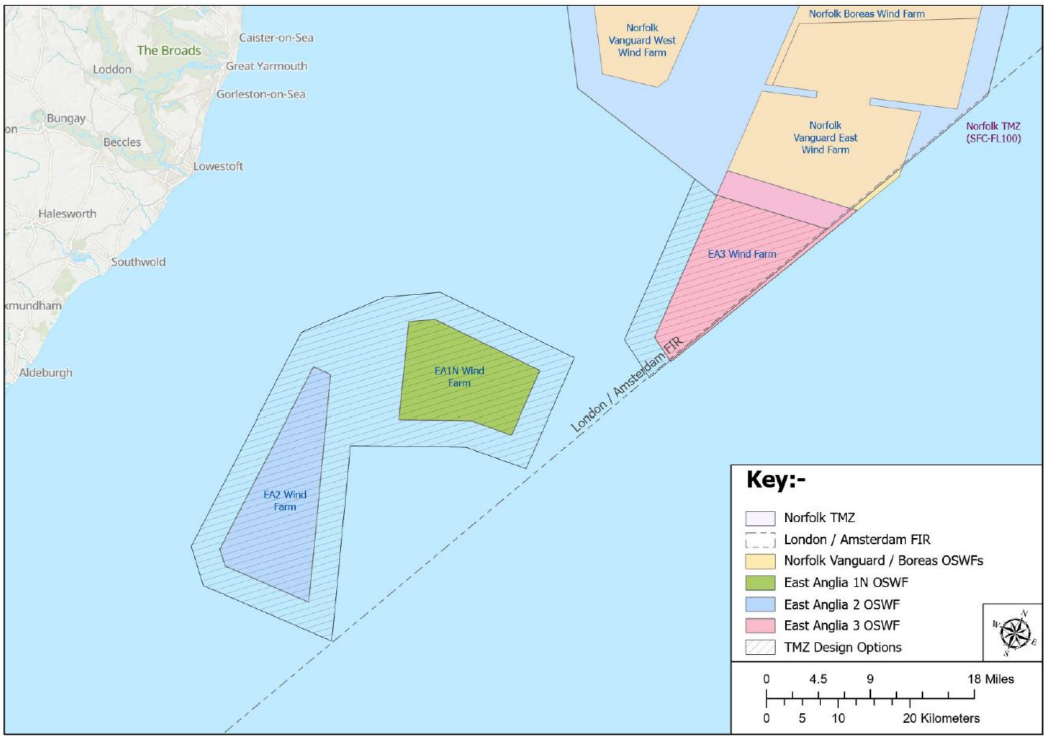

Figure 8 - Option 14 TMZ (2) and RAG Blanking with Norfolk TMZ Adjoined.

This option maintains a GA corridor across the London/Amsterdam FIR at the EA Hub site (in-between EA3 and EA1N) whilst utilising the least amount of airspace required. This option has also closed the potential unsafe corridor between EA1N and EA2 which could have caused funnelling of GA traffic between the TMZs.

As per Option 13, the only consideration with this Option is that for non-transponding aircraft, there is now a virtually unusable section of airspace between the London/Amsterdam FIR boundary and EA1 and EA2 joint RAG blanked area with TMZ buffer. However, the impact of this will be minimal as a transponder is required to cross the FIR boundary.

A further consideration was also applicable to Option 11; the northern edge of EA3 is no longer future proofed against any issues with the creation or early termination of the Norfolk TMZ. Therefore this option has vulnerabilities which are out with the control of this ACP.

Option 14 is **considered to offer a viable solution, but with concerns regarding the Norfolk TMZ.**

2.18 Option 15: TMZ (2) and RAG Blanking, FIR Aligned and with Norfolk TMZ Overlap

As illustrated in Figure 9, Option 15 provides two distinct TMZs and a RAG blanking airspace solution. Each TMZ's perimeter is extended to include a 2nm buffer within established UK airspace. The EA1N/EA2 combined TMZ is extended to the London/Amsterdam Flight Information Regions (FIR). This option overlaps the Norfolk TMZ perimeter. This option encompasses a total area of 2,049 km^2.

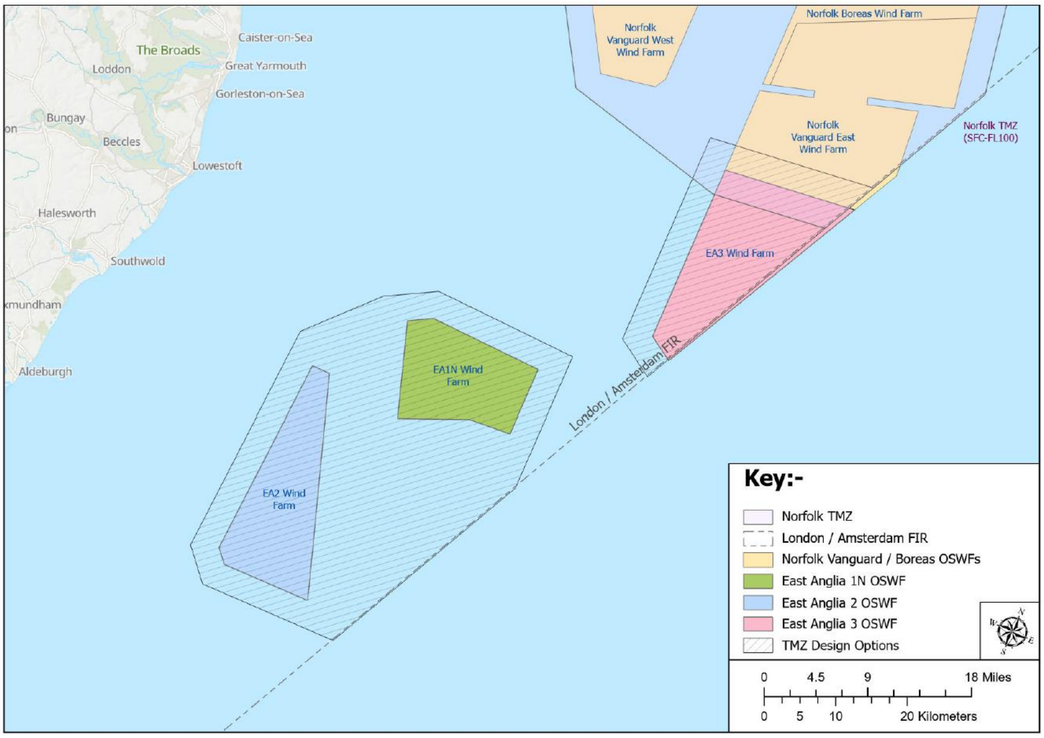

Figure 9 - Option 15 TMZ (2) and RAG Blanking, FIR Aligned and with Norfolk TMZ Overlap.

The advantages of this Option are similar to Option 13 but with the addition of the TMZ buffer around EA1 and EA2 which now extends south to align with the FIR boundary. The funnel between EA1 and EA2 has now been closed. The additional sector of airspace incorporated to the south also includes another OSWF which would now be embodied into the TMZ and RAG blanking area. A gap is maintained between the two TMZs and RAG blanking areas through which non-SSR transmitting GA users could plan to use. This option also maintains some future proofing against future issues with the Norfolk TMZ.

This Option does however utilise a large volume of airspace, although the gap 'filled' between the joint EA1 and EA2 TMZ and the FIR boundary is arguably unusable for other purposes in any event.

Option 15 is **considered to offer a viable solution**.

2.19 Option 16: TMZ (2) and RAG Blanking, FIR Aligned and with Norfolk TMZ Adjoined.

As illustrated in Figure 10, Option 16 provides two distinct TMZs and RAG blanking airspace solution. Each TMZs perimeter is extended to include a 2nm buffer within established UK airspace. The EA1N/EA2 combined TMZ is extended to the London/Amsterdam Flight Information Regions (FIR). This option does not overlap the Norfolk TMZ perimeter. This option encompasses a total area of 1,889 km^2.

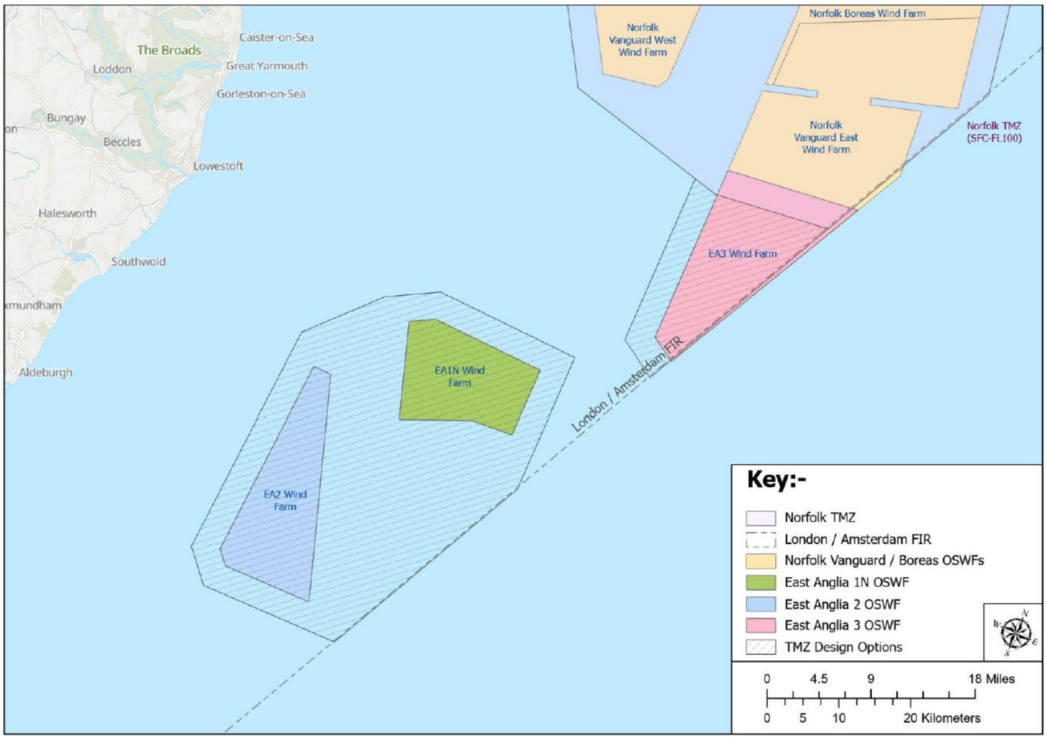

Figure 10 - Option 16 TMZ (2) and RAG Blanking, FIR Aligned and with Norfolk TMZ Adjoined.

This option has advantages similar to those for Options 15 and 13 as it includes the TMZ buffer around EA1 and EA2 which extends south to align with the FIR boundary. The funnel between EA1 and EA2 has now been closed. The additional sector of airspace incorporated to the south also includes another OSWF which would now be embodied into the TMZ and RAG blanking area. A gap is maintained between the two TMZs and RAG blanking areas through which non-SSR transmitting GA users could plan to use.

This Option, however, does have a TMZ buffer on the northern edge of the EA3 TMZ and RAG blanked area. As previously mentioned, this does not provide any future proofing for this ACP and leaves the CS vulnerable to and changes or cessation of the Norfolk TMZ. It utilises a large amount of airspace, but less than Option 15. However, as stated before this airspace is arguably unusable for other purpose.

Option 16 is therefore **considered to offer a viable solution, but with concerns regarding the Norfolk TMZ.**

2.20 Option 17: TMZ (1) and RAG Blanking and Norfolk TMZ Overlap

As illustrated in Figure 11, Option 17 provides a single TMZs and RAG blanking airspace solution. The TMZ perimeter is extended, outward from the OSWF boundary, to include a 2nm buffer within established UK airspace. The TMZ perimeter buffers are joined in a direct line ensuring the buffer to each OSWF, then continued along the London/Amsterdam Flight Information Regions (FIR). This option overlaps the Norfolk TMZ perimeter. This option encompasses a total area of 2,618 km².

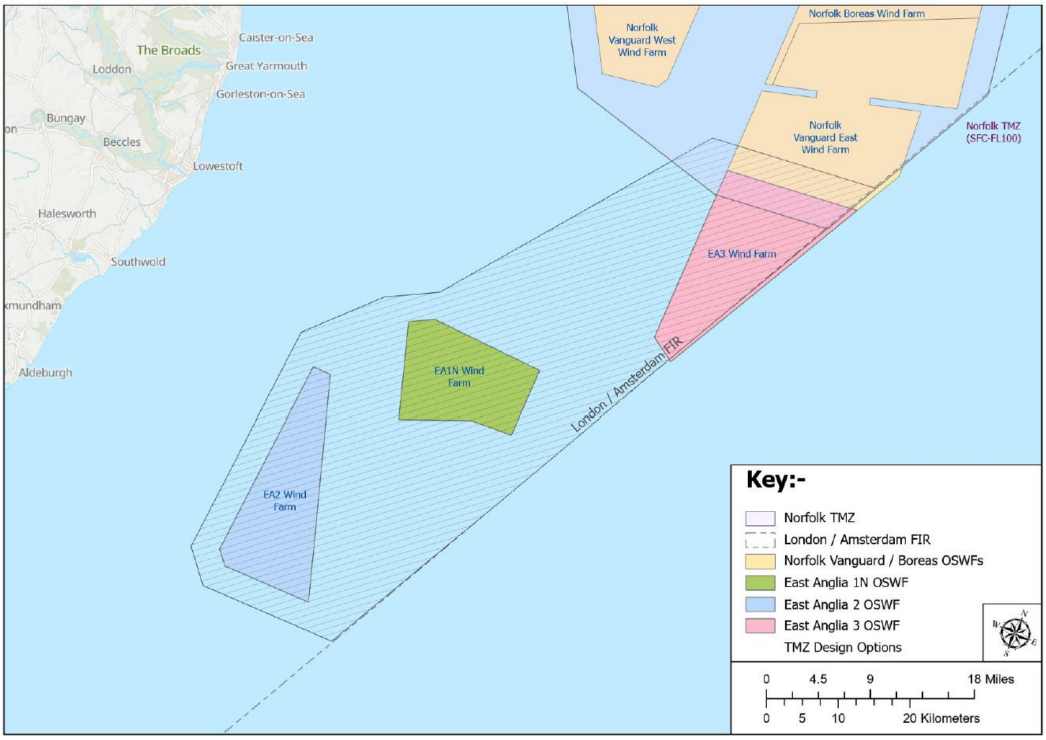

Figure 11 - Option 17 TMZ (1) and RAG Blanking and Norfolk TMZ Overlap.

This Option is the simplest and arguably the safest solution as it provides an easily identifiable single area that includes a TMZ buffer to protect EA1N and EA2, as well a protection against speculative future issues related to the Norfolk TMZ as described in earlier options.

Option 17 is however an alternative that utilises the largest volume of airspace. It could be argued that this represents an unsympathetic use of available airspace might be considerably more restrictive to GA, non-transponding airspace users wishing to transit between the UK and the European mainland.

Option 17 is therefore **not considered to offer a viable solution**.

3 Next Steps

Osprey Consulting Services Ltd (Osprey) on behalf of SPR are progressing this ACP to define a mitigating solution that addresses the issues that result from radar interference on the NATS Cromer PSR systems (anticipated as a result of radar detectability from the operational wind turbines of the EA Hub Wind Farm complex).

We are currently at Stage 2 of the CAP1616 Airspace Change process. This stage involves preparing design options for this change and provides an opportunity to develop a series of potential design options. The options are then evaluated against the design principles through a formal process known as the Design Principles Evaluation (DPE).

Although several of the DOs have been initially assigned as 'not viable', it is important to show the CAA and all invested stakeholders that alternative airspace solutions were discussed and have been fully documented.

As this ACP (pre-scaled Level 3) is seeking to support radar clutter mitigation mechanisms, there is a greater likelihood that an outcome of the ACP will take the form of a TMZ in accordance with the ACP's Statement of Need (SoN)[10]. The CAA acknowledge that there are only a limited number of variations to TMZ designs and thus the CS can proceed to the next stage without the need for stakeholder engagement on the design options.

At this stage of the CAP 1616 process, we are required to provide evidence that all considered design options have been documented and developed for further evaluation. This document will support the next stage of the ACP (Stage 2 – DEVELOP: Design Principle Evaluation), where all the DO's contained within this document will be formally evaluated against the final design principles (See Annex 2).

[10] CAA DAP 1916 Statement of Need (SoN): SPR EA Hub ACP (14 November 2023)

A1 Summary of Design Options

Option	Description Summary	Initial DO Viability Assessment
0	Do Nothing.	Not Viable
1	Temporary Wind Turbine Suspension of Operation.	Not Viable
2	Secondary Surveillance Radar (SSR) Only Operations.	Not Viable
3	In Fill Radar Solution.	Not Viable
4	Introduction of Class D or E Controlled Airspace.	Not Viable
5	Class E + Transponder Mandatory Zone (TMZ) Airspace.	Not Viable
6	Radio Mandatory Zone (RMZ).	Not Viable
7	RAG Blanking Only.	Not Viable
8	TMZ (3) Only. (Note 2)	Not Viable
9	TMZ (3) and RAG Blanking with No Buffers. (Note 1 & 2)	Viable [Suboptimal]
10	TMZ (3) and RAG Blanking with Norfolk TMZ Overlap. (Note 1)	Viable [Suboptimal] [Safety]
11	TMZ (3) and RAG Blanking with Norfolk TMZ Adjoined. (Note 1)	Viable [Safety]
12	TMZ (3) and RAG Blanking with Extended Norfolk TMZ Boundary. (Note 1)	Viable [Safety] [Efficiency]
13	TMZ (2) and with Norfolk TMZ Overlap. (Note 1)	Viable
14	TMZ (2) and RAG Blanking with Norfolk TMZ Adjoined. (Note 1)	Viable [Norfolk TMZ]
15	TMZ (2) and RAG Blanking, FIR Aligned and with Norfolk TMZ Overlap. (Note 1)	Viable
16	TMZ (2) and RAG Blanking, FIR Aligned and with Norfolk TMZ Adjoined. (Note 1)	Viable [Norfolk TMZ]
17	TMZ (1) and RAG Blanking and Norfolk TMZ Overlap. (Note 1)	Not Viable

Table 1 - Summary of Design Option Viabilities

Notes:

1. A TMZ established over EA2 OSWF would require sectorisation into two components (A & B). Sector B (southern sector) would be from SFC to FL85 to accommodate for the existing Clacton CTA Sector 5's lower limit (Class C airspace). Sector A remains a standard TMZ vertical upper limit (SFC-FL100).

2. Not exceeding the designated OSWF perimeter boundaries.

A2 Design Principles

During Stage 2 of the ACP process, all stakeholders were given the opportunity to engage with the CS on how the design principles should evolve. The design principles from a prior work package within Stage 2 of the process are detailed below.

A2.1 Mandatory Design Principles (MDP)

- **MDP Safety**: The airspace change proposal must maintain a high standard of safety and should seek to enhance current levels of safety.
- **MDP Policy**: The airspace change proposal should not be inconsistent with relevant legislation, the CAA's airspace modernization strategy or Secretary of State and CAA's policy and guidance.
- **MDP Environment**: The airspace change proposal should deliver the Government's key environmental objectives with respect to air navigation as set out in the Government's Air Navigation Guidance 2017.

A2.2 Discretionary Design Principles (DDP)

- **DDP Technical 1 (Other aviation stakeholders)**: The airspace change proposal should consider the impacts on air navigation service providers and other aviation stakeholders such as nearby airports operators.
- **DDP Technical 2 (Ministry of Defence requirements)**: The airspace change proposal should be compatible with the requirements of the Ministry of Defence.
- **DDP Technical 3 (Accessibility for all airspace users)**: The airspace change proposal should satisfy the requirements of operators and owners of all classes of aircraft, including general aviation and other civilian airspace users.

A2.3 Bespoke Design Principles (BDP)

- **BDP Policy**: The airspace change proposal should ensure that the design of the proposed TMZ complies with the CAA TMZ Policy[1].
- **BDP Technical 3 (Airspace)**: The airspace change should be designed to fit with existing background airspace classification and any known planned changes.
- **BDP Technical 4 (Airspace)**: The volume of airspace affected should be the minimum necessary to deliver a safe solution to counter the effects of wind turbine generators on ATC surveillance infrastructure.

[1] SARG Policy Statement: Policy for Radio Mandatory Zones and Transponder Mandatory Zones (13 Jan 2022).

A3 Acronyms

Acronym	
ACAS	Airborne Collision Avoidance Systems
ACP	Airspace Change Proposal
ADS-B	Automatic Dependent Surveillance-Broadcast
ATC	Air Traffic Control
ATCRMS	Air Traffic Control Radar Mitigation Scheme
ATM	Air Traffic Management
ATS	Air Traffic Service
CAA	UK Civil Aviation Authority
CAP	Civil Aviation Publication
DP	Design Principles
EA Hub	East Anglia Hub
EFIS	Electronic Flight Information Systems
GW	GigaWatt
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LAT	Lowest Astronomical Tide
m	metre
MAA	Military Aviation Authority
MAC	Mid Air Collison
MW	MegaWatt
nm	Nautical Mile
PSR	Primary Surveillance Radar
RA	Regulatory Article
RAF	Royal Air Force

Acronym	
RAG	Range Azimuth Gating
RCS	Radar Cross Section
RDDS	Radar Data Display Screen
RDP	Radar Data Processor
RMZ	Radio Mandatory Zone
SFC	Surface
SSR	Secondary Surveillance Radar
TMZ	Transponder Mandatory Zone
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

Table 2 - List of Acronyms

A4 Terminology

Term	Meaning
Automatic Dependent Surveillance-Broadcast (ADS-B)	An ADS-B system is a hardware equipment installed onboard aircraft. It automatically transmits the location (latitude, longitude) of the aircraft and its movement data (speed, heading, altitude) via a digital data link. These transmissions are received and can be used by other aircraft and Air Traffic Control to display the aircraft's position.
EA Hub complex	The proposed geographic location of the East Anglia Hub Wind Farms (EA1N, EA2, & EA3).
Primary Surveillance Radar (PSR)	A conventional radar sensor that illuminates a large portion of space with an electromagnetic wave and receives back the reflected waves from targets within that space. Primary radar detects aircraft (and other objects, such as flocks of birds, weather phenomena, other environmental factors, and wind turbines) without selection, regardless of whether or not they possess a transponder. It can also detect and report the position of anything that reflects its transmitted radio signals, including the rotating blades of the wind turbines. It indicates the position of targets but does not identify them. Because wind turbines blades are moving targets, it is hard for a radar to distinguish them from aircraft. Radar data processing connects returns from successive sweeps of the radar, and from this infers speed. Multiple wind turbines in a wind farm create multiple radar returns and these can appear as stationary or rapidly moving primary returns on the radar display.
Primary Radar RAG Blanking	Range Azimuth Gate (RAG) radar blanking blocks any primary radar return within selected ranges and azimuth sectors. This can be mapped to suppress plots within wind turbine clutter regions. However, the primary blanking in any given area is complete, hence the primary return from any aircraft entering this area would also be suppressed. Thus, the aircraft would not appear on the radar unless they were operating with a transponder, and hence detected by the Secondary Surveillance Radar (SSR).
Radar Mitigation Scheme	A scheme necessary and sufficient to prevent the operation of the East Anglia Hub wind turbines impacting adversely on the primary surveillance radar performance at Cromer. The scheme may be in combination, or individually and take the form of a hardware or software solution which will be implemented and maintained for the lifetime of the development or for such shorter period as may be agreed in consultation with NATS as necessary to mitigate any such adverse impact.
Secondary Surveillance Radar (SSR)	Secondary Surveillance Radar works together with transponders which are installed on the aircraft. The ground based SSR radar interrogates the transponder which transmits a signal which is

Term	Meaning
	captured by the radar. The information transmitted by the transponder identifies the aircraft, along with details as to aircraft altitude (note that transponder equipage is mandatory for instrument flight, and flight above Flight Level (FL) 100 however, some aircraft may operate above FL100 subject to specific rules and areas of operation. As such all commercial aircraft and the vast majority of general aviation aircraft are transponder equipped.
Transponder Mandatory Zone (TMZ)	A Transponder Mandatory Zone is an area of defined dimensions wherein the carriage and operation of aircraft transponder equipment is mandatory. All flights operating in airspace designated by the competent authority as a TMZ shall carry and operate SSR transponders capable of operating on Modes S or, in exceptional circumstances, SSR Modes A and C. However, the advent and increasing affordability of technology such as Automatic Dependent Surveillance – Broadcast (ADS-B) means that the concept of a TMZ may now evolve to utilise alternate types of electronic conspicuity systems. A pilot wishing to operate in a TMZ without serviceable transponder equipment may be granted access subject to specific arrangements agreed with the TMZ Controlling Authority via satisfactory 2-way communication.

Table 3 - List of Useful Terminology