Directorate of Airspace Policy

Civil Aviation Authority

CAP 764

CAA Policy and Guidelines on Wind Turbines

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Appendix 7 Proposed Assessment Method for Determining the Impact of Wind Turbines on Aeronautical Radar Stations

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Explanatory Note

1 Introduction

1.1 Neither aviation nor the wind energy industry is at a steady state and both can be expected to evolve in ways which may impact the other. Therefore, it is expected that this CAP will be a living document, which will be updated to reflect the outcome of any further research into the interaction between wind turbine developments and aviation. It will also be revised at intervals to take account of changes in regulations, feedback from industry, and recognised best practice.

1.2 Contact addresses, should you have any comments concerning the content of this document or wish to obtain subsequent amendments, are given on the inside cover of this publication.

2 Technical Changes

The following Chapters have been amended as shown:

Chapter	Page	Description

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Foreword

1 Introduction and Background

The DfT White paper "The Future of Air Transport" presented to Parliament in Dec 2003, recognised the value and importance of aviation to the UK in terms of its contribution to the national economy and in meeting social demands. The White Paper set out a strategic framework for the development of airport capacity in the United kingdom over a 30 year period, against the background of wider developments in air transport. An abridged Executive Summary of the White paper is included at Appendix 1.

However, whilst recognising the need for further aviation capacity in the UK, the strategy is based on the requirement for a balanced approach, which also addresses the wider impacts and the need for sustainable development.

The Government is also committed to reducing greenhouse gas emissions within the UK and, in turn, this means there is now a shift towards economically viable renewable energy sources rather than carbon fuels. It is Government policy that 10% of the UK's electricity supply should come from renewable sources by 2010 and this target is expected to further increase after this, as the UK is likely to become subject to more stringent emission controls. Further background on the Government's renewable energy policy is at Appendix 2.

It is anticipated that wind energy will provide a significant contribution to renewable energy targets. In order to harness this energy supply, both on-and offshore wind turbine developments are being constructed, which range in size from single structures to developments encompassing over one hundred wind turbines. The physical characteristics of wind turbines coupled with the size and siting of the developments can result in effects which can impact on aviation.

Both wind energy and aviation are important to UK national interests and both industry sectors have legitimate interests that must be balanced carefully. It is important, therefore, that the aviation community recognises the increasing role that wind turbine developments will play in the national economy. As such, the aviation community must engage positively in the process of developing solutions to potential conflicts of interest between wind energy and aviation operations. In a similar vein, wind turbine developers need to understand the potential impact of developments on aviation, both at a local and a national level.

Those involved in addressing wind energy and aviation issues must do so in a positive, cooperative and informed manner. Whilst the aims and interests of the respective industries must be protected, a realistic and pragmatic approach is essential for resolving any conflicts between the Government's energy and transport policies.

2 Aim of this Publication

The aim of this CAP is to provide assistance to aviation stakeholders when addressing wind energy related issues, thereby ensuring greater consistency across the whole aviation industry in the consideration of the potential impact of proposed wind turbine developments.

3 Scope

This document provides details of the policies and issues, together with guidance, that will need to be considered by aviation stakeholders. It is not the intention or purpose of this CAP to provide instruction on the need to object to wind turbine developments. This must remain the decision of individual Aerodrome Operators, Service Providers or other organisations. Furthermore, it should be noted that within the framework of these guidelines, specific circumstances will have to be addressed on a case-by-case basis, as it is not possible or appropriate to prescribe a standard solution.

4 Feedback

Stakeholders are encouraged to provide feedback on their experiences with wind turbine development so that this CAP can be updated as appropriate.

Glossary

A list of specialised words or terms with their definitions follows:

AD	Air Defence
ANO	Air Navigation Order
ANSP	Air Navigation Service Provider
AOA	Airport Operators Association
ASD	Aerodrome Standards Department
ATC	Air Traffic Control
ATS	Air Traffic Service(s)
ATSD	Air Traffic Standards Department
ATSIN	Air Traffic Services Information Notice
BWEA	British Wind Energy Association
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
CNS	Communications, navigation and surveillance
DAP (CAA)	Directorate Of Airspace Policy (Civil Aviation Authority)
DB	Decibels
DBM	Decibel Milliwatts
DBW	Decibel watts
DCLG	Department for Communities and Local Government
DE	Defence Estates (MOD)
DfT	Department for Transport
DME	Distance Measuring Equipment
DTI	Department of Trade And Industry
DTLR	Department of Transport, Local Government and the Regions
DTM	Digital Terrain Mapping
DVOF	Defence Vertical Obstacle File
EIRP	Effective Isotropic Radiated Power
EM	Electromagnetic
FSPL	Free Space Path Loss
FT	Feet
GA	General Aviation
IFP	Instrument Flight Procedures

ILS	Instrument Landing System
ITU- RP	International Telecommunications Union - Recommendations propagation
JAR	Joint Aviation Requirements
Latt	Attenuation of a Radar System
Lbr	Basic Transmission Loss of a Radar System
LF	Low Flying
LPA	Local Planning Authority
M	Metre(s)
MAP	Missed Approach Procedure
MATS	Manual of Air Traffic Services
MHZ	Mega Hertz
MOD	Ministry Of Defence
Mode S	Mode Select
MSD	Minimum Separation Distance
MW	Mega Watts
NAFW	National Assembly for Wales
NAIZ	Non-Automatic Initiation Zones
Navaids	Navigation Aids
NDB	Non Directional Beacon
NERL	Nats En Route Ltd
Nm	Nautical miles
NSL	Nats Services Ltd
ODPM	Office of the Deputy Prime Minister
OLS	Obstacle Limitation Surface
PLM	Piecewise Linear Model
PPG	Planning Policy Guidance Note
Pr	Power
P-RNAV	Precision Area Navigation
PSR	Primary Surveillance Radar
RCS	Radar Cross-Sectional
RF	Radio Frequency
RNAV	Area Navigation
RX	Receiver
SID	Standard Instrument Departure
SMS	Safety Management Systems

SRG	Safety Regulation Group
SSR	Secondary Surveillance Radar
STAR	Standard Instrument Arrival Route
TWH	Terawatt Hours
TX	Transmission
VFR	Visual Flight Rules
VOR	VHF Omni Directional Range

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Chapter 1 CAA Responsibilities

1 General

The Civil Aviation Authority (CAA) is responsible for safety regulation of civil aviation in the United Kingdom under the Civil Aviation Act 1982. The Safety Regulation Group (SRG) is responsible for the regulation of licensed aerodromes and Air Traffic Services in the UK. The Directorate of Airspace Policy (DAP) is responsible for the planning and regulation of all UK airspace, including the communications, navigation and surveillance (CNS) infrastructure, to support safe and efficient operations. DAP also has the lead responsibility for the CAA for all wind turbine related issues. In the context of wind turbine development, this advice is largely grouped in the areas set out in the paragraphs below.

Legislative provisions on wind turbine development are set out for England and Wales in Annex 2 of the Town and Country Planning (Safeguarded Aerodromes, Technical Sites and Military Explosives Storage Areas) Direction 2002 (ODPM Circular 01/2003). Similar provisions are set out for Scotland in the Town & Country Planning Safeguarded Aerodromes, Technical Sites and Military Explosives Storage Areas)(Scotland) Direction 2003 (Scottish Planning Circular 2/2003).

It should be noted that the CAA does not have regulatory powers to approve or reject planning applications.

2 Aerodrome Safeguarding

In domestic legislation, civil aerodromes are licensed in accordance with an Air Navigation Order made under section 60 of the Civil Aviation Act 1982. The CAA is responsible under the Air Navigation Order for being satisfied that a licensed aerodrome is safe for use by aircraft, having regard in particular to the physical characteristics of the aerodrome and its surroundings. This is a continuing responsibility, which it discharges by means of regular audits, by placing obligations on the licensee to inform it when material changes take place and by ensuring that proposed developments are assessed. In addition a requirement is placed on the licensee to take all reasonable steps to ensure that the aerodrome and its surrounding airspace are safe at all times for use by aircraft.

Certain civil aerodromes, selected on the basis of their importance to the national air transport system are, therefore, officially safeguarded, in order to ensure that their operation and development are not inhibited by buildings, structures, erections or works which infringe protected surfaces, obscure runway approach lights or have the potential to impair the performance of aerodrome navigation aids, radio aids or telecommunication systems; by lighting which has the potential to distract pilots; or by developments which have the potential to increase the number of birds or the bird hazard risk. A similar official safeguarding system applies to certain military aerodromes, selected on the basis of their strategic importance. In order to determine the safety implications of a planning application for a development within the approach, take-off or circuit areas of an aerodrome, a safeguarding process is established with all the relevant Local Planning Authorities (LPAs). Because the safety of aircraft in United Kingdom airspace is often dependent on ground-based navigation and radio aids, certain civil technical sites currently owned by NATS Holdings Ltd or its subsidiaries and certain military technical sites owned by the Secretary of State for Defence are also officially safeguarded under a similar process.

In general, aerodrome safeguarding is limited to the vicinity of the aerodrome. CAP 738 details statutory safeguarding whilst specific safeguarding criteria for licensed aerodromes are laid down by the CAA in CAP 168 (Licensing of Aerodromes). These involve the definition of 3D surfaces where obstructions, such as wind turbine developments, should not penetrate. Furthermore, where an Instrument Landing System (ILS) is used at an aerodrome, safeguarding criteria are used to protect the ILS radio signals from corruption. Technical safeguarding aspects are detailed in CAP 670.

The CAA's Aerodrome Standards Department (ASD) has responsibility for setting the obstacle limitation surfaces (OLS) that should be applied for aerodrome safeguarding but do not involve themselves in the role of safeguarding aerodromes. However, where a potential safety issue arises, a Statutory Direction from Government allows for the matter to be referred to the CAA for resolution or consideration by the First Secretary of State. Safeguarding guidance relating to unlicensed aerodromes is contained in CAP 428 (Safety Standards at Unlicensed Aerodromes).

3 Airspace Management

DAP, as the airspace approval and regulatory authority, is responsible for developing, approving, monitoring and enforcing policies for the safe and efficient allocation and use of UK airspace and its supporting infrastructure, taking into account the needs of all stakeholders, national security and environmental issues.

DAP is directed by the Secretaries of State for Transport and Defence to act with impartiality to ensure that the interests of all airspace users and the community at large are taken into account in respect of how the UK airspace is managed. To this end, formal consultation with airspace users, service providers and other relevant bodies shall be conducted with the aim of obtaining consensus, wherever possible, before making changes in the planning or design of UK airspace arrangements. The environmental impact of proposals for change shall be taken into consideration by ensuring that consultation is conducted with the appropriate authorities, to lessen or mitigate such impact to the maximum extent possible.

4 Approvals for Equipment and Service Provision

In order to provide an Air Traffic Service (ATS) in the UK, for example a radar service, a service provider must be granted an Approval by the CAA. Article 124 of the Air Navigation Order 2005 (ANO), concerning the suitability of the equipment to be used for the service, and Article 100, concerning the suitability of the operation in general, apply. Those service providers that run mature Safety Management Systems (SMS) may have CAA-agreed standing Article 124 and 100 approvals.

Where service providers use a remote feed of radar data from a contracted source, they remain responsible for gaining the requisite approvals for the use of data as part of a radar service. Regardless of whether the service is approved under discrete Article 124 and 100 Approvals or via an SMS, service providers must be able to achieve the following in order to retain these approvals:

a) Safeguard their service through being able to recognise when wind turbine developments may affect their service and by participating in the planning activities;

b) Be able to assess the likely effect of a wind turbine development on their service. It is not automatically the case that a wind turbine development brought to the attention of a service provider by the LPA, CAA or other means will cause a problem to the service. The service provider must first assess whether the planned development will technically impact upon the CNS systems used. Where it is assessed that there will be a technical impact, the service provider must then assess whether this has any operational significance (see also Chapter 2 of this CAP);

c) Be able to establish what reasonable measures may be put in place to mitigate the effect of a wind turbine development; and

d) Where a service provider has to make a change to equipment or operational procedures in order to safely accommodate a wind turbine development then the following must be addressed:

i) The service provider must perform a safety assessment on the change. This will either be in accordance with procedures documented as part of the SMS of the organisation, or be a standard safety assessment process (cognisant of European requirements[1]) such as that documented in CAP 760;

ii) As part of the safety assessment, the service provider should at least consider the issues raised in Chapter 2 of this CAP concerning the impact of wind turbines on aviation;

iii) Where considering mitigations to address the impact of the wind turbine development, service providers are advised to review the issues and limitations described in Chapter 4 of this CAP;

iv) Where the service is approved under discrete Article 100 and 124 approvals, then the service provider must notify their SRG Regional Inspector of the change and supply evidence that the change has been addressed in the appropriate safety case(s) for the service;

v) Where the service is part of a standing approval under an SMS regime, then the service provider must notify their SRG Regional Inspector of the change. The Regional Inspector will make a decision whether to request any further information (this will depend, in part, on the maturity of the SMS in the organisation and the significance of the change being made); and

vi) Service providers that fail to address the effects of a wind turbine development on a service properly may have the existing Approval withdrawn by the CAA, which may result in the closure of that service.

5 Advice to Government

In discharging its role as an independent regulator, the CAA is required to provide advice to Government as required. To this end, the CAA is proactive with appropriate Government departments in respect of wind energy related issues. The CAA is a member of the DTI Aviation Steering Group and its sub-groups to provide expert input on aviation aspects of the Government's renewable energy programme. Details of these groups are contained in Appendix 6.

1. For example European Safety Regulatory Requirement No.4 (ESARR4) covering risk assessment and mitigation in ATM.

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Chapter 2 Impact of Wind Turbines on Aviation

1 Introduction

The development of wind turbines has the potential to cause a variety of effects on aviation. These range from physical safeguarding, generation of unwanted returns on primary radar, affecting the performance and propagation of SSR, navigation aids and communication facilities, through to consideration of turbulence. It should be noted that wind turbines do not in themselves cause electromagnetic interference.

This chapter is aimed at providing a summary of the issues, which aviation stakeholders should consider when assessing the impact of a proposed wind turbine development. It is not intended to be exhaustive in that local circumstances may raise issues which are unique to a specific case. For this reason, the local airport operator and ATC service providers are best qualified to provide the expert interpretation of what this impact will be and how it will affect the safety, efficiency and flexibility of operations.

2 Primary Radar

Wind turbine developments can have the following effects on Primary Radar:

a) **Swamping of the Receivers**

If rotating wind turbine blades are within or close to the 'Radar Line of Sight', which is different from 'Optical Line of Sight', then the bulk of the wind turbine structure may reflect sufficient energy to swamp any reflected energy of aircraft in the same area, thus making it difficult to detect the aircraft. This may still be the case even where radar 'Moving Target' processing eliminates the false wind turbine detections.

b) **Defeating Moving Target Processing**

If the rotating wind turbine blades are within or close to the 'Radar Line of Sight', then the Doppler shift in reflected energy from the blades may defeat any moving target processing and display the blades as targets or tracks that could be mistaken for aircraft. Depending on the arrangement of the wind turbines within a development and the synchronicity of the blades, they may be displayed intermittently and may appear to twinkle or even form tracks. This can be distracting to a controller. In addition, where a controller cannot be certain that the false targets generated by a wind turbine development are not real aircraft, then separation of other aircraft from these targets must be maintained.

c) **Presenting an Obstruction**

If the wind turbines are within 'Radar Line of Sight' and aircraft are required to be detected at longer range behind the wind turbines then the following two effects may occur:

i) **Obstruction**

This occurs where aircraft detection is lost in the shadow of the wind turbines. As the aircraft tracks behind a series of wind turbines, the aircraft may appear intermittently.

ii) **Diffraction**

This occurs where partial obscuration of the aircraft radar reflections by the wind turbines causes azimuth errors at the radar. This results in the aircraft being displayed in a skewed position, or appearing to jitter in position as it passes behind multiple blades.

In view of the complex issues surrounding wind farm development, a method is needed to assist in assessing whether such a development is likely to be detected by an aeronautical radar station and the impact this will have upon its operational effectiveness. The CAA have, therefore, developed an assessment method to provide a first order approximation to the detection of wind turbines by radar, and the impact of a wind farm development upon the airport approach/en-route functionality at a particular radar site. The aim is that armed with this knowledge a radar service provider could respond appropriately to a wind farm planning application. The full assessment method can be found at Appendix 7. This is not a definitive process and is offered as but one of several methods including the use of a range of commercially available software tools. Further advice can be sought from DAP/CAA on these issues.

3 Secondary Surveillance Radar

Secondary Surveillance Radar (SSR) does not rely on reflections from objects for detection. Instead, aircraft to be detected are required to carry a transponder, which replies to radar interrogations. Therefore, although clutter will not be generated, the propagation of the signal in space can be affected as follows:

a) **SSR Reflections**

This occurs where the wind turbine structures are sufficiently close (empirical evidence suggests less than 15 Nm) and are within 'Radar Line of Sight'. SSR energy may be reflected off the structures in both the uplink and downlink directions. This can result in aircraft, which are in a different direction to the way the radar is looking, replying through the reflector and tricking the radar into outputting a false target in the direction where the radar is pointing i.e. at the obstruction. Traditional SSR (Mode A and C) is susceptible to this, but employs reflection processing and Gain-Time control to try to eliminate the reflections. It is not always successful and can be defeated where a reflection has strong energy and has lasted a long time. The selective and predictive tracking used by Mode Select (Mode S) radars makes them virtually immune to the effects of reflections (i.e. the reflection is not in the predicted location where the aircraft should be, so the selective interrogation will not be directed there).

b) **Presenting an Obstruction**

If the wind turbines are within 'Radar Line of Sight' and aircraft are required to be detected at longer range behind the wind turbines, then similar effects to those described for Primary Radar above can occur.

4 Aeronautical Navigation Aids

A wide range of systems, including aids such as ILS, VOR/DME and NDB, together with air-ground communications facilities, could potentially be affected by wind turbine developments. As previously stated, wind turbines do not emit RF interference but their physical characteristics, depending on how they are sited in relation to the specific facility, can affect the propagation of the radiated signal from the affected system. As a result, the integrity and performance of these systems can be unacceptably degraded. The CAA has sought to have the specific affects on these systems investigated and defined, so that the measures necessary to protect these systems through safeguarding can be clearly promulgated. Although further work is still awaited, there is sufficient empirical evidence to suggest that existing safeguarding arrangements as detailed in CAP 670 GEN02 in respect of navigation and landing aids and communication facilities provide adequate protection. However, aerodrome operators and ATC service providers are advised to consider each proposal carefully and if necessary, seek specific technical advice.

5 Air Traffic Services

Where a Service Provider determines that any of the above effects on the radar service or navigational aid are likely as a result of a planned wind turbine development, this may not in itself, be sufficient reason to justify grounds for rejection of the planning application. The Service Provider must determine whether the effect on the radar has any significant impact on the ATC service being provided, and whether any mitigating actions can be taken by the Service Provider and/ or wind turbine developer to work around any problems. Any objection to a wind turbine development that is not backed up by this consideration may weaken the service providers position where a planning application objection leads to an inquiry.

Much of this depends on where the effect of the wind turbine development is located compared to where the ATC operation is being provided. If a proposed development is in an area likely to be detected by the radar, but where there is no ATC provision, then an objection to a wind turbine development planning application is unlikely to be successful.

To help identify the likely impact of wind turbines on an ATC service, the Service Provider should establish where the effects of the wind turbines will appear. It should be noted that the effects of a development might extend behind the actual wind turbine site with respect to where the radar is situated (see obstruction and diffraction above). This work may be assisted by studies commissioned by the wind turbine developer.

Where possible, it can be beneficial for the Service Provider to record or plot real traffic patterns over a period of time using the radar system, and to use this to identify the prevalent traffic patterns. This can then be compared to the location of the proposed wind turbine development.

When examining the effects of wind turbines on an ATC service, particular attention should paid to the following:

a) SID Routes;

b) STAR Routes;

c) Airways;

d) RNAV and P-RNAV Routes;

e) Sector Entry and Exit points;

f) Holding points (including the holding areas);

g) Missed Approach Routes;

h) Radar Vectoring Areas;

i) Final Approach Tracks;

j) Visual Reporting Points;

k) Published IFP for the aerodrome; and

l) Future Airspace and Operational requirements where the airport growth is anticipated (Section 10 provides comment on future requirements).

The impact of wind turbine clutter on the provision of a radar service will also depend on the airspace classification and the service being provided by the ATC unit. As mentioned in Chapter 1, wind turbines may generate clutter that resembles an aircraft track. In Classes A, C and D airspace, if radar derived or other information indicates that an aircraft is lost, has experienced radio failure or is making an unauthorised penetration of the airspace, then avoiding action shall be given and traffic information passed (see CAP 493 - MATS Part 1 Paragraph 1-5-13). Therefore, if wind turbine radar clutter generates a spurious aircraft track, the controller will need to make a judgement as to whether an unauthorised penetration may have occurred and if necessary provide avoiding action. ATC providers should note that guidance and amplification on the interpretation will continue to be published within the normal CAA documentation e.g. CAP 493 - MATS Pt 1, ATSINS, etc.

Clearly, the impact of radar clutter within Class E, F and G airspace have different consequences in terms of the need to be avoided.

Therefore, the class of airspace in which an aircraft is operating, and the degree to which wind turbine radar clutter generates credible, spurious targets, will determine whether traffic avoidance must be routinely provided.

6 Offshore Helicopter Operations

Wind turbine developments within 6 Nm of an offshore destination could impact on the ability to conduct some helicopter operations, namely instrument procedures, at the associated facility.

Ultimately, there might be a consequential economic impact relating to the operation of the offshore platform. Moreover, because of the potential to restrict helicopter operations, wind turbine developments within 6 Nm, may also threaten the integrity of offshore platform safety cases, where emergency scenarios are based on the use of helicopters to evacuate the platform.

Section 3, Paragraph 3 provides background information on the issues related to wind turbine developments and offshore activities. Section 3, Paragraph 4 provides background information on the issues related to wind turbine developments and HMRs.

7 Cumulative Effects

There is no doubt that whilst small wind turbine developments can cause an effect that has an adverse impact on aviation, proliferation of developments and the subsequent cumulative effect is of far more significant concern. For airport operators, there is a difficulty in protecting an aviation activity from the cumulative effects of proliferation. This is due to pre-planning consultation (see Chapter 5) requests generally being dealt with on a "first come, first served" basis and once aware of a certain number of developments, an airport operator would be likely to object to any future proposals. The basis for the objection may be that the safety and efficiency of the airport may not be maintained or that the growth of an aerodrome may be constrained in the event of any further development. However, it is recognised that many developments, which are notified during the early planning stages, fail to reach maturity. Nevertheless, it is in the interests of aviation stakeholders to take all developments of which they are aware into account until they have been formally notified that a proposal has been abandoned.

It is recommended that to address this issue, airport operators meet with their Regional Planning Authority to brief them on this aspect and to seek a strategic approach, which ensures that acceptable development can proceed effectively. Many regional authorities have produced Strategic Joint Structure Plans and stakeholders are encouraged to participate in the development of these to ensure their high level planning concerns are taken into account in the plans for renewable energy development.

In some areas, regional Government Offices have undertaken work to consolidate information on aviation activity by all airspace users which may be affected by wind turbine developments. As a factor in assisting regional planning and ensuring that early identification of particular issues is achieved, this approach has been supported by the CAA. Aviation stakeholders are requested to work with Regional Planning Authorities if their assistance in pursuing this approach is sought.

8 Turbulence

Wind turbines are generally large structures which can inevitably cause turbulence. However, although there may be some local variations as a result, given the requirements for minimum separation and avoidance of obstacles, turbulence in relation to wind turbine developments is not seen as requiring any additional consideration than that which would normally be given. Nevertheless this aspect should be assessed on a case by case basis taking into account the proximity of the development and the type of aviation activity conducted.

9 Economic Issues

As a result of the role and responsibilities of the CAA and aviation stakeholders, action will be taken to maintain the high standards of safety, efficiency and flexibility. Therefore, as a consequence of wind turbine development, aviation activity may have to be constrained. Even in circumstances where a proposed development may not affect a current activity, future expansion may be restricted were it to go ahead. This could eventually have an economic impact on the airport or activity and this aspect should be taken into consideration when assessing the impact of any proposed wind turbine development. Therefore, it is considered entirely appropriate for an airport/aerodrome to include an assessment of the economic impact, which may arise from a proposed wind turbine development. However, it is important to note that comments made in this respect need to be unambiguous. This will then allow a regional LPA to ensure that this important aspect is appropriately taken into account.

10 En-Route Obstructions

It is possible that existing or proposed, wind turbine development that is located outside an aerodrome obstacle limitation surfaces (OLS) may nevertheless have a potential impact upon local aviation activity. For example, a development beyond any OLS, but only marginally clear, laterally or vertically, of controlled airspace might be assessed as having such a potential adverse impact upon operators within Class G airspace, perhaps by causing chock points as aircraft operations are constrained by airspace and tall structures. Whilst the CAA will highlight such issues away from the immediate vicinity of aerodromes, aerodrome operators/licensees should be cognisant of such issues when engaging with other parties on wind turbine issues. Further related comments is contained at Chapter 3, paragraph 2 (Obstructions and Lighting).

Chapter 3 Safeguarding Considerations

1 General Considerations

There are currently in excess of 140 licensed aerodromes in the UK. In the region of one third of these have been designated by the Government as aerodromes to be safeguarded by statutory process; this is known as 'official' safeguarding. A Statutory Direction obliges LPA to consult the aerodromes' operations managers about proposed developments that might affect safety. The remaining aerodromes safeguard themselves under privately agreed consultation with LPAs.

Through a pre-planning application process, which is described in the flow chart at Appendix 3, proposed wind turbine sites should be notified to the CAA's Directorate of Airspace Policy (DAP) and the Ministry of Defence (Defence Estates) prior to application for planning permission. DAP will plot the site in question and refer the developer to any civil aerodromes for which the proposed development might cause a potential safeguarding problem. DAP's assessment is generically based on the safeguarding requirements and guidance contained in CAP 168 and historical guidance drawn from CAP 428 as follows:

a) Developers will be referred to the aerodrome licensee of **aerodromes with a surveillance radar** facility within 30 km of the proposed wind turbine development or to the distance specified by the aerodrome or indicated on the aerodromes published wind turbine consultation map. the distance can be far greater than 30km depending upon a number of factors including the type and coverage of the radar and the particular operation at the aerodrome. To this end, aerodrome licensees should formally advise the DAP of any requirement extend the 30 km impact range associated with radar issues[1].

b) Developers will be referred to the aerodrome licensee of non-radar equipped **licensed aerodromes with runways of 1100 m or more** within 17 km of the proposed wind turbine development.

c) Developers will be referred to the aerodrome licensee of non-radar equipped **licensed aerodromes with runways of less than 1100 m** within 5 km of the proposed wind turbine development.

d) Developers will be referred to the aerodrome licensee of **licensed aerodromes where the proposed wind turbine development would lie within airspace coincidental with any published Instrument Flight Procedure (IFP)**. To this end, aerodrome licensees should formally advise the DAP of any requirement to extend those ranges highlighted in sub-paragraphs a) to c) to take account of the aerodrome's requirement to protect its IFPs[1].

e) Developers will be referred to the aerodrome operator of non-radar equipped **unlicensed aerodromes with runways of more than 800 m** within 4 km of the proposed wind turbine development.

f) Developers will be referred to the aerodrome operator of non-radar equipped **unlicensed aerodromes with runways of less than 800 m** within 3 km of the proposed wind turbine development.

1. Ranges highlighted to DAP should be generic, ie a single range for radar issues and IFP protection safeguarding.

Aerodrome licensees should address physical safeguarding issues in accordance with the guidance contained within CAP 168, and also CAP 738 as applicable. Operators of unlicensed aerodrome should refer to CAPs 428 and 738, as applicable.

Where areas of known civil aviation activity take place that are annotated on CAA VFR charts within 3 km of a proposed wind turbine development, but which are not related to a recognised or single aerodrome (for example, charted free-fall parachute drop zones, glider launch sites or hang/para-gliding winch launch sites), developers are referred to appropriate organisational points of contact.

The ranges employed in the DAP assessment are for guidance only. If proposed developments lay marginally outside the ranges highlighted above, but nevertheless in close proximity to other developments which are closer to an aerodrome, DAP will refer the developer to the aerodrome licensee or operator accordingly. The object of the pre-planning process is to flag up all possible aviation concerns to the developer at an early stage. As such, the DAP assessment is likely to err on the conservative side.

2 Obstructions and Lighting

Pilots of aircraft are required to carry aeronautical charts that will show the position of significant obstructions and their height above mean sea level. Obstacle lighting is not a substitute for the knowledge of the presence of such structures but is a significant and important aid to their visual acquisition and hence avoidance.

The treatment of land-based obstacles to air navigation is covered by existing legislation. Obstacles located close to licensed aerodromes are covered under Section 47 of the Civil Aviation Act 1982. Government aerodromes are similarly covered under the Town & Country Act (General Permitted Development) Order 2000. Article 133 of the Air Navigation Order 2005 (CAP 393) details the requirement for the lighting of land-based tall structures located outside of the safeguarded areas of licensed and government aerodromes.

Article 133 requires that structure away from the immediate vicinity of an aerodrome, which have a height of 150 m or more (Above Ground Level) are fitted with medium intensity steady red lights[1], positioned as close as possible to the top of the obstacle[2], and also at intermediate levels spaced so far as practicable equally between the top lights and ground level with an interval not exceeding 52 m. Obstruction lights should be illuminated at night, visible in all directions and, in the event of any lighting failure, rectified as soon as is reasonably practicable.

In addition, the CAA will provide advice and recommendations regarding any extra lighting requirements for aviation obstruction purposes where, owing to the nature or location of the structure, it presents a significant hazard to air navigation. However, in general terms, structures less than 150 m high, which are outside the immediate vicinity of an aerodrome are not routinely lit; unless the "by virtue of its nature or location" argument holds fast. unless the "by virtue of its nature or location" argument holds fast. UK AIP ENR 1.1.5.5 paragraph 4.3 refers.

1. 'Medium intensity steady red light' means a light which complies with the characteristics described for a medium intensity type C light as specified in Volume 1 (Aerodrome Design and Operations) of Annex 14 (Third edition November 1999) to the Chicago Convention.
2. In relationship to wind turbines, the requirement to fit aviation obstruction lighting 'as close as possible to the top of the obstacle', is translated to mean the fitting of lights on the top of the supporting structure (the nacelle) rather than the blade tips.

The CAA's DAP will provide further advice and guidance to wind turbine developers and local planning authorities on lighting requirements for en-route obstructions and will routinely comments that, in respect to a proposed wind turbine development, there might be a need to install aviation obstruction lighting to some or all of the associated turbines. This comment was made specifically if there were concerns expressed by other elements of the aviation industry; ie the operators. For example, if the Ministry of Defence or a local aerodrome had suggested such a need, we the CAA (sponsor of policy for aviation obstruction lighting) would wish, in generic terms, to support such a claim. We would do so if it could reasonably be argued that the structure(s), by virtue of their location and nature, could be considered a significant navigational hazard. That said, if the claim was clearly outside credible limits (ie the proposed turbine(s) was/were many miles away from an any aerodrome or it/they were of a height that was unlikely to effect even military low flying) the Authority would play an 'honest-broker' role. All that said, experience has shown that without the support of regulation or legislation based documents, planning authorities (or equivalent) which approve or otherwise turbine development, need to balance the aviation lighting requirement against other considerations (eg environmental).

The CAA's DAP will provide further advice and guidance to wind turbine developers on lighting requirements for en-route obstructions.

Recently introduced legislation requires the fitting of obstacle lighting, primarily for night-time use, on offshore wind turbines with a height of 60 m or more above the highest astronomical tide. Whilst Article 134 of the Air Navigation Order 2005 refers, in general, offshore wind turbines of 60 m and higher are required to be fitted with aviation obstruction lighting as follows:

a) At least one medium intensity steady red light positioned as close as possible to the top of the fixed structure; or

b) Where four or more wind turbines are located together in the same group, with the permission of the CAA only those on the periphery of the group need be fitted with obstruction lighting.

The downward spread of light is restricted as far as possible to minimize any potential confusion with maritime lighting whilst maintaining flight safety.

3 Obstacle Free-Zones Around Offshore Helicopter Platforms

The CAA has, for some years, indicated the need to maintain a 6 Nm obstacle-free zone around offshore helicopter destinations to allow for the safe operation of associated instrument approaches. This requirement has placed restrictions upon offshore wind turbine developments. The following paragraphs provide, in lay-terms, an explanation of the reasoning behind the 6 Nm zones. Whilst procedures will differ depending upon the platform, operator and aircraft type involved, the following notes are based upon JAR-OPS documentation and the practical application of such requirements:

a) **Basic Requirement**

The 6 Nm zone aims to provide a volume of airspace within which a controlled approach profile and, in the event of a pilot not being able to complete his approach, a missed approach, can be safely flown. Such profiles must allow for an acceptable pilot workload, a controlled rate of descent and allow for single-engine performance.

b) **Approach**

Routinely, helicopters making pilot-interpreted radar approaches to offshore destinations will commence the approach from not below 1500 ft. As helicopters approaching offshore platforms must make the approach substantially into wind, the approach could be from any direction. The obstacle-free zone must, therefore, extend throughout 360° to prevent restrictions being placed on the direction of instrument approaches. The approach sequence and descent below 1500 ft routinely commences at 6 Nm from the landing platform and the final approach starts at 4 Nm and 1000 ft. The helicopter descends to a minimum descent height (routinely 200 ft by day and 300 ft at night), which is commonly achieved within 2 Nm of leaving 1000 ft (at 2 Nm from the destination). Thereafter, it flies level at that height to the missed approach point. At 1.5 Nm from the offshore destination, the helicopter is turned 10° and at 1 Nm it is offset a further 5°, such that it would pass 300-400 m to one side of the destination structure. This can be to the left or right of the structure according to the circumstance prevailing on the day. If, at a range of 0.75 Nm from the installation, the pilot cannot continue the approach visually, a missed approach must be initiated.

c) **Missed Approach Procedure (MAP)**

On initiating a MAP, the helicopter is turned a minimum of 30° away from the destination structure and a climb initiated. This turn could be left or right. The anticipated rate of climb during the missed approach phase is based upon single engine performance criteria. For obvious safety reasons, a MAP, involving a climb from 200 ft, needs to be conducted in an area free of obstructions; safe avoidance of the destination structure being assured by the MAP turn.

In summary, wind turbines within 6 Nm of an offshore destination would potentially impact upon the feasibility to conduct some helicopter operations (namely, instrument procedures) at the associated site. Owing to the obstruction avoidance criteria, inappropriately located wind turbines could delay the descent of a helicopter on approach such that the required rate of descent (at very low level) would be excessive and impair the ability of a pilot to safely descend to 200/300 ft by the appropriate point of the approach (2 Nm). Moreover wind turbines within 6 Nm of an offshore platform may breach the integrity of the obstruction free status of the area in which a missed approach is carried out. Additionally, there might be a consequential economic impact relating to the operation of the offshore platform. This might also threaten the integrity of offshore platform safety cases where emergency scenarios are based on the use of helicopters to evacuate the platform.

4 Helicopter Main Routes (HMRs)

HMRs, as defined in the UK AIP, have been in use over the North Sea and in Morecambe Bay for many years. Whilst such routes have no lateral dimensions (only route centre-lines are charted) they provide a network of offshore routes utilised by civilian helicopters. Wind turbine development could impact significantly on operations associated with HMRs. The effect will depend on the degree of proliferation. A small number of individual turbines should cause minimal effect. However, a large number of turbines beneath an HMR could result in significant difficulties by forcing the aircraft to fly higher in order to maintain a safe vertical separation from wind turbines. The ability of a helicopter to fly higher would be dependant upon the zero degree isotherm (icing level); this might preclude the aircraft from operating on days of low cloudbase if the zero degree isotherm was at 2000 ft or below. From a regulatory perspective, whilst in an ideal world, the area 2 Nm either side of a HMR should be obstacle free, providing one side of the route was obstacle free, some wind turbine development within 2 Nm could be manageable.

5 Promulgation of Wind Turbine Developments

The need to promulgate the existence of tall structures that might constitute a significant aviation obstruction is self-evident. Notwithstanding the voluntary pre-planning notification, which advises civil and military aviation regulators of proposed future wind turbine developments, LPAs routinely advise the Defence Geospatial Intelligence organisation of all proposed developments. Through the updated promulgation of a database document, the DAP Aeronautical Charts and Data Section is advised of all such developments and update aviation charts accordingly. All wind turbines in excess of 300 ft above ground level are depicted on charts and details of each wind turbine are promulgated in the AIP, CAP 32, Section 5.4.

In addition, wind turbines which are less than 300 ft above ground level may be depicted on charts if their presence is deemed to be of navigational significance.

6 Certification of Safeguarding Maps

Maps of officially safeguarded aerodromes are signed on behalf of the Head of ASD before they are issued to LPAs. These signed maps denote that the CAA recognises them as being ones issued for the purposes of the Planning Circular and confirm it is the map the aerodrome wishes to use. Other aerodromes may produce a safeguarding map and request that their LPA recognise their wish to be included in consultation for planning purposes. However, these maps are not signed by ASD.

7 Wind Turbine Safeguarding Maps

In order to assist the consultation process with wind energy developers and in providing a diagrammatic illustration of the related aviation issues in discussion with LPA, many airfields have developed specific wind turbine safeguarding maps. These depict those areas where no development would be acceptable, those where development would be undesirable but some may be possible, and those areas where in principle, development could be tolerated but with some constraints (particularly to address cumulative effects and proliferation issues). The production of such maps is encouraged.

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Chapter 4 Potential Mitigation Measures

1 Operational Mitigation

1.1 Re-Routing Air Traffic

Where a wind turbine development is likely to impact on the provision of an Air Traffic Service, then the developer and service provider should cooperate to mitigate such impacts wherever possible. The re-routing of an aircraft around an area of wind turbine radar clutter may be required for the following reasons:

a) To maintain radar identification and situational awareness of flights; or

b) To provide radar separation between primary radar returns, where these returns form the basis for the separation being applied.

Subject to airspace restrictions, including environmental constraints, ATC may be able to re-route aircraft to avoid flying through radar clutter caused by wind turbine developments, thereby maintaining aircraft identity. This may have an impacts on the efficiency of the airspace concerned and the more wind turbine developments there are in an area, the more restricted the airspace may become.

In assessing any potential re-routing measures as mitigation, service providers will need to be aware of the need to comply with the CAA Airspace Change process if appropriate. Therefore, early consultation with DAP is essential and service providers are reminded that airspace changes designed solely to accommodate wind turbine developments are unlikely to be accepted.

Furthermore, any re-routing proposals will lead to a change in noise footprint and may lead to increased track miles being flown, thereby leading to an increase in CO_2 emissions. These factors will be considered by DAP when assessing any Airspace Change proposal in accordance with the Ministerial Directions to DAP and the associated Environmental Guidance[1].

1.2 Small Areas of Wind Turbine Radar Clutter

Small areas of radar clutter may be excluded from operational consideration, i.e. when vectoring aircraft, only when:

a) The small area of radar clutter will not conceal other aircraft that may be operating in the area; and

b) The radar identification of the aircraft and the situational awareness of the controller will not be lost when allowing an aircraft to pass through a small area of radar clutter.

Attention is drawn to the following issues that should be considered as part of the full safety assessment to mitigate any operational procedures that allow aircraft to fly through small areas of radar clutter:

a) The maximum extent of the wind turbine radar clutter that is tolerable. This may be related to the radar separation standard being applied in the vicinity of the clutter;

b) The proximity of the wind turbine radar clutter to the area where any turn manoeuvre is regularly conducted. For example, turns associated with SIDs,

1. CAP 725 - Environmental Guidance is currently being consulted on and is due for publication in August 2006.

STARs, RNAV, P-RNAV, Missed Approach routes and Radar Vectoring, including vectoring to Instrument/Final approach;

c) The proximity of the wind turbine radar clutter to other displayed wind turbine clutter areas i.e. the cumulative effect of the clutter;

d) The proximity of the wind turbine radar clutter to areas of regular aviation activity including GA activity;

e) The characteristics of the aircraft typically operating in the airspace concerned;

f) The radar system performance e.g. the update rate; and

g) The Air Traffic Service Unit complexity and workload.

2 Equipment Mitigation

2.1 Non Auto-Initiation Zones

Some plot extracted Primary Radar systems have the ability to define zones where plot extracted tracks will be prevented from initiating. However, mature tracks flying through the zone will not be inhibited. These zones are referred to as Non Auto Initiation Zones (NAIZ). NAIZ can be programmed in areas of wind turbine clusters to prevent the rotating blades from forming tracks within the cluster. Nevertheless, although the use of NAIZ may inhibit distracting tracks from being generated from within the wind turbine cluster, it may still be hazardous to allow real aircraft tracks to fly through the cluster. This is because, although not seen, the wind turbine blade radar returns still exist. If these are of equivalent or greater return signal strength than the real aircraft, it may seduce the aircraft track and display it in the wrong position. If this persists for several scans, the false track will eventually run out due to the extent of the cluster, but the real aircraft track may not appear due to the NAIZ rules until it emerges from the cluster. Therefore, when flying aircraft over a wind turbine development, NAIZ should be avoided unless it is known that the wind turbine returns are of significantly lower signal strength than the real aircraft returns in the area. NAIZ will stop real aircraft tracks starting within the zone. For example aircraft climbing into radar cover from low altitude may reach radar cover within the boundaries of an NAIZ and therefore not be shown until they emerge out of the zone. It is for this reason that the use of NAIZ is discouraged. Where NAIZ is used, the size of the zone should be minimal and proliferation of zones should be avoided.

2.2 Advanced Tracking Algorithms

Advanced Tracking Algorithms are classified as non-traditional tracking methods, for example using Alpha-Beta and Kalman based filters. Advanced methods include Particle Filtering, Multiple Hypothesis, Baysesian Algorithms and H-Infinity. These modern tracking systems make use of high capacity and speed processing systems to perform multiple calculations to determine the most probable target positions. These non-deterministic approaches to target detection and tracking have yet to be fully accepted in the UK civil radar arena, where more traditional deterministic tracking methods are the norm. These methods are currently undergoing trials to explore the feasibility of these concepts.

One of the problems that advanced tracking algorithms face is in proving that the software and algorithms work all of the time and will not produce hazardous results. This is in part due to the non-deterministic nature of the algorithms. As such, it may be difficult for any service provider to provide a robust safety assessment, including necessary verification evidence, for systems using advanced tracking algorithms. Nevertheless, this does not mean that it may not possible.

2.3 Use of SSR Only

The permanent use of SSR only in the Approach environment is not approved in the UK. This is due to the increased risk of non-transponder equipped aircraft remaining undetected and coming into conflict with aircraft receiving an air traffic service. However, it may be justifiable to use SSR only to maintain the identity of an aircraft transiting through small areas of airspace affected by the clutter caused by wind turbine developments. Attention is drawn to the following issues that should be considered as part of the full safety assessment to mitigate any operational procedures that allow aircraft to fly through small area of radar clutter:

a) The maximum extent of the wind turbine radar clutter tolerable. This may be related to the radar separation standard being applied in the vicinity of the clutter and the performance of the radar;

b) The proximity of the wind turbine radar clutter to other displayed wind turbine clutter areas i.e. the cumulative effect of the clutter; and

c) The likelihood that the wind turbine radar clutter will be hiding other aircraft.

It should be noted that the CAA is currently pursuing a proposal which it is intended will require the mandatory carriage and operation of Mode S in all UK airspace with effect from 31 March 2008. Although it is likely that there will be some exceptions to this proposal (e.g. winch launched gliders remaining within the pattern of a charted gliding strip) and that a transition period to achieve compliance is likely, this policy change has the potential to provide a significant mitigation to the effects of wind turbines on primary radar. This policy will be subject to full Regulatory Impact Assessment consultation. Progress on the regulatory changes and subsequent implementation will be notified through the appropriate publications and this CAP amended as appropriate. Furthermore, the potential amendment to regulatory requirements as a result of these proposed changes will be considered by CAA as necessary.

3 Hazard and Risk Assessment of Potential Mitigation Measures

Any mitigation, either Operational or Equipment, should be assessed to determine if new hazards are likely to be introduced. This should be in accordance with the Service Providers Unit Safety Management System. Ultimately, failure to address the issue may result in withdrawal of the Article 100/124 Approval thereby preventing the provision of the air navigation service.

In assessing proposed mitigations submitted by wind turbine developers, it is not unreasonable for an aviation stakeholder to request a supporting safety case. Whilst it is not unreasonable to place the burden of this requirement on the developer, it would be unreasonable to expect a developer to complete this work without full co-operation from the aviation stakeholder making the request.

There are a number of mathematical, or similar, models that are employed to demonstrate potential impacts of wind turbine developments on radar. Such models are constantly developing and will offer some guidance as to the likelihood of wind turbines presenting a radar return, although the nature of wind turbine operations vary in the unpredictability of both variable turbine rotation speed and the times of operation of individual turbines. Therefore, the degree of certainty as to whether a turbine, or group of turbines, will be displayed or not in marginal 'radar line of sight' cases cannot be guaranteed. In such cases safety should always be applied in a conservative manner.

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Chapter 5 Wind Turbine Development Planning Process

1 Pre-Planning and Consultation

The pre-planning consultation process is available to developers to establish, at an early stage, the potential for impact on aviation interests is described in Chapter 3.

A key purpose of this consultation process is to initiate liaison that will result in the obstacle limitation surface (OLS) surrounding an aerodrome remaining clear of obstructions. The most effective way of protecting these surfaces is for a LPA (or developer) to consult with the aerodrome or safeguarding consultee to request a safeguarding assessment. Early communication with sufficient details of any proposed developments together with co-operation is paramount between all parties to ensure progress for all sides.

2 Formal Planning

Regardless of whether the voluntary pre-planning consultation process has been followed, all proposals for wind turbine developments must eventually move into a formal approval process either through the Electricity Act or through the Town and Country Planning Acts if the project is to come to fruition. The process is outlined in the subsequent paragraphs, although these guidelines do not purport to be a comprehensive guide to planning procedures.

In England and Wales LPAs handle consent applications for land-based generating stations with a capacity up to 50 MW under the general planning regime set out in the Town and Country Planning Act. The Secretary of State for Trade and Industry considers applications for development consent under Section 36 of the Electricity Act 1989 (see below)[1] for land-based generating stations with a capacity greater than 50 MW and offshore[2] generating stations with a capacity over 1 MW.

In Scotland, there is a similar division of responsibility. Onshore stations of a capacity up to 50 MW are handled under the planning regime of the Town and Country Planning Act (Scotland). Similarly, onshore developments with a capacity greater than 50MW require consent from the Scottish Executive under Section 36. In Scotland, offshore developments are currently treated similarly to those in waters adjacent to England and Wales.

In Northern Ireland the Planning Service, an Agency within the department of the Environment, handles all proposals for land-based generating stations irrespective of capacity under the general planning regime set out in the Planning (Northern Ireland) Order 1991. All proposals for land-based generating stations with a capacity of 10MW and over must also obtain development consent from the Department of Enterprise, Trade and Investment in accordance with article 39 of the Electricity (Northern Ireland) Order 1992. The Electricity Act 1989 does not extend to Northern Ireland, although the procedures under the 1992 Order are broadly the same.

1. The act can be found at http://www.opsi.gov.uk/acts/acts1989/Ukpga_19890029_en_1.htm
2. Defined as between the low water mark and the seaward boundary of territorial waters, a distance of 12 nautical miles.

3 Call-Ins and Inquiries

3.1 **Call-Ins**

Whilst the aviation industry has no powers of veto, there is a legal obligation placed upon LPA to give warning if they are minded to grant planning permission against advice given by a statutory safeguarding consultee (ODPM/DfT/NAFW Circular 1/2003 and Scottish Executive Circular 2/2003 refer). This process offers an opportunity for the CAA to establish whether a solution is apparent or, if it fails to resolve the issue, to refer the matter for a decision by central Government. This procedure is always a last resort, as it is anticipated that communication and cooperation can obviate the need for it. This procedure is only applicable to those aerodromes listed in the Circular as 'officially' safeguarded.

3.2 **Inquiries**

In the event that a planning application is referred to a planning inquiry, CAA may be requested by the LPA to provide expert witness evidence. This may be by providing written statements or by attendance at the Inquiry.

4 Consistency, Accuracy and Use of Consultants

When aviation stakeholders are consulted over wind turbine developments, either at the pre-planning stage or once the formal planning application process has begun, it is critical that the responses made are consistent, factually accurate and cover all relevant aspects. It should be noted that these responses may be subject to challenge and CAA may be asked to provide an impartial regulatory perspective on what has been submitted.

In submitting a wind turbine development proposal, developers will regularly use consultants to prepare reports to counter any issues raised by aviation if the proposal is objected to. These reports are regularly forwarded to DAP for comment. In addition, as part of the formal process, developers are required to submit an environmental impact assessment which will address aviation issues and mitigations, often based on supporting reports commissioned by the developers. In responding to these documents, CAA will request that LPAs pursue any assertions or statements made in respect of aviation with the appropriate aviation stakeholder.

Appendix 1 Abridged Executive Summary of The Future of Air Transport - White Paper and the Civil Aviation Bill

This White Paper sets out a strategic framework for the development of airport capacity in the United Kingdom over the next 30 years, against the background of wider developments in air transport.

It does not itself authorise or preclude any particular development, but sets out a policy framework against which the relevant public bodies, airport operators and airlines can plan ahead, and which will guide decisions on future planning applications. It sets out the conclusions of the Government, and of the devolved administrations where appropriate, on the case for future expansion at airports across the country. In doing so it takes account of views expressed in an extensive consultation exercise, in the course of which around 500,000 responses were received.

The Government recognises the benefits that the expansion in air travel has brought to people's lives and to the economy of this country. Its increased affordability has opened up the possibilities of foreign travel for many people, and it provides the rapid access that is vital to many modern businesses. But we have to balance those benefits against the environmental impacts of air travel, in particular the growing contribution of aircraft emissions to climate change and the significant impact that airports can have on those living nearby.

Air travel has increased five-fold over the past 30 years, and demand is projected to be between two and three times current levels by 2030. Some of our major airports are already close to capacity, so failure to allow for increased capacity could have serious economic consequences, both at national and at regional level. That must be balanced by the need to have regard to the environmental consequences of air travel. The Government believes that simply building more and more capacity to meet demand is not a sustainable way forward. Instead, a balanced approach is required which:

- recognises the importance of air travel to our national and regional economic prosperity, and that not providing additional capacity where it is needed would significantly damage the economy and national prosperity;
- reflects people's desire to travel further and more often by air, and to take advantage of the affordability of air travel and the opportunities this brings;
- seeks to reduce and minimise the impacts of airports on those who live nearby, and on the natural environment;
- ensures that, over time, aviation pays the external costs its activities impose on society at large - in other words, that the price of air travel reflects its environmental and social impacts;
- minimises the need for airport development in new locations by making best use of existing capacity where possible;
- respects the rights and interests of those affected by airport development;
- provides greater certainty for all concerned in the planning of future airport capacity, but at the same time is sufficiently flexible to recognise and adapt to the uncertainties inherent in long-term planning.

As part of this approach, the Government believes more needs to be done to reduce and mitigate the impacts of air transport and airport development. At the global level, the Government will play a major role in pressing for new solutions and stronger action by international bodies. And the White Paper sets out proposals to bring aviation within the European Union emissions trading scheme, to help limit greenhouse gas emissions.

To tackle local impacts around airports, the White Paper prescribes a range of measures to be applied nationally and locally. These include new legislation and economic instruments as well as improved technology and stringent planning conditions attached to airport development. The Government's under-pinning objectives are to limit and, where possible, reduce noise impacts over time, to ensure air quality and other environmental standards are met, and to minimise other local environmental impacts. Where noise impacts cannot practically be limited, the White Paper sets out new measures which it expects airport operators to take to help those affected, by offering to insulate or, in more severe cases, purchase properties.

Looking at other broader issues, the White Paper sets out the Government's approach to the crucial areas of aviation safety and security, as well as proposals for further action to promote consumer interests. It emphasises the importance of aviation for the tourism industry, and of air freight for business in general.

Airport growth needs to reflect the Government's wider objectives for sustainable communities and helping to improve the economic performance of the English regions. Airports are particularly important for the development of regional and local economies, and proposals for their development need to be incorporated within the relevant spatial and economic development strategies. The Government wishes to encourage the growth of regional airports in order to support regional economic development, provide passengers with greater choice, and reduce pressures on more over-crowded airports in the South East. Proposals to establish Centres of Excellence for aircraft maintenance and aviation-related business clusters at or around regional airports could also contribute to these aims.

The Government recognises too that for many areas of the UK the availability of air services to London is crucial to their economic prosperity. Working within EU legislation, the Government will if necessary intervene to protect slots at the London airports through Public Service Obligations, subject to certain criteria being met. The Government will also work to secure improvements to the existing legislation. In addition, the Government considers that the establishment of Route Development Funds in Wales and some English regions - along the lines of those already operating in Scotland and Northern Ireland - could help to establish valuable new services.

Airports are an important part of our national transport infrastructure, and their development needs to be planned within that context. Current and future enhancements to the long-distance rail network could help to meet some future demand for travel on certain routes. Ensuring easy and reliable access to airports, which minimises environmental, congestion and other local impacts, is a key factor in considering any proposal for new airport capacity. The Government expects airport operators to develop appropriate access plans, and to contribute to the costs of the additional infrastructure or services needed.

The White Paper sets out the Government's conclusions on the future development of airport capacity across the UK region-by-region and case-by-case. Where appropriate these conclusions were reached in conjunction with the relevant devolved administrations. The main conclusions are summarised below. In all cases where development is envisaged, full environmental assessment will be required when specific proposals are brought forward.

Appendix 2 UK Government Renewable Energy Policy

1 General

This Appendix outlines UK energy policy and is based upon DTI guidelines, both up to and beyond 2010, discusses the potential contribution of wind energy and examines current and future wind energy technologies. The aim is to help those responsible for aviation interests to understand the Government's wind energy aims within a broader context.

Wind power is now a viable and well-established source of electricity generation, which creates no harmful emissions. As the UK is the windiest country in Europe, it is well placed to exploit this limitless resource. Consequently, the Government believes that wind power will play a major role in meeting policy targets for renewable energy generation over the next decade and beyond.

In February 2000, the Government published its conclusions on a policy for renewable energy, setting out targets for the amount of electricity to be generated from renewables in the near-term. These targets are to generate 10% of UK electricity from renewable energy sources by 2010 and 20% by 2020, as well as to cut carbon dioxide emissions by 60% by 2050. The 2010 10% target equates to 33.6 Terawatt-hours (TWh) per year of electricity. A substantial proportion of the target is likely to be met by wind energy. It is conservatively estimated by the BWEA that this could represent around 4,000 wind turbines, in both land-based and offshore locations.

Government policy does not set targets for individual renewable energy sources, but wind energy is currently the most economically viable renewable energy source. Therefore, it may be expected to make the largest contribution.

2 The Renewables Obligation

The Government has recently introduced the Renewables Obligation with the aim of increasing the amount of electricity generated in Great Britain from renewable sources, and thus contributing to a reduction in greenhouse gas emissions. The Obligation (and the associated Renewables Obligation (Scotland)), which came into force on 1 April 2002, requires that suppliers derive a specified and increasing proportion of the electricity they supply to customers from eligible renewables. The Renewables Obligation will create extra demand for renewable energy worth £1 billion by 2010.

The initial proportion of electricity generated from renewables is proposed to be 3% in the first period (2002-3), rising annually to over 10% in 2010-11. The Obligation will then remain at least constant after 2010, but may well be increased. It will not be reduced.

3 The Potential for Renewable Energy

A report commissioned by the DTI and the former Department of Transport, Local Government and the Regions (DTLR), which was published in February 2002, examined regional assessments of the potential for renewable energy generation in 2010. The report examined the proposed regional targets to find whether, in aggregate, they would meet the target set by the national government. It discovered that over half of the total of the regions' assessments consisted of wind power, both on and offshore, and even this may be an underestimate. Table 1 gives an indication, from the OXERA Report, of how different renewables technologies might contribute to the Renewables Obligation. The figures given are indicative only and do not reflect official Government policy or forecasts.

SOURCE	**Mwe**	**TWh**	**Proportion of RO5**
land-based wind	4542	11.9	37%
Offshore wind	1483	5.2	16%
Marine technology	72	0.2	1%
Landfill gas	615	4.8	15%
Biomass	874	6.5	20%
Anaerobic digestion	87	0.6	2%
Small hydro	111	0.4	1%
Photovoltaics	56	0.1	Less than 1%
Energy from biodegradable waste	329	2.4	8%
TOTAL	**8170**	**32.3**	**100%**

Table 1 Potential Renewable Electricity Generation in 2010 - High Estimate

The Scottish Executive Report "Scotland's Renewable Resource 2001" identified that there is enough potential energy from land-based wind power alone to meet Scotland's peak winter demand for electricity twice over. In all, the total renewable resource amounts to 75% of the total UK existing generating capacity. The study considered the potential availability of renewable resources out to 2020 and found that offshore wind and land-based wind could provide 82 TWh and 45 TWh respectively.

The next few years are likely to see large wind turbine developments in the UK. So far as land-based wind turbine developments are concerned, developers have plans for a number of large projects, predominantly in Scotland (including the islands) to take advantage of the windy conditions there. As for offshore wind, this is at an earlier stage of development in the UK but is now the focus of considerable attention by developers and may in due course overtake land-based wind in terms of its contribution to renewables targets. The country's first offshore wind turbines were installed off the coast of Blyth, Northumberland, in October 2000. Wind turbine developments at 19 sites around the UK coast are now planned and statutory consents have already been given for 30-wind turbine projects on Scroby Sands off the coast of Great Yarmouth, Norfolk (April 2002) and at North Hoyle off the coast of North Wales (July 2002). Looking ahead, much larger offshore wind turbine developments around the coast of the UK are in prospect.

4 Prospects for Wind Energy Post 2010

A report by the Cabinet Office's Performance and Innovation Unit (PIU)[1] in February 2002 made several recommendations for energy policy up to 2050. These include that

1. The report can be found at www.strategy.gov.uk/downloads/su/energy/theenergyreview.pdf

the target set for the proportion of electricity generated from renewables should be increased to 20% by 2020, in part owing to the fact that the UK will be subject to increasingly demanding carbon reduction targets. This is in line with the report's recommendation that measures should be taken over the coming decades to ensure the UK energy system is environmentally sustainable and affords security of supply. A White Paper on Energy Policy will be produced at the turn of the year and will include a Government response to the PIU Report. The Scottish Executive has set a target that 18% of the electricity generated in Scotland is from renewable resources by 2010 rising to 40% by 2020. The Executive has indicated that progress will be more readily monitored against an equivalent figure in terms of installed capacity, suggesting a total of 6000MW, although it should be noted that Ministers have confirmed this should not be regarded as a cap.

There is a likelihood that more stringent greenhouse gas targets will be adopted in the future and this will justify giving environmental objectives high priority within future energy policy. Wind energy is the most mature and economically viable renewable energy source and thus it follows that the growing priority given to renewable electricity will mean growing priority given to wind turbine development.

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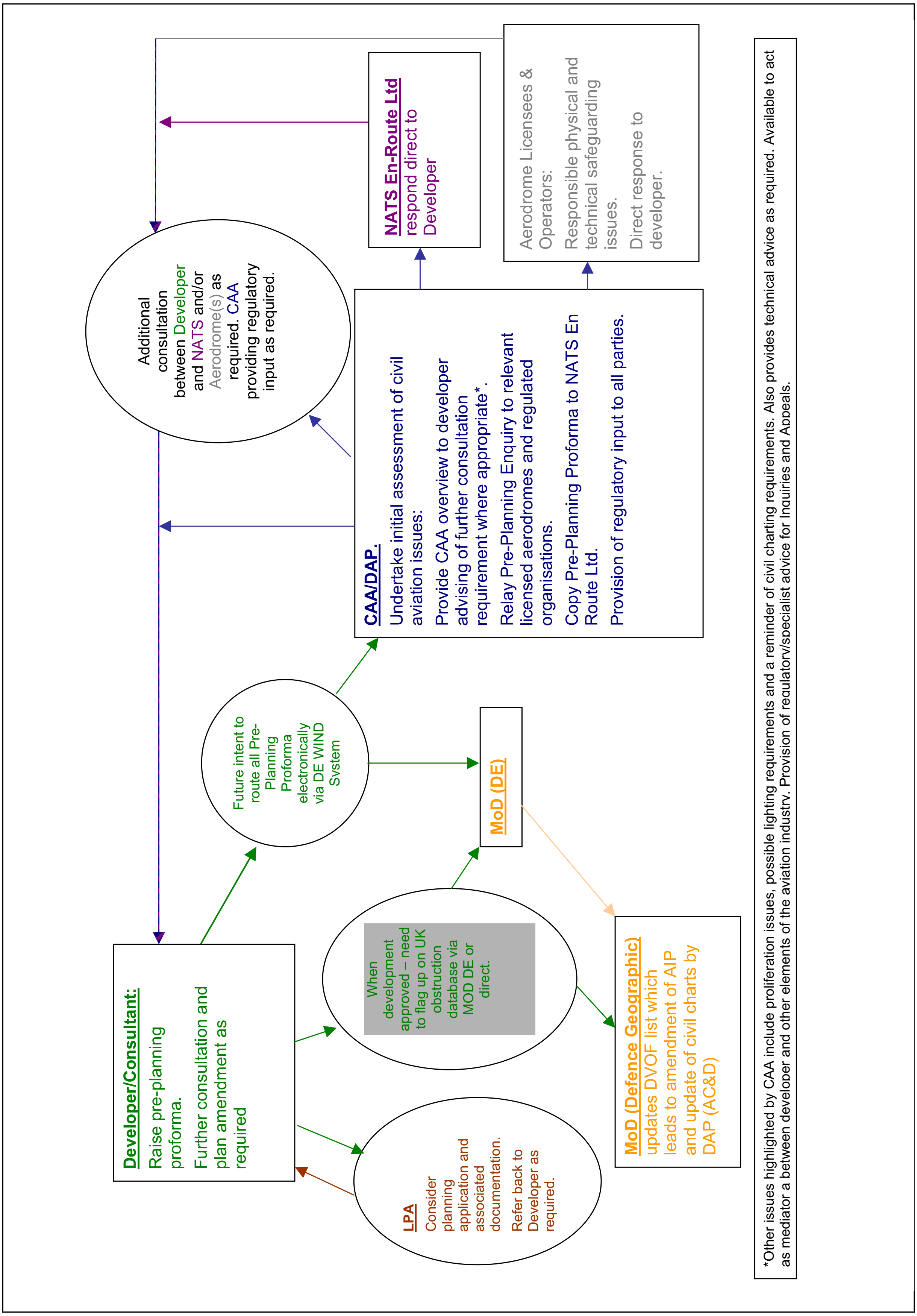
Appendix 3 Flow of Information Involving CAA/DAP



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Appendix 4 References[1]

CAP 32 (United Kingdom Integrated Aeronautical Information Package)

CAP 393 (Air Navigation Order)

ATSIN 56

Wind Energy and Aviation Interest Interim Guidelines

CAP 493 (Manual of Air Traffic Services Part 1)

CAP 168 (Licensing of Aerodromes)

CAP 428 (Safety Standards at Unlicensed Aerodromes)

CAP 670 (ATS Safety Requirements)

CAP 738 (Safeguarding of aerodromes)

CAP 760 (Guidance on the Conduct of Hazard Identification, Risk Assessment and the Production of Safety Cases)

CAA, AOA & GACC advice note on the Safeguarding of aerodromes

Joint ODPM, DfT, NAFW Planning Circular 1/2003 guidance on Safeguarding, Aerodromes, Technical Sites and Military Explosives Storage Areas

CM 6046 (Department for Transport, The Future of Air Transport)

CAP 725 (Airspace Change Process Guidance Document)

The Energy Review (www.strategy.gov.uk/downloads/su/energy/theenergyreview.pdf)

1. In all cases please refer to the latest edition

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Appendix 5 Contact Information

CAA Contacts

Directorate of Airspace Policy

Policy lead for CAA on wind turbine issues affecting aviation.

Civil Aviation Authority
Directorate of Airspace Policy
CAA House
45-59 Kingsway
London
WC2B 6TE

Contact: Manager, Surveillance and Spectrum Management
Telephone: 020 7453 6530
www.caa.co.uk/dap
windfarms@dap.caa.co.uk

Safety Regulation Group Aerodrome Standards

For information on aerodrome licensing criteria, obstacle limitation surfaces and call-in procedures, contact:

Civil Aviation Authority
Aerodrome Standards
Safety Regulation Group
Aviation House
Gatwick Airport South
West Sussex
RH6 0YR

www.caa.co.uk/srg
aerodromes@srg.caa.co.uk

Safety Regulation Group Air Traffic Safety Standards

Where a service provider has to update the safety documentation for a service as a result of a wind turbine development, then they should follow standard practice and contact their regional inspector for approval as necessary. Contact details are below:

CAA En-Route Regulation
Safety Regulation Group
Aviation House - 2W
Gatwick Airport South
West Sussex
RH6 0YR

Tel: (+44) (0)1293 573060
Fax: (+44) (0)1293 573974

E-mail to: ats.enquiries@srg.caa.co.uk (mark to 'En-Route Regulation')

Southern Regional Office (Gatwick)

By post:

Regional Manager ATS Safety Regulation (Southern Region)
Air Traffic Standards Department
Safety Regulation Group
Civil Aviation Authority
Aviation House
Gatwick Airport South
West Sussex
RH6 0YR

Tel (+44) (0) 1293 573426
Fax: (+44) (0) 1293 573974

By e-mail:
ats.southern.regional.office@srg.caa.co.uk

Central Regional Office (Manchester)

By post:

Regional Manager ATS Safety Regulation (Central Region)
Air Traffic Standards Department
Safety Regulation Group
Civil Aviation Authority
Suite 5a, Manchester International Office Centre
Styal Road
Wythenshawe
Manchester
M22 5WB

Tel: (+44)(0)161 499 3055 ext 221
Fax:(+44) (0) 161 499 3048

By e-mail:
ats.central.regional.office@srg.caa.co.uk

Northern Regional Office (Stirling)

By post:

Regional Manager ATS Safety Regulation (Northern Region)
Air Traffic Standards Department
Safety Regulation Group
Civil Aviation Authority
7 Melville Terrace
Stirling
Scotland
FK8 2ND

Tel: (+44) (0) 1786 431400
Fax :(+44) (0) 1786 448030

By e-mail:
ats.northern.regional.office@srg.caa.co.uk

Other Contacts

The Airport Operators' Association

3 Birdcage Walk
London
SW1H 9JJ

www.aoa.org.uk

British Wind Energy Association

Renewable Energy House
1 Aztec Row
Berners Road
London
N1 0PW

www.bwea.com

Department for Environment, Food and Rural Affairs

Nobel House
17 Smith Square
London
SW1P 3JR

www.defra.gov.uk

Department of Trade and Industry

1 Victoria Street
London
SW1H 0ET

Robert Lilly (Telephone 020 7215 6122; email Robert.Lilly@dti.gsi.gov.uk)

www.dti.gov.uk/energy/leg_and_reg/consents/index.shtml

Department for Transport

Great Minster House
76 Marsham Street
LONDON
SW1P 4DR

www.dft.gov.uk/stellent/groups/dft_aviation/documents/sectionhomepage/dft_aviation_page.hcsp

Ministry of Defence (Defence Estates)

Kingston Road
Sutton Coldfield
West Midlands
B75 7RL

Margaret Struebig (Telephone 0121 311 3847)
e-mail: margaret.struebig@de.mod.uk

www.defence-estates.mod.uk

National Air Traffic Services

Fifth Floor
Brettenham House South
Lancaster Place
London
WC2E 7EN

www.nats.co.uk

National Assembly for Wales

Planning Division
Cathays Park
Cardiff
CF10 3NQ

www.wales.gov.uk/subiplanning/index.htm

Northern Ireland Planning Service Headquarters

Millennium House
19-25 Great Victoria Street
Belfast
BT2 7BN

www.planningni.gov.uk

Department for Communities and Local Government

Eland House
Bressenden Place
London
SW1E 5DU

www.planning.dclg.gov.uk

Office of Gas and Electricity Markets (OFGEM)

9 Millbank
London
SW1P 3GE

www.ofgem.gov.uk

70 West Regent Street
Regents Court
Glasgow
G2 2QZ

Scottish Executive

Planning and Consents
Meridian Court
Cadogan Street
Glasgow
G2 6AT

www.scotland.gov.uk/planning

Appendix 6 DTI Governance and Meeting Structure

1 Aviation Steering Group: Wind Energy, Defence and Civil Aviation Interests

Aim

To facilitate the development of the wind industry, in order to meet the Government's targets for renewable energy production in 2010 and beyond, while ensuring that national defence and air safety are not compromised.

Objectives

a) To identify the issues associated with defence and civil aviation interests that affect the development of wind energy in the UK:

   i) provide a strategic approach to understanding the significance of issues identified; and

   ii) provide a high level understanding of current and developing policy amongst stakeholders;

b) To develop a programme of work for 2005-2007, which will accelerate the development of appropriate solutions or mitigation measures to the highest priority problems identified. This will include:

   i) development of mitigation technologies; and

   ii) streamlining and formalising the wind turbine developments pre-planning application process.

c) To generate guidance acceptable to all stakeholders. To encourage the widespread adoption of the guidance; and

d) To ensure that the actions taken, and future developments in the Wind and Aviation industries, lead to a significant reduction in planning rejections due to aviation and defence interests.

Membership

DTI
DfT
FES
Scottish Exe.
Welsh Assembly
ODPM
CAA
NATS (NSL)
NERL
Defence Estates
MoD representatives from ATC and AD
BWEA
AOA/BAA

2 Radar Sub-Group

Aim

To reduce the number of wind turbine developments planning rejections resulting from concerns about radar interference while enabling the aviation industry to maintain safety standards and improve their radar systems.

Objectives

a) To understand, how current developments in civil and military radar operations affect radar / wind turbine developments interactions;

b) To identify and to recommend to the ASG actions which are required to reduce the constraints on wind turbine developments;

c) To identify and evaluate mitigation technologies;

d) To prioritise work required enabling the effects of proposed wind turbine developments on radar systems to be deemed manageable by the system operators;

e) To maintain an oversight of the radar work programme and assessment of research outcomes;

f) To assess the impacts on civil and military radar from the Round 2 offshore developments;

g) To agree a consistent approach in assessing the impact of proposed wind turbine developments on radar signals; and

h) To improve the effectiveness of the wind turbine development pre-planning consultation process.

Membership

DTI
FES
CAA
NATS (NSL)
NERL
Defence Estates
MoD representatives from ATC and AD
BWEA
AOA/BAA
Developers (Scottish Power, RES Ltd. and RWE npower Renewables)

3 Editorial Sub-Group

Aim

To educate stakeholders about the effects of wind turbine developments on the aviation industry and promote in order to accelerate the consenting process and reduce costs to the developers, MoD, NATS and the airport operators.

Objectives

a) To periodically review and update the Guidelines on wind energy and aviation interests and ensue that all stakeholders agree them;

b) To encourage the widespread adoption of these guidelines by the wind industry and aviation stakeholders by:

   i) Reviewing the use and effectiveness of the current guidance and communications to key stakeholders;

   ii) Recommending how the new guidance will be distributed and promoted; and

   iii) Overseeing the distribution, promotion and uptake of the new guidelines.

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Appendix 7 Proposed Assessment Method for Determining the Impact of Wind Turbines on Aeronautical Radar Stations

1 Introduction

As part of the UK Government's commitment to generating electricity from alternative 'Green' energy sources, it is providing incentives for the development of wind turbines throughout the United Kingdom. Due to the tower height and blade size of a wind turbine, it is known that these can cause unwanted reflections to radar positioned within line of site of a wind turbine development. The effect is to display false targets (clutter) on a radar screen and to obscure the detection of a wanted target such as an aircraft.

In view of the complex issues surrounding wind turbine development, a method could assist in assessing whether such a development is likely to be detected by an aeronautical radar station and the impact this will have upon its operational effectiveness. Use of this method is voluntary and there are other means, eg. commercial software packages which can provide similar results. Advice is available from CAA/DAP on the use of such techniques or software

2 Background

At the Aviation Interests Radar Sub-Group meeting held on 1 April 2003, the CAA presented a paper proposing an outline method for assessing the impact of wind turbines on aeronautical primary radars.

The aim of this assessment method was to provide a first order approximation to the detection of wind turbines by radar, and the impact of a wind turbine development upon the airport approach/en-route functionality at a particular radar site. With this knowledge a radar operator could respond appropriately to a wind turbine development planning application.

This appendix provides CAA, a worked example using this methodology. It is important however, to remember that this is only an un-validated illustration.

3 General Principles

This assessment method relies upon the availability of radar cross-sectional (RCS) data for the static (tower, nacelle, etc) and moving (rotor blades) elements of the proposed wind turbine(s). It should be noted, that where these figures are not available, data derived from a generic wind turbine could be substituted. Similarly, it is assumed that radar vertical aperture antenna patterns would be available as PLM data tables.

This method also relies on the availability of a propagation prediction tool with a Digital Terrain Mapping (DTM) database of good resolution (i.e. 50 m or better).

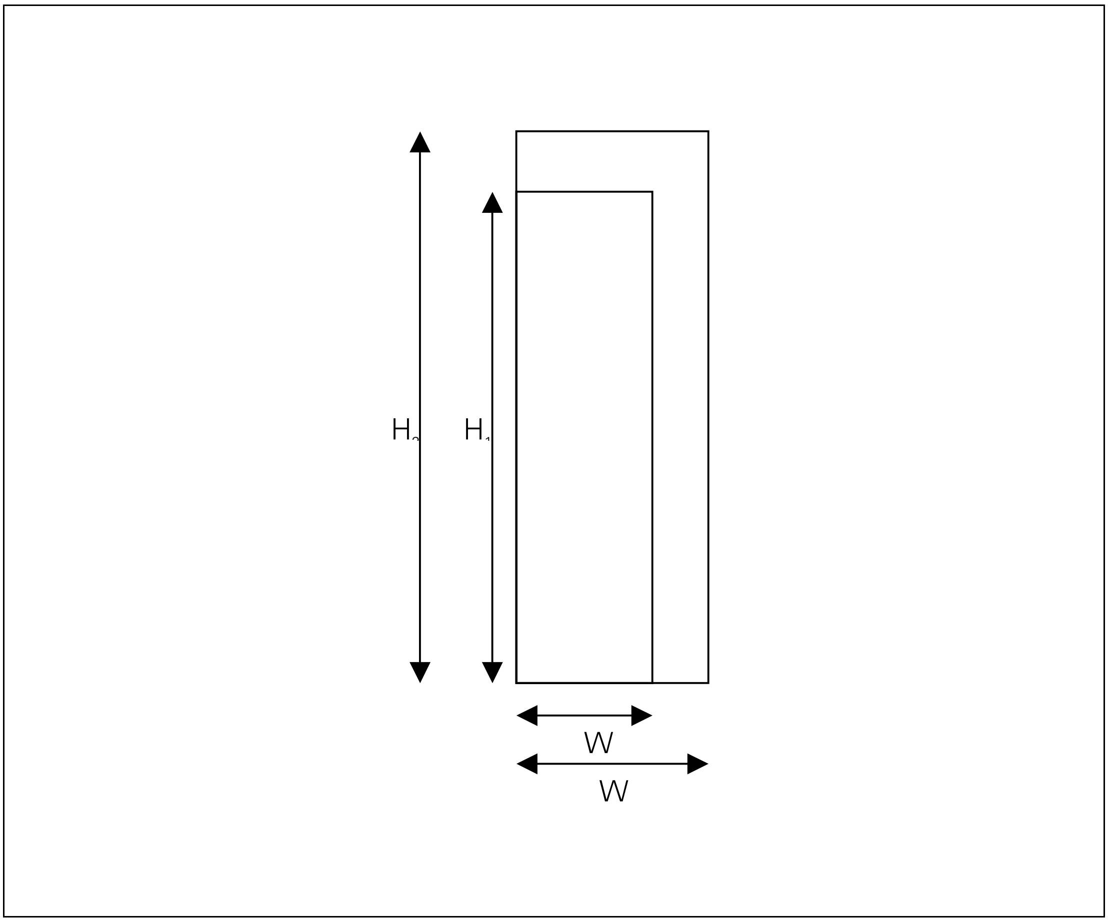
A key objective of this assessment method is to ensure that it is open and transparent. With the above pre-requisites in place, it is envisaged that anyone could enter the relevant data into an agreed pro-forma or spreadsheet and obtain an initial assessment as to the visibility of a wind turbine development upon a particular primary radar station.

4 Methodology

4.1 Assessment of the RCS area of the wind turbine

In order to assess the radar returns from a wind turbine, the RCS area values for the static and moving elements of the wind turbine are required. However, where figures for the wind turbine being considered are not available, they can be derived using generic wind turbine values.

Derivation of figures using generic values and a scaling factor is illustrated below:



Where: H2 = A x H1

Then W2 = A x W1

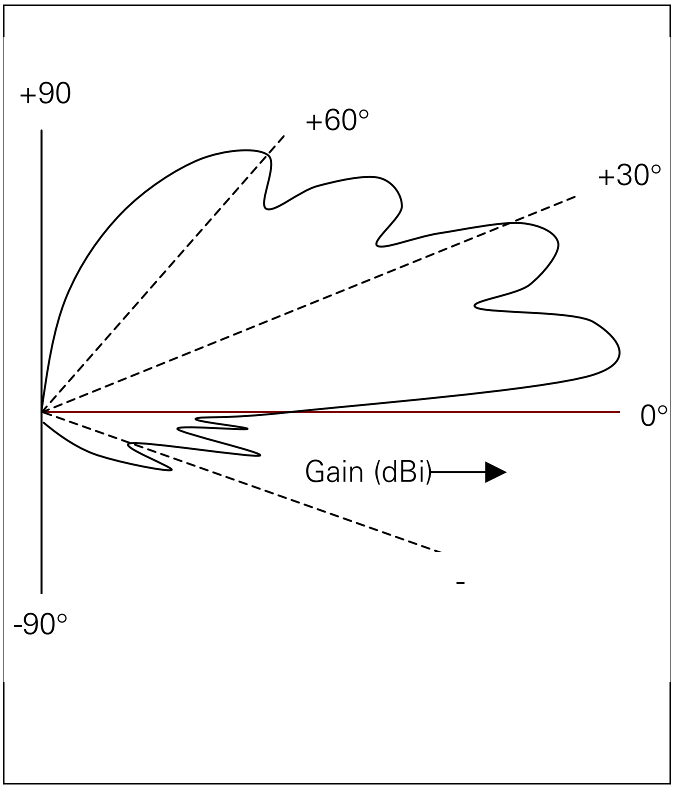
And Radar Cross-Sectional area = A2 x Generic Radar Cross-Sectional Area

Therefore, if we know the RCS area for a generic wind turbine, the figure for a specific wind turbine can be derived for both the static and moving elements.

4.2 Radar antenna PLM data

PLM values for the radar antenna's vertical aperture gain profile are also required for the assessment. The table below contains hypothetical values that could be expected for a typical S-band radar antenna. It should be noted that the gain figures contained in any PLM table would be relative to the antenna's axis, and any calculation would require an offset to be applied according to the amount of tilt (this information would be supplied by the radar operator).

Off-axis Elevation Angle	Gain (dBi)
-3.0	5
-2.5	7
-2.0	11
-1.5	14
-1.0	12
-0.5	10
0	15
+0.5	22
+1.0	30
+1.5	34
+2.0	32
+2.5	31
+3.0	31



4.3 **Determine elevation angles and separation distance**

A propagation prediction tool is used to determine the elevation angle and separation distance from the electrical centre of the radar antenna to the middle of the maximum overall height of the wind turbine.

4.4 **Divide wind turbine structure into parts**

The wind turbine structure is divided into parts of equal height. The RCS area, for the static and moving elements are then apportioned on a pro-rata basis. For the moving elements, i.e. the blades and rotor, the RCS area for each part is determined by the position that provides the largest return to the radar. In the case of wind turbine blades the RCS area will vary according to the amount of blade area that is visible to the radar.

4.5 **Determination of the path loss between a radar antenna and wind turbine**

This step is performed using a coverage prediction tool with a Digital Terrain Mapping (DTM) database.

The total predicted path loss and the free space path loss between the radar antenna and the top part of each wind turbine is determined using ITU-R Recommendations P.525 and P.526, assuming K=4/3. A difference between the path loss and free space loss can be expected, which is due to the geographical terrain between the wind turbine and the radar.

4.6 **Determine the radar return for each part of the wind turbine structure**

The aim of this step is to determine the amount of signal reflected back to the radar from each of the constituent parts of the wind turbine's structure. The reflected signal can be estimated for both static and moving parts.

To do this, we use the equation specified in ITU-R P.525-2 for the free-space basic transmission loss (Lbr) of a radar system:

$L_{br} = 103.4 + 20 \log_{10} f + 40 \log_{10} d_{km} - 10 \log \sigma$

Where: f: Frequency (MHz)

σ: Radar target cross section (square metres)

However, in order to determine the actual transmission loss we need to modify the equation to include the additional attenuation (L_{att}) in each direction, as follows:

L_{br} (actual) = $103.4 + 20 \log_{10} f + 40 \log_{10} d_{km} + (2 \times Latt) - 10 \log \sigma$

The level of the reflected signal level seen by the radar receiver (P_r) can then be calculated as follows:

P_r = Tx power - Tx loss + Tx Ant Gain - Lbr (actual) + Rx Ant Gain - Rx loss

By substituting: Tx power - Tx loss + Tx Ant Gain with 'EIRP'
Rx Ant Gain - Rx loss with 'Rx System Gain'

We can simplify the equation as follows:

P_r = EIRP - L_{br} (actual) + Rx System Gain

Having determined the power received from all of the individual static elements of the wind turbine, the total power returned is determined by the summation of these individual parts. A similar calculation is then performed for the moving elements of the wind turbine.

Interpretation of results

Calculations performed up to and including section 4.6 provide the total power received by the radar from both the static and moving elements of the wind turbine. In order to determine whether the radar can theoretically detect the wind turbine, we need to compare these results with the figures specified for the sensitivity of the radar receiver.

Where the radar has a speed filter then, only the power figure for the wind turbine's moving elements is considered. However, if the radar is not fitted with or not using a speed filter then the summed value of both the static and moving power components need to be considered.

5 Conclusions

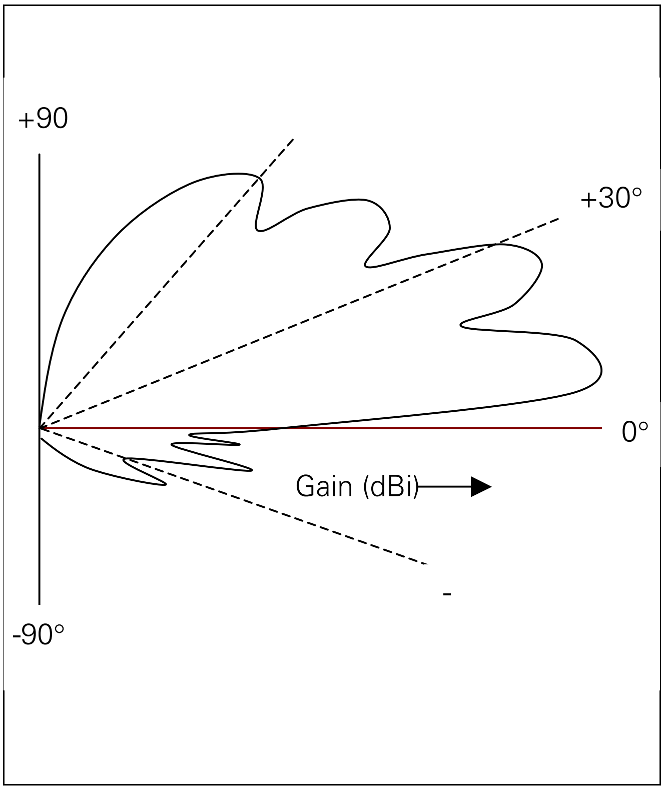
This methodology provides a means of determining whether a wind turbine will be theoretically visible to a radar station. On the basis of this, and a knowledge of the radar's operational requirement a radar operator can determine whether they wish to object to a proposed development of a new wind turbine development.

A Worked Calculation

A1.1 Input Parameters

Generic Wind Turbine:	Height of tower	= 50 m
	Tower Radar Cross-Sectional Area	= 80 m2
	Blade Length	= 30 m
	Blade Radar Cross-Sectional Area	= 9 m2
Wind Turbine:	Height of the Tower	= 60 m
	Blade Length	= 40 m
	Number of Blades	= 3
Path:	Length	= 31.3 km
	Slope	= +1 degree
Radar:	Power Radiated	= 80 dBW
	Sensitivity	= -130 dBW
	Down Tilt	= 2 degrees
	Frequency	= 2765 MHz
	Receiver loss	= 3 dB
	Speed filter	= Fitted/Operational

Off-axis Elevation Angle	**Gain (dBi)**
-3.0	5
-2.5	7
-2.0	11
-1.5	14
-1.0	12
-0.5	10
0	15
+0.5	22
+1.0	30
+1.5	34
+2.0	32
+2.5	31
+3.0	31



A1.2 **Assessment of the Radar Cross-Sectional Area of the Wind turbine**

Since no specific data is available for the wind turbine under consideration, RCS figures need to be calculated using generic values.

Static Element: Scaling factor = 1.2 (60/50)
Radar cross-sectional area = 115.2 m2 (80 x 1.22)

Moving Element: Scaling factor = 1.33 (40/30)
Radar cross-sectional area = 16 m2 (9 x 1.332)

A1.3 **Radar Antenna PLM Data**

From the data provided by the input parameters for the radar antenna PLM, the down tilt of the radar antenna and the path slope of the antenna gain in the direction of the wind turbine development can be derived as follows:

The off-axis elevation angle = Radar down tilt + path slope
= 3 degrees (2+1)

The gain of the radar antenna towards the wind turbine = 31 dB

A1.4 **Determine Elevation Angles and Separation Distance**

The Elevation angle and the separation distance is derived from the path profile, but for illustrative purposes they are given here as +1 degrees and 31.3 km respectively.

A1.5 **Divide Wind Turbine Structure into Parts**

Given that the overall height of the wind turbine in this example is 100 m, 10 m sections have be considered. Also, the peak returns from the moving elements of the wind turbine have been determined with the wind turbine blades pointing vertically.

Height (m)		10	20	30	40	50	60	70	80	90	100
RCS	Static (m2)	19.2	19.2	19.2	19.2	19.2	19.2	0	0	0	0
	Moving (m2)	0	0	0	0	16.0	16.0	4.0	4.0	4.0	4.0

A1.6 **Determine the radar return for each part of the wind turbine structure**

In order to assess the radar return from each part of the wind turbine structure, the additional attenuation over free space path loss needs to be determined. This can be achieved with use of a coverage prediction tool. For the case under consideration this tool gives the following path loss results:

Height (m)	10	20	30	40	50	60	70	80	90	100
Actual One-Way Path Loss (dB)	163.2	161.7	160.0	158.0	155.6	153.0	144.3	138.6	135.7	133.5
FSPL (dB)	132.0	132.0	132.0	132.0	132.0	132.0	132.0	132.0	132.0	132.0
Additional Attenuation (dB)	31.2	29.7	28.0	26.0	23.6	21.0	12.3	6.6	3.7	1.5

With this information, the radar return from both the static and moving elements of the wind turbine can be determined:

(i) Static parts (tower, nacelle etc)

EIRP = 80 dBW

Rx System Gain = 31 - 3 = 28 dB

Height (m)	σ	L_{br} (dB)	L_{att} (dB)	L_{br} (actual)	P_r (dBm)
10	19.2	219.0	31.2	281.6	-143.6
20	19.2	216.0	29.7	278.6	-140.6
30	19.2	212.6	28	275.2	-137.2
40	19.2	208.6	26	271.2	-133.2
50	19.2	203.8	23.6	266.4	-128.4
60	19.2	198.6	21	261.2	-123.2
70	0				
80	0				
90	0				
100	0				
				Total	-121.5

(ii) Moving static parts (tower, nacelle etc)

EIRP = 80 dBW

Rx System Gain = 31 - 3 = 28 dB

Height (m)	σ	L_{br} (dB)	L_{att} (dB)	L_{br} (actual)	P_r (dBm)
10	0				
20	0				
30	0				
40	0				
50	16	204.6	23.6	267.2	-129.214
60	16	199.4	21.0	262.0	-124.014
70	4	188.0	12.3	250.6	-112.635
80	4	176.6351	6.6	239.2	-101.235
90	4	170.8351	3.7	233.4	-95.4351
100	4	166.4351	1.5	229.0	-91.0351
				Total	-89.4

Overall power received = -89.3 dBm

A1.7 **Interpretation of the results**

The static parts give a received power of -121.5 dBm which is below the receiver sensitivity and hence should not be received. The moving parts however are above the sensitivity level and hence is likely to be detected.