

Welsh Government

**Assessment of onshore wind and  
solar energy potential in Wales**

Stage 1 - Development of Priority  
Areas for Wind and Solar Energy

Issue | 7 March 2019

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 263184-00

**Ove Arup & Partners Ltd**  
63 St Thomas Street  
Bristol BS1 6JZ  
United Kingdom  
[www.arup.com](http://www.arup.com)

**ARUP**

# Document Verification

<b>Job title</b>		Assessment of onshore wind and solar energy potential in Wales		<b>Job number</b>		263184-00	
<b>Document title</b>		Stage 1 - Refinement of Priority Areas for Wind and Solar Energy		<b>File reference</b>			
<b>Document ref</b>							
<b>Revision</b>	<b>Date</b>	<b>Filename</b>	Onshore wind and solar energy potential assessment_Final report				
Draft 1	November 2018	<b>Description</b>	First draft				
			Prepared by	Checked by	Approved by		
		Name	Kirsty Smyth	Bethan Lawson / David Brown	Ann Cousins		
		Signature					
Draft 2	28 Feb 2019	<b>Filename</b>	WG energy potential assessment_FINAL.docx				
		<b>Description</b>	Updated based on WG comments				
			Prepared by	Checked by	Approved by		
		Name	Kirsty Smyth	Bethan Lawson / Ann Cousins	Peter Hulson		
		Signature					
Issue	7 Mar 2019	<b>Filename</b>	WG energy potential assessment_FINAL_07.03.docx				
		<b>Description</b>	Arup comments addressed				
			Prepared by	Checked by	Approved by		
		Name	Bethan Lawson	Ann Cousins	Peter Hulson		
		Signature	 pp				

Issue Document Verification with Document



Mae'r ddogfen yma hefyd ar gael yn Gymraeg.  
This document is also available in Welsh.

## Contents

---

	Page
<b>1 Introduction</b>	<b>3</b>
1.1 Project background and purpose	3
1.2 Project approach	3
1.3 Report overview	4
<b>2 Policy context and background</b>	<b>6</b>
2.1 Current policy and consenting regime	6
2.2 Future policy and consenting	9
<b>3 Overview of dashboard and methodology</b>	<b>11</b>
3.1 Approach to methodology development	11
3.2 Stages of methodology	12
3.3 Tool	13
<b>4 Options and analysis</b>	<b>14</b>
4.1 Introduction	14
4.2 Analysis	14
<b>5 NDF policy options</b>	<b>21</b>
5.1 Introduction	21
5.2 Areas of most opportunity	21
5.3 Areas of varying opportunity	22
5.4 Areas of least opportunity	22
5.5 Spatial analysis	23
<b>6 Recommendations and next steps</b>	<b>28</b>
6.1 Conclusions	28
6.2 Next steps for NDF policy	28
6.3 Guidance for local planning authorities and regional planning	29
6.4 Energy Atlas	29

## Tables

Table 1: Areas available for scenarios 1 and 4

Table 2: Scenario specific benefits and challenges

Table 3: Categorisation of constraints – fixed constraints

Table 4: categorisation of constraints – user variable constraints

Table 5: Area associated with measuring ‘areas of most and varying opportunity’

- Table 6: Assessment of options for policy related to areas of most opportunity  
Table 7: Assessment of options for policy related to areas of varying opportunity  
Table 8: Assessment of options for policy related to areas of least opportunity  
Table 9: Rationale for, and considerations which could provide evidence for inclusion or exclusion of the priority areas (within their given zones) in the NDF  
Table 10: Fixed constraints applied to all scenarios  
Table 11: Categorisation of constraints – overlay constraints

## Figures

- Figure 1: Overview of project development  
Figure 2: Visual overview of the methodology  
Figure 3: Wind preferred scenario  
Figure 4: Solar preferred scenario  
Figure 5: Map of priority areas for refinement

## Appendices

### Appendix A

Methodology

### Appendix B

Summary of constraints used to assess potential scenarios

**B1 Summary of underpinning fixed assumptions – wind and solar**

**B2 Summary of underpinning variable assumptions – wind**

**B3 Summary of underpinning variable assumptions – solar**

**B4 Maps of scenarios**

### Appendix C

Categorisation of constraints - overlay constraints

**C1 Categorisation of constraints – overlay constraints**

### Appendix D

Further maps

# 1 Introduction

---

## 1.1 Project background and purpose

Welsh Government commissioned Ove Arup and Partners Ltd. (Arup) to undertake research into the onshore wind and solar energy development opportunities and constraints in Wales to inform the preparation of an Energy Atlas for Wales and the National Development Framework (NDF). This was achieved by producing an interactive tool to indicate the potential output of onshore wind and solar energy across Wales against specific technical, environmental and landscape constraints. This report forms Arup's response to the specification set out by the Welsh Government.

The objectives for this study were two-fold;

- To identify the most appropriate locations for a range of scales of onshore wind and solar energy development in Wales (community scale to Developments of National Significance (DNS) and Nationally Significant Infrastructure Projects); and
- To provide data and maps to form part of an Energy Atlas for Wales and to support the development of spatial policies in the NDF.

## 1.2 Project approach

In order to deliver on the project objectives, the following tasks were undertaken between August 2018 and January 2019;

- Creation of a methodology to undertake the onshore wind and solar energy assessment and specify the logic for the interactive tool, as outlined in Section 3;
- Stakeholder engagement in the form of two key workshops. The first provided input into the methodology, and the second input into the analysis of outputs to support policy as discussed in Section 3;
- Assessment of energy potential and development of maps showing suitable locations for onshore solar and wind energy development using GIS; and
- Analysis of the outputs to inform policies to be taken forward in the NDF.

The project approach is shown visually in Figure 1. Continuous dialogue was maintained with Welsh Government throughout the duration of the project to inform decisions.

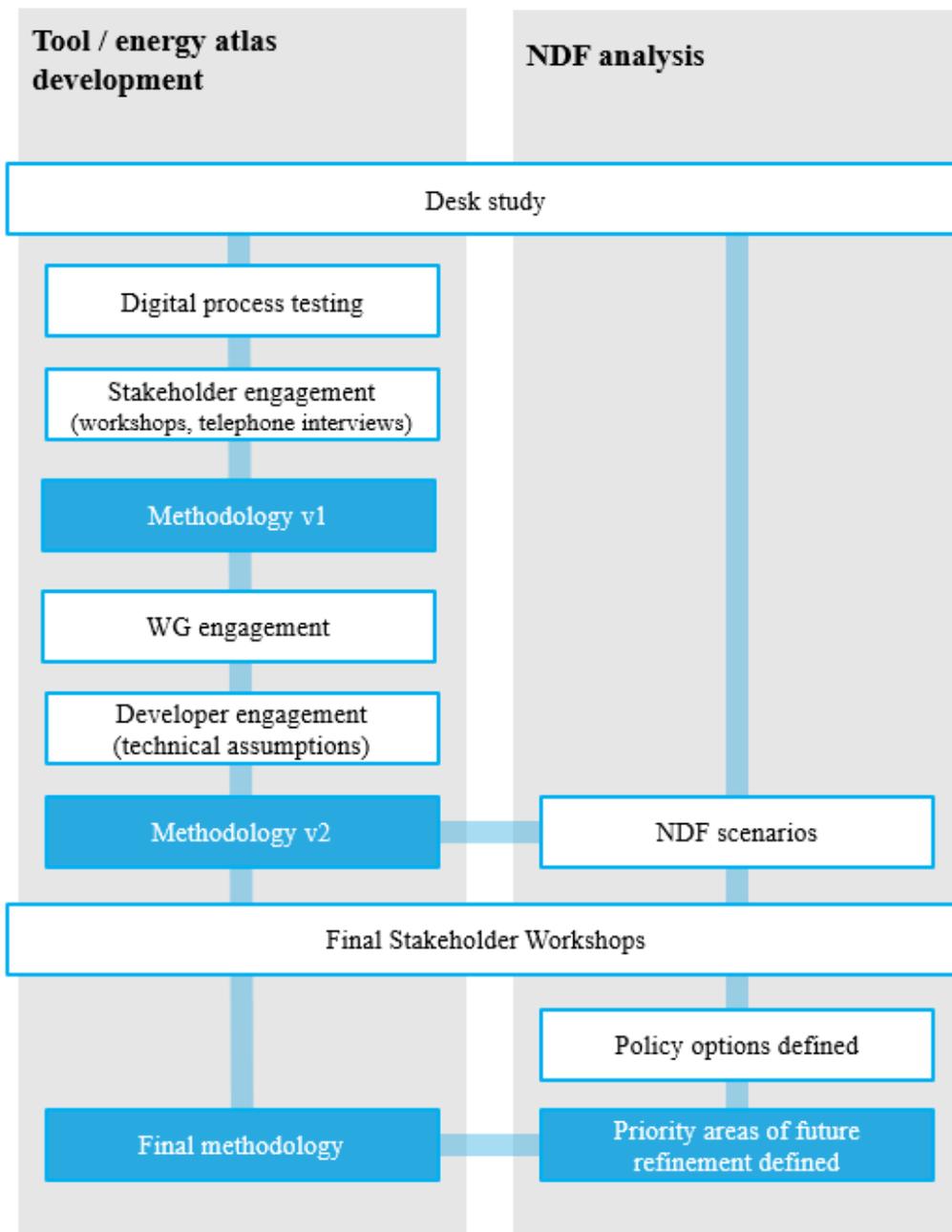


Figure 1: Overview of project development

### 1.3 Report overview

This report provides a summary of the approach taken to deliver the objectives. The remainder of this report is structured as follows:

- Section 2 provides an overview of the policy context surrounding the project requirements;
- Section 3 provides a summary of the approach taken by Arup to develop the method for assessment of the onshore wind and solar potential of Wales;

- Section 4 provides the approach to developing mapped outputs required for the Energy Atlas and the NDF;
- Section 5 presents the options for NDF policy development for given areas; and
- Section 6 provides recommendations for the NDF outputs and an exploration of recommended next steps.

## 2 Policy context and background

---

### 2.1 Current policy and consenting regime

#### 2.1.1 Energy and climate change policy

The Welsh Government has identified that energy and the environment is a priority sector for Wales<sup>1</sup>.

The Environment (Wales) Act 2016<sup>1</sup> details the various actions that must be taken across different sectors to protect Wales' natural resources. The Act sets out that net Welsh emissions must be at least 80% lower than a defined base level and that ministers must set interim emissions targets and carbon budgets in order to meet the 2050 goal.

In order to achieve this, Ministerial commitments have been made which seek:

1. for Wales to generate 70% of its electricity consumption from renewable energy by 2030;
2. for one gigawatt of renewable electricity capacity in Wales to be locally owned by 2030; and
3. for new renewable energy projects to have at least an element of local ownership by 2020.

#### 2.1.2 Planning policy

The current policy context for onshore wind and solar developments in Wales is focussed on Planning Policy Wales (PPW) (Edition 10) at the national level. This is supported by Technical Advice Note (TAN) 8<sup>2</sup> which was developed in 2005 and reflected technology available at the time.

At the local level, Local Development Plans (LDPs) have utilised the Renewable Energy Assessment (REA) process to inform renewable energy opportunities and targets and through the latest edition of PPW, local authorities are being asked to set renewable energy targets as part of any LDP refresh process.

### Planning Policy Wales 10

Published in December 2018, Edition 10 of Planning Policy Wales ("PPW") establishes the national planning policy framework for guiding development throughout Wales. PPW is closely aligned with the Well-being of Future Generations (Wales) Act 2015 and its focus on sustainable development in the context of wellbeing of future generations. PPW defines sustainable development as 'the process of improving the economic, social, environmental and cultural

---

<sup>1</sup> <http://www.legislation.gov.uk/anaw/2016/3/contents>

<sup>1</sup> <http://www.legislation.gov.uk/anaw/2016/3/contents>

<sup>2</sup> <https://gov.wales/topics/planning/policy/tans/tan8/?lang=en>

well-being of Wales by taking action, in accordance with the sustainable development principle, aimed at achieving the well-being goals’.

PPW sets out that Local Planning Authorities should ensure that ‘social, economic, environmental and cultural benefits are considered in the decision-making process and assessed in accordance with the five ways of working to ensure a balanced assessment is carried out to implement the Well-being of Future Generations Act and the Sustainable Development Principle’ (paragraph 2.21). PPW acknowledges that it may not always be possible for development proposals to benefit all aspects of sustainable development equally. In such cases, the document states that strong evidence should be presented in support of these decisions.

PPW outlines that Planning authorities should give significant weight to renewable and low carbon energy generation targets. In circumstances where protected landscape, biodiversity and historical designations and buildings are considered in the decision-making process, only the direct irreversible impacts on statutorily protected sites and buildings and their settings (where appropriate) should be considered.

The policy document also explicitly requires planning authorities to identify spatial areas in their development plan where renewable energy developments will be permitted, as well as requiring local authorities to establish targets for renewable energy generation.

## Technical Advice Note 8: Planning for Renewable Energy

Published in 2005, Technical Advice Note (TAN) 8 provides advice to supplement the policy in PPW. The TAN identifies seven Strategic Search Areas (SSAs) where large scale onshore wind development should be focussed in Wales and provides further guidance in relation to land use planning considerations of renewable energy.

In relation to onshore wind, the TAN directs large scale onshore wind developments to the SSAs and also encourages support for onshore wind within urban/ industrial brownfield sites for up to 25MW.

The TAN encourages LPAs to assess the detailed locational requirements for the siting of onshore wind developments and refine the SSAs where appropriate. In addition, it encourages Local Planning Authorities to consider the cumulative impact of small schemes in areas lying outside of the SSAs and establish suitable criteria for separation distances from each other and from the perimeter of existing wind power schemes or the SSAs.

The TAN does not contain a large amount of guidance in relation to solar developments and does not identify specific search areas for this purpose. The TAN does outline that proposals should be supported for appropriately designed solar thermal and solar photo-voltaic systems with the exception of circumstances where visual impact is critically damaging to a listed building, ancient monument or a conservation area vista.

## Renewable Energy Assessments

Welsh Government Practice Guidance: Planning for Renewable and Low Carbon Energy – A Toolkit for Planners provides a framework for local planning authorities to develop an evidence base for the LDPs. The renewable energy assessment (REA) process was designed to enable LPAs to identify potential areas for renewable energy development and to inform the development of renewable and low carbon energy policies.

The toolkit highlights the opportunities with using GIS to aid the LDP process, through the use of constraint layers across various geographies. The toolkit nevertheless embraces that although there may be constraints in a location, it is not to be prejudged as not appropriate for wind development. It is for each planning applicant to demonstrate whether the impacts are within acceptable limits and meet relevant policy and guidance.

### 2.1.3 Consenting regime

The Planning (Wales) Act 2015 introduced a new consenting regime / category of planning application, Developments of National Significance (DNS). These applications cover large scale infrastructure projects considered to be of national importance and are considered by the Planning Inspectorate on behalf of the Welsh Ministers, rather than at the LPA level.

The introduction of the DNS regime followed the removal of onshore wind from the Nationally Significant Infrastructure Projects (NSIPs) process and the devolution of energy consenting to Wales.

In relation to this study, the DNS (Specified Criteria and Prescribed Secondary Consents) (Wales) Regulations 2016 identifies the construction of a generating station as one of the constitute developments as follows:

1. “The construction of a generating station is within regulation 3(1)(a) only if the generating station is expected to have (when constructed) an installed generating capacity of between 10 and 50 megawatts.
2. The extension or alteration of a generating station is within regulation 3(1)(a) only if the effect of the extension or alteration is expected to increase the installed generating capacity by at least 10 megawatts, but not so that the installed generating capacity exceeds 50 megawatts.”

The DNS process was designed to encourage the applicants of applicable schemes to undertake early engagement with:

- the relevant Local Planning Authority,
- local communities,
- statutory consultees and
- other stakeholders.

The applications require this early pre-application work in advance of being submitted to the Planning Inspectorate for determination. The regime was designed to give greater certainty in the decision-making process at a time where large scale applications were experiencing lengthy delays in the planning process at the local level.

## 2.2 Future policy and consenting

### 2.2.1 Aims

In seeking a Wales which focusses on low carbon generation, Welsh Government have set a number of ministerial aims / targets. As set out in section 2.1.1, by 2030, Wales should generate 70% of its electricity from renewable sources, and one gigawatt of renewable electricity capacity should be locally owned. Moreover, all new renewable energy projects should have an element of local ownership by 2020.

In monitoring current progress, it has been approximated that in 2017, 48% of electricity in Wales was generated by renewable sources, and 750MW of renewable energy capacity is under local ownership<sup>2</sup>.

### 2.2.2 Energy and climate change policy

In July 2018, the Welsh Government launched a consultation on a low carbon pathway for Wales seeking public opinion on what action should be taken to reduce greenhouse gas emissions by 2030. This sets actions on a 5 yearly cycle in order to meet carbon targets. It is currently being revised and is expected to come in March 2019.

The Welsh Government have also committed to producing an Energy Atlas, this is expected to help with regional level energy planning.

### 2.2.3 Planning policy

#### National Development Framework

The National Development Framework (“NDF”) will set out a 20-year land use development plan for Wales and will replace the current Wales Spatial Plan (2008). The NDF will form part of the statutory plan for determining planning applications and Developments of National Significance (DNS).

#### Strategic Development Plans

The Planning (Wales) Act provides a legal framework for the preparation of Strategic Development Plans (SDPs) which have emerged as a concept given feedback that single local planning authorities have found it difficult to plan for

---

<sup>2</sup> Energy Generation in Wales, 2017: <https://gov.wales/docs/desh/publications/181212-energy-generation-in-wales-2017-en.pdf> Accessed: February 2019

and address more strategic issues in isolation or through the development of Local Development Plans (LDPs).

In principle, the SDPs would allow more strategic issues that do not stop at local authority boundaries (e.g. strategic housing, strategic employment sites and supporting transport and electricity infrastructure) to be considered and planned for in an integrated way. The Planning (Wales) Act does not specify the areas over which these SDPs should be prepared but instead provides flexibility.

## 2.2.4 Consenting regime

### Welsh Infrastructure Consent

In April 2018, the Welsh Government Planning Directorate published a consultation paper, which proposed changes to the consenting of infrastructure development in Wales, following new powers given to the Welsh Ministers under the Wales Act 2017 (“the 2017 Act”). A formal Government response on the consultation was published in November 2018.

The 2017 Act sets out amendments to the Government of Wales Act 2007, devolving further powers to Wales. Specifically, the 2017 Act devolves legislative and executive competence to the Welsh Ministers for:

- The consenting of electricity generating stations up to 350MW, both on and offshore and associated overhead electric lines, up to and including 132KV which are associated with devolved generating stations;
- Harbour revision and empowerment orders; and
- Marine licences beyond the inshore area up to the limits of the Welsh Zone.

On 29th November 2017, the Secretary of State for Wales set a commencement date for energy consenting provisions contained in the 2017 Act to come into force on 1st April 2019. Additionally, the 2017 Act has already devolved consenting for Harbour Revision and Empowerment Orders, made under the Harbours Act 1964, for most Welsh ports. These new powers came into force on 1st April 2018.

The 2017 Act places the consenting of this infrastructure in various regimes which will create a fragmented consenting process.

The Welsh Government acknowledges that the industry needs a ‘one-stop-shop’ for infrastructure consenting rather than various regimes. Therefore, to implement the 2017 Act in the long-term coherently, it is proposed to introduce a Welsh Infrastructure Consent (“WIC”); for the consenting of those newly devolved projects, as well as more widely to highways, rail, water and waste projects in a one-stop shop approach.”

## 3 Overview of dashboard and methodology

---

### 3.1 Approach to methodology development

This document defines the methodology, which was used to create the tool which will be used to define and assess potential scenarios for use in the NDF and the Energy Atlas.

The development of the methodology has been an iterative process, with input from stakeholder workshops, Arup experts, stakeholder engagement, and meetings with the Welsh Government core team.

Two initial external workshops (covering North and South Wales) were designed and facilitated by Arup, in collaboration with the Welsh Government, to inform understanding of the key constraints and opportunities according to stakeholder groups. Stakeholders included representatives of local planning authorities, distribution network operators, transmission operators, national parks and NRW. Constraints and opportunities were explored across the following for themes:

- Landscape and visual;
- Technical;
- Environmental;
- Cumulative impacts and wider benefits.

Findings from the initial workshops were used to inform the design of the tool. The design has also been informed through consultation with developers and experts within Arup. The initial workshops also allowed insight into the successes and limitations of previous approaches to assess solar and wind resource.

The assessment considered the most efficient solar panels and wind turbines commercially available, but were not based on a specific manufacturer or device model. The assessment includes floating solar panels but not rooftop solar panels. It includes onshore wind, but not building integrated wind turbines.

The full method developed is summarised here and is included in the report as shown in Appendix A.

### 3.2 Stages of methodology

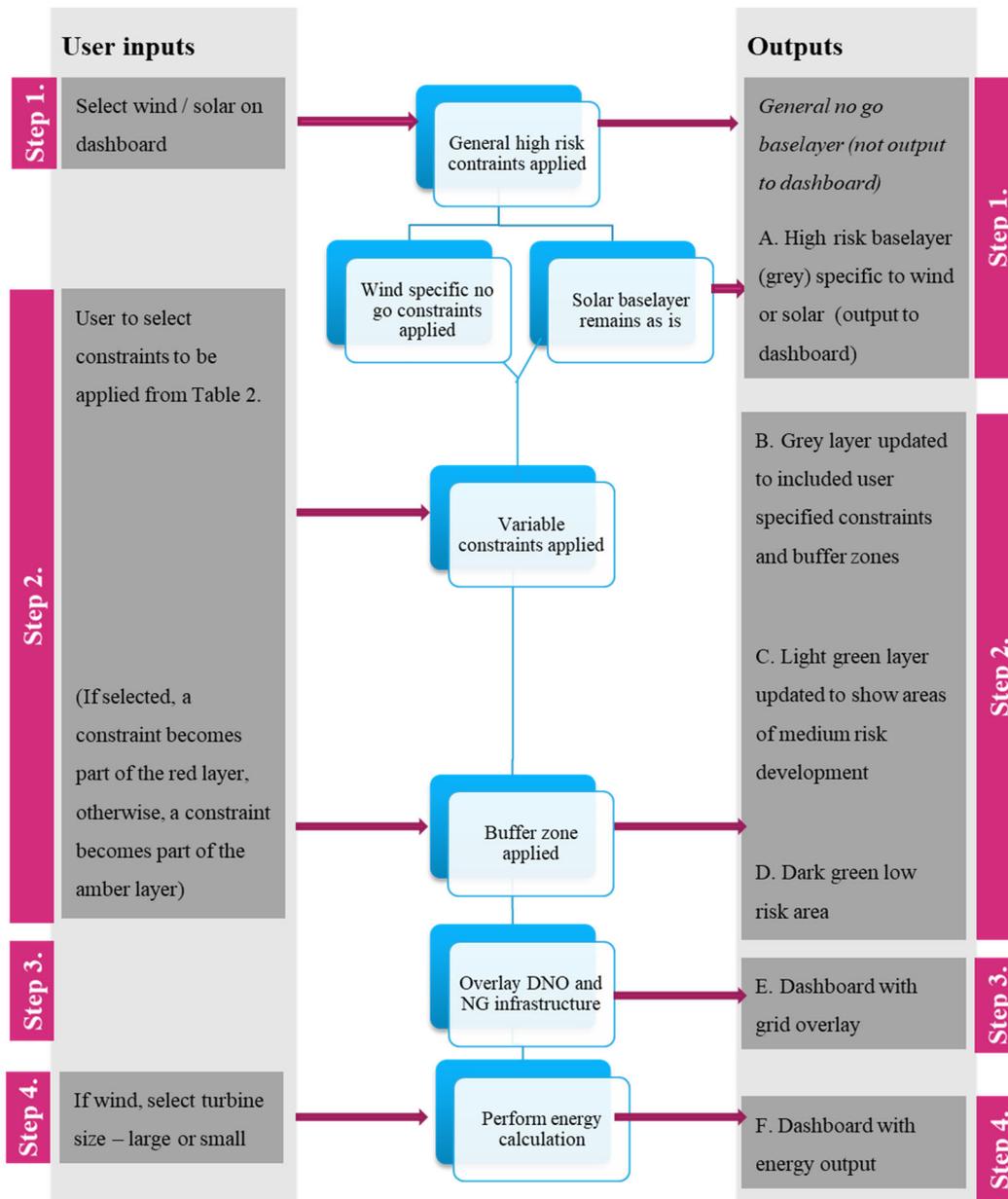


Figure 2: Visual overview of the methodology

Figure 2 above provides a visual overview of the methodology we have developed. This methodology is based on various constraints that were identified through stakeholder engagement at workshops and through a range of other sources including the Welsh Government Practice Guidance: Planning for Renewable and Low Carbon Energy – A Toolkit for Planners and TAN 8. Dialogue between Arup, Welsh Government and solar and wind developers allowed each constraint to be classified as ‘fixed’, ‘variable’ or ‘overlay’ depending on its level of importance.

- Fixed constraints are those which cannot be varied. They form the base map of areas and are the grey ‘areas of least opportunity’.

- Variable constraints are those which can be switched on and off. They are shown in light green, forming the ‘areas of varying opportunity’. They can be selected and would then be combined with the grey area.
- Any areas in which an applicable constraint was not identified was included as a dark green and labelled the ‘areas of greatest opportunity.’
- Constraints within the ‘overlay’ category are for information purposes and do not have an effect on the size of the areas of opportunity, or the energy output from these areas.

Constraints were categorised prior to the initial workshop and critiqued by attendees. The first version of the tool was then produced from the list of constraints formulated as an output of the initial workshop. A full list of the constraints used for the final tool are listed in Appendix B.

Based on user defined type and size of technology, the approach then calculated the energy output available for ‘areas of most opportunity’, that is areas that included no constraints, and of ‘varying opportunity’, areas containing variable constraints but no fixed constraints.

### 3.3 Tool

The final version of the tool has the following features:

- Built using ESRI ArcGIS Enterprise;
- Divides Wales into cells of 250m by 250m to allow a balance between tool accuracy and performance;
- Excludes a cell if more than 50% is covered by a constraint; and
- Uses a calculation methodology for wind and solar based on resource availability rather than being constrained by current device capabilities. This calculation is included in Section 2.5 of methodology in Appendix A.

## 4 Options and analysis

### 4.1 Introduction

In order to inform the NDF, four scenarios were developed in consultation with the Welsh Government. Each scenario had varying levels of constraints applied, corresponding to varying levels of energy output.

- Scenario 1: This scenario had the fewest constraints switched on in the dashboard. Only constraints defined as fixed were applied to the map. This left the maximum amount of land available for development and therefore would correspond to maximum potential energy output.
- Scenario 2 and Scenario 3: In these scenarios, varying levels of the constraints considered to be variable were applied to the map.
- Scenario 4: This scenario had all of the constraints identified as variable switched on in the dashboard. This left the minimum amount of land available for development and would therefore correspond to the minimum potential energy output.

The mapped outputs and tables outlining constraints used to generate Scenarios 1 to 4 for solar and wind are included in Appendix B.

The second stakeholder workshops were used to explore the benefits and challenges associated with each of the four scenarios and asked for views on a preferred scenario. Attendees were also asked to discuss how each of the areas should be treated within national planning policy and strategic and local development plans.

### 4.2 Analysis

The difference between the areas of least constraint between Scenarios 1 to 4 for wind and solar are significantly different as shown in Table 1. The assumptions underpinning each of these four scenarios are presented in Appendix B.

Table 1: Areas available for scenarios 1 and 4

	Scenario 1 (km <sup>2</sup> )		Scenario 2 (km <sup>2</sup> )		Scenario 3 (km <sup>2</sup> )		Scenario 4 (km <sup>2</sup> )	
	Wind	Solar	Wind	Solar	Wind	Solar	Wind	Solar
Areas of most opportunity	30	325	30	325	30	325	30	325
Areas of varying opportunity	8,710	8,350	2,000	4,310	783	1,670	0	0
Areas of least opportunity	12,700	12,800	19,500	16,900	20,700	19,500	21,500	21,200

Table 2 sets out the benefits and challenges of each of the four scenarios. This is based on input from the second workshops held in December 2018.

Table 2: Scenario specific benefits and challenges

Scenario	Benefits	Challenges
Scenario 1: Presented the list of fixed constraints for critique	<ul style="list-style-type: none"> <li>The application of fewer constraints allows for more flexible development compared to other scenarios thus enabling Welsh Government to make progress towards its renewable energy targets.</li> </ul>	<ul style="list-style-type: none"> <li>The maximum level of land being available for development means that this scenario would provide very little guidance regarding areas which could be allocated for development. This could mean more of the decision making is left to local authorities.</li> <li>Many of the constraints initially identified as fixed were considered surmountable, either by technical advancement or the potential for creative use of land. This meant that several constraints were moved from the 'fixed' category to the 'variable' category including inland waters, slope angle, flood zones, existing onshore wind and solar sites and other proposed or existing developments (major housing, industrial and individual dwellings).</li> <li>Larger area available for allocation means that there is more likelihood of an areas prompting objection being allocated.</li> </ul>
Scenarios 2 & 3: Presented varying levels of variable constraints for critique	<ul style="list-style-type: none"> <li>These options provide a middle ground whilst preserving some of the benefits of Scenarios 1 and 4.</li> </ul>	<ul style="list-style-type: none"> <li>Reviewers required justification as to why some constraints are switched on and others off. This implies a prioritisation of constraints, opinion on which is likely to differ between different users of the tool.</li> <li>Applying large buffers related to landscape and visual impacts can cause unnecessary exclusion of sites, when the this should be assessed on a site by site basis.</li> </ul>
Scenario 4: Presented all of the fixed and the maximum number and level of variable constraints for critique	<ul style="list-style-type: none"> <li>Areas left available for development have the lowest risk of facing objection as no constraints have been identified by stakeholders in these areas.</li> </ul>	<ul style="list-style-type: none"> <li>Lowest level of land available for potential development. Scenario in which Welsh Government would be least likely to meet their renewable energy targets.</li> </ul>

## 4.2.1 Preferred scenario

Following the December 2018 workshops, Arup and Welsh Government worked together to define a single preferred scenario. Through discussion, the list of fixed constraints was reduced to reflect comments from the second workshops along with the preference of the Welsh Government to form a list of constraints which would be useful to informing outputs of the NDF. The redefined list of fixed constraints took into account the following considerations.

- Some of the fixed constraints, such as inland waters and slope angle, were deemed to be more of a developer decision, rather than useful for informing NDF outputs.
- Due to the scale of development being considered, constraints existing as a geographical point location, such as ‘scheduled ancient monuments’, were deemed to be unhelpful in the list of fixed constraints due to the need to analyse priority areas for refinement, but important to keep in the tool so that their location could inform micro siting decisions.

Constraints moved from the fixed list were added to the variable or the overlay layer list.

The final list of and categorisation of the constraints informing the preferred scenarios for fixed constraints and user-variable constraints are shown in Table 3 and Table 4 respectively. Overlay constraints are shown in Appendix C.

It should be noted that this categorisation does not preclude any policy treatment of these constraints.

Table 3: Categorisation of constraints – fixed constraints

Fixed constraints	Wind/Solar/Both
Ramsar	Both
World Heritage Sites	Both
Special Protection Areas (SPAs)	Both
Special Areas of Conservation (SACs)	Both
candidate Special Areas of Conservation (cSACs)	Both
Ancient Woodland	Both
Area of Outstanding Natural Beauty (AONB)	Both
National Parks	Both
Conservation Areas	Both
NATS specified Communication Systems	Both
Airports and Runways	Both
Urban Regions	Both

Table 4: categorisation of constraints – user variable constraints

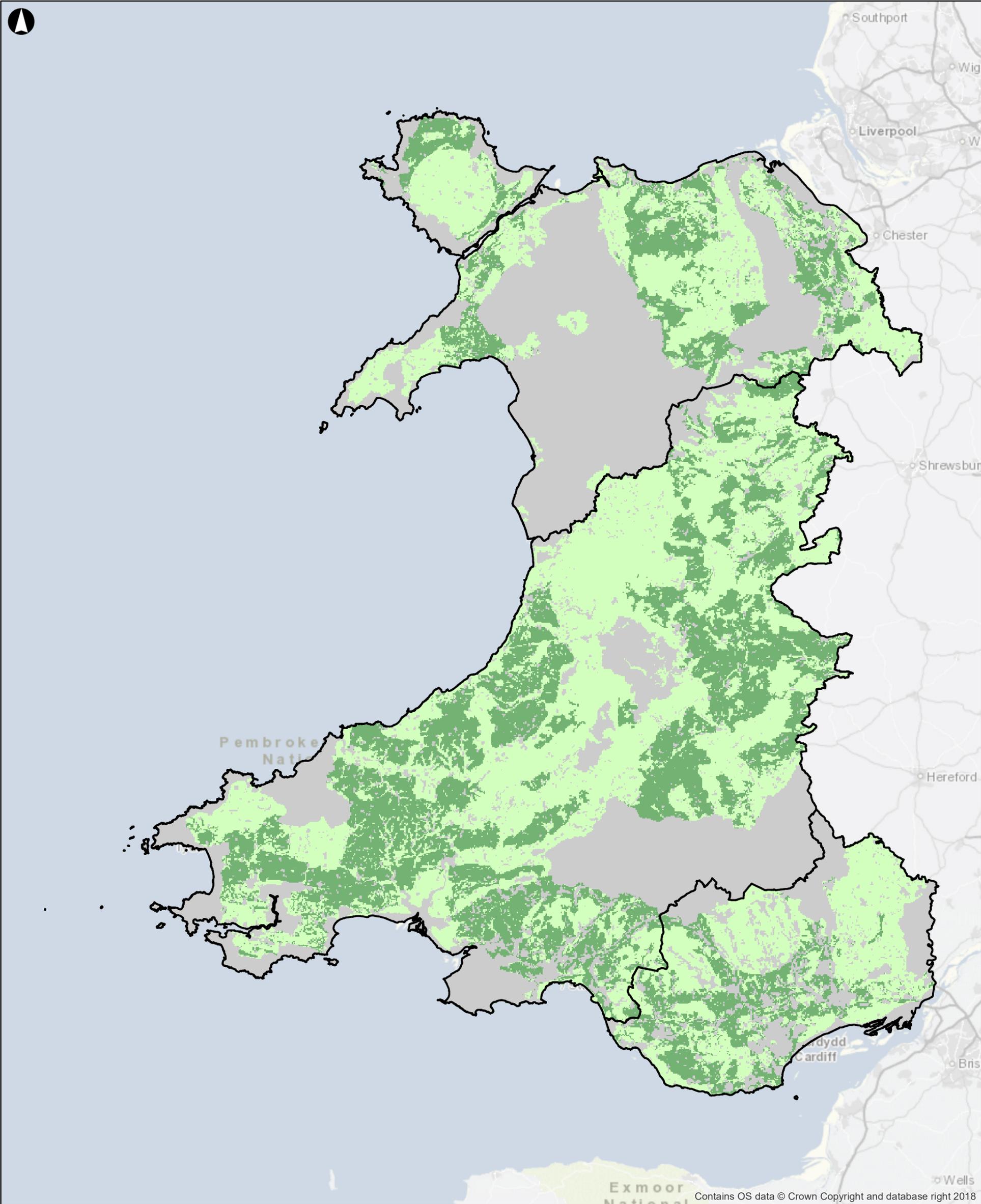
<b>Variable constraints</b>	<b>Wind/Solar/Both</b>
All Inland Waters	Wind
Inland Waters (excluding rivers and canals)	Solar
Woodland	Both
Peat deeper than 45cm	Both
Special Site of Scientific Interest (SSSI)	Both
Agricultural Land Classification (ALC) 1, 2	Both
National Nature Reserve (NNR)	Both
LandMap Visual Sensory – High and Outstanding	Both
Open Access	Both
Historic Landscape	Both
Regionally Important Geological and Geomorphological Sites (RIGS)	Both
Geo Parks – Fforest Fawr	Both
UNESCO Biosphere	Both
Allocated Major Developments	Both
NATS navigation Aids and Air Ground Air Communication	Wind

Figure 3 and Figure 4 show the outputs of the preferred scenario. In each of these figures, dark green represents the areas of greatest opportunity, light green represents areas of varying opportunity and grey represents the areas of least opportunity. Full size versions of these maps are included in Appendix D.

Table 5 summarises areas estimated for each of the areas of opportunity for both wind and solar

Table 5: Area associated with measuring ‘areas of most and varying opportunity’

	<b>Wind</b>	<b>Solar</b>
Areas of most opportunity	5,060 km <sup>2</sup>	5,360 km <sup>2</sup>
Areas of varying opportunity	8,710 km <sup>2</sup>	8,400 km <sup>2</sup>
Total	13,770 km <sup>2</sup>	13,760 km <sup>2</sup>



Contains OS data © Crown Copyright and database right 2018

- Welsh Regions
- Areas of greatest opportunity
- Areas of varying opportunity
- Areas of least opportunity

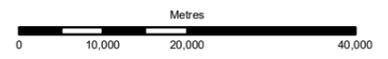
F1	2019-01-17	FH	BL	AC
Issue	Date	By	Chkd	Appd

# ARUP

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951  
www.arup.com

Client  
**Welsh Government**

Job Title  
**Energy Potential Wales**



**Wind Preferred Scenario**

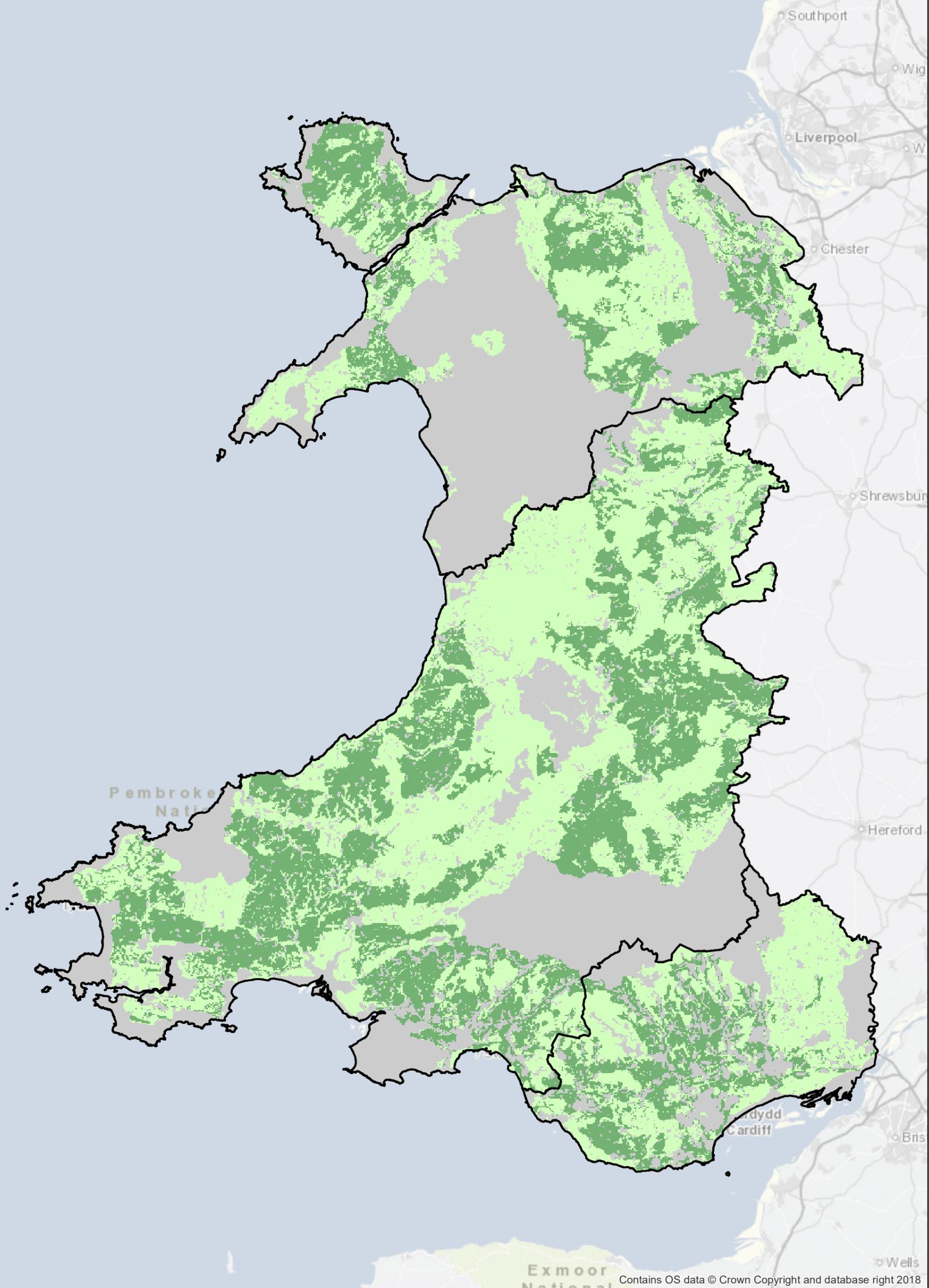
Scale at A3 **1:840,000**

Job No  
**263184-00**

Drawing Status  
**For Issue**

Drawing No  
**005**

Issue  
**F1**



Contains OS data © Crown Copyright and database right 2018

- Welsh Regions
- Areas of greatest opportunity
- Areas of varying opportunity
- Areas of least opportunity

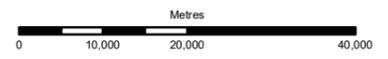
F1	2019-01-17	FH	BL	AC
Issue	Date	By	Chkd	Appd

# ARUP

63 St Thomas Street  
 Bristol, BS1 6JZ  
 T +44 117 976 5432 D +44 117 988 6951  
 www.arup.com

Client  
**Welsh Government**

Job Title  
**Energy Potential Wales**



## Solar Preferred Scenario

Scale at A3 **1:840,000**

Job No <b>263184-00</b>	Drawing Status <b>For Issue</b>
----------------------------	------------------------------------

Drawing No <b>006</b>	Issue <b>F1</b>
--------------------------	--------------------

## 5 NDF policy options

### 5.1 Introduction

The selection of a preferred scenario provides three different areas for Welsh Government to make a decision about their policy approach:

- Areas of most opportunity;
- Areas of varying opportunity; and
- Areas of least opportunity

The options for the policy approach within each of these areas were explored in the second stakeholder workshops and are discussed further in this section.

### 5.2 Areas of most opportunity

The policy options within these areas can be summarised as:

- A criteria-based approach
- Allocation of sites
- Highlighting areas of search or priority areas for refinement

Table 6 provides an overview of the benefits and dis-benefits of these approaches.

Table 6: Assessment of options for policy related to areas of most opportunity

Option	Description	Benefits	Dis-benefits
Positive criteria-based approach	A policy that sets a 'presumption in favour' position for development in the areas identified, encouraging development whilst setting the criteria through which development management decisions are made.	Could be used to encourage development.	Likely to require additional input from developers to confirm compliance Less certainty
Allocation of sites	Specific sites determined as areas for development. Potentially supported by a call for sites. A call for sites approach is in line with good practice for development, taking into consideration deliverability and viability.	Stronger position in plan if sites are allocated Provides greater clarity for all stakeholders Less onus on regional / local level planning to undertake the assessment / refinement exercise.	Areas have not yet been assessed in further detail against factors which could affect deliverability Could be perceived that areas outside priority areas for refinement are excluded from development.

Areas of search / Priority Areas for Refinement	Wider areas identified, to be assessed in further detail (either through regional or local development plans or in combination with criteria-based policy during determination) Similar to TAN8 Strategic Search Areas.	Alternative approach to allocation – provides slightly more flexibility and allows developers to make decisions on land to promote. Less impact on value of land than through allocation approach	Could be perceived that areas outside priority areas for refinement are excluded from development.
---	--	--	--

### 5.3 Areas of varying opportunity

The policy options within these areas can be summarised as:

- A criteria-based approach
- A sequential test approach

Table 7 provides an overview of the benefits and dis-benefits of these approaches.

Table 7: Assessment of options for policy related to areas of varying opportunity

Option	Description	Benefits	Dis-benefits
Positive criteria-based approach	As per criteria-based approach in Table 6. Would not preclude development but would set clearly the criteria that need to be met in order to make a development acceptable in planning terms.		
Sequential test approach	An approach to seek to develop certain types or locations of land before others – the applicant would need to confirm why their site is better than those in the area of most opportunity and/or show how efforts have been made to identify sites within areas of most opportunity and the reasons why this was not viable.	Provides options to promote a range of sites, whilst maintaining preference for those of greatest opportunity.	Very onerous for applicants and development management.

### 5.4 Areas of least opportunity

The policy options within these areas can be summarised as:

- No go; and
- A negative criteria-based approach.

Table 8 provides an overview of the benefits and dis-benefits of these approaches.

Table 8: Assessment of options for policy related to areas of least opportunity

Option	Description	Benefits	Dis-benefits
No go	A policy setting out a blanket ban for onshore wind and solar development at the scale of 10MW and above.	Provides clear direction and saves development time being spent on areas with immovable barriers to development	Pessimistic approach, and potentially prohibitive, could discourage investment and further assessment being undertaken by the development community Could create a negative perception for development for other forms of renewables in the area.
Negative criteria-based approach	A policy that sets a 'presumption against' development (10MW and above) and sets the criteria through which development management decisions are made.	Less prohibitive than the 'No go' approach. This approach avoids ruling out areas where a different approach might be more appropriate for assessing small scale development at local level.	Provides less certainty and more assessment time.

## 5.5 Spatial analysis

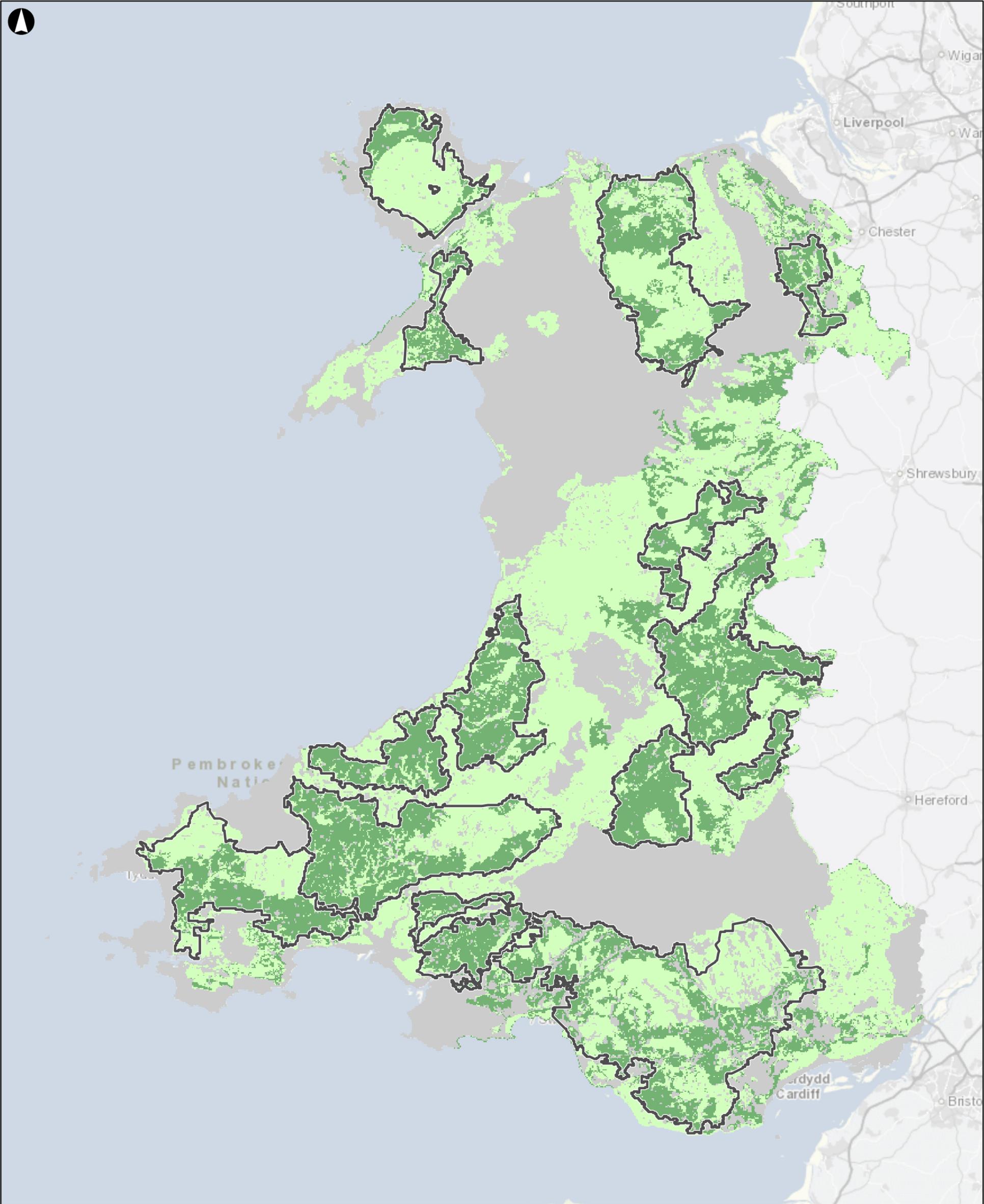
### 5.5.1 Areas of most opportunity

Based on the spatial distribution of the areas of most opportunity, Arup has worked closely with Welsh Government to develop fifteen priority areas for refinement.

These areas were developed taking into consideration the following:

- Maximising the areas of greatest opportunity where possible, focussing on the areas which could accommodate development at a scale of over 10MW;
- Each area has at least some grid infrastructure and road infrastructure within it;
- Wind speed, this was to used highlight areas where energy generation potential could be maximised; and
- A final cross check and review against the TAN 8 SSAs.

Figure 5 shows the fifteen priority areas for refinement. These are the same for wind and solar at this stage. These are recommended for further assessment and refinement before being included in the NDF.



<ul style="list-style-type: none"> <li><span style="display: inline-block; width: 15px; height: 10px; border: 1px solid black; margin-right: 5px;"></span> Priority Area for Refinement</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #006400; margin-right: 5px;"></span> Areas of greatest opportunity</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #90EE90; margin-right: 5px;"></span> Areas of varying opportunity</li> <li><span style="display: inline-block; width: 15px; height: 10px; background-color: #A9A9A9; margin-right: 5px;"></span> Areas of least opportunity</li> </ul>	<p style="font-size: 8px;">Contains OS data © Crown Copyright and database right 2018</p> <table border="1" style="width: 100%; border-collapse: collapse; font-size: 8px;"> <tr> <td style="width: 10%;">P1</td> <td style="width: 15%;">2019-01-08</td> <td style="width: 10%;">FH</td> <td style="width: 10%;">BL</td> <td style="width: 10%;">AC</td> </tr> <tr> <td>Issue</td> <td>Date</td> <td>By</td> <td>Chkd</td> <td>Appd</td> </tr> </table>	P1	2019-01-08	FH	BL	AC	Issue	Date	By	Chkd	Appd	<h1 style="margin: 0;">ARUP</h1> <p style="font-size: 8px; margin: 0;">63 St Thomas Street Bristol, BS1 6JZ T +44 117 976 5432 D +44 117 988 6951 www.arup.com</p> <hr/> <p style="font-size: 8px; margin: 0;">Client <b>Welsh Government</b></p> <hr/> <p style="font-size: 8px; margin: 0;">Job Title <b>Energy Potential Wales</b></p>	<div style="text-align: right; font-size: 8px; margin-bottom: 5px;">Metres</div> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;"> <span style="margin-right: 20px;">0</span> <span style="margin-right: 20px;">9,500</span> <span style="margin-right: 20px;">19,000</span> <span>38,000</span> </div> <div style="text-align: center; border: 1px solid black; padding: 5px; margin-bottom: 5px;"> <b>Priority Areas for Refinement</b>              (Wind Preferred Scenario)         </div> <div style="font-size: 8px; margin-bottom: 5px;">             Scale at A3 <b>1:800,000</b> </div> <table border="1" style="width: 100%; border-collapse: collapse; font-size: 8px;"> <tr> <td style="width: 50%;">Job No <b>263184-00</b></td> <td style="width: 50%;">Drawing Status <b>Preliminary</b></td> </tr> <tr> <td style="font-size: 8px;">Drawing No <b>007</b></td> <td style="font-size: 8px;">Issue <b>P1</b></td> </tr> </table>	Job No <b>263184-00</b>	Drawing Status <b>Preliminary</b>	Drawing No <b>007</b>	Issue <b>P1</b>
P1	2019-01-08	FH	BL	AC													
Issue	Date	By	Chkd	Appd													
Job No <b>263184-00</b>	Drawing Status <b>Preliminary</b>																
Drawing No <b>007</b>	Issue <b>P1</b>																

This study was GIS based and focused on environmental and landscape constraints. It is therefore recommended that further assessment is undertaken in terms of deliverability and more detailed landscape assessment before areas are taken forward. The primary factors that we consider will contribute to deliverability are;

- Grid – capacity and cost of connection;
- Landscape;
- Access; and
- Land ownership.

More detailed discussion and analysis of the priority areas for refinement is provided in Table 9.

Maps of the divided areas, zoomed in, are given in Appendix D. Also included in Appendix D is a map of wind speed for Wales and existing wind and solar sites. These maps can be used to further assess the priority areas.

Table 9 outlines some of the key considerations for further assessment of the priority areas for refinement. A further refinement exercise is taking place to address the considerations outlined in the second column of Table 9.

Table 9: Rationale for, and considerations which could provide evidence for inclusion or exclusion of the priority areas (within their given zones) in the NDF

Area	Rationale for area included	Key elements for consideration in refinement
002 North Wales (Anglesey & Gwynedd)	Good wind speeds across the island of Anglesey. Energy Island designation. Areas including all areas of greatest opportunity, where there is also grid infrastructure present and road access.	Proximity to Caernarfon castle. Proximity to AONB and National Park. Radar / NATS constraints.
003 North Wales (NE)	Areas including all areas of greatest opportunity, where there is also grid and road access. Avoiding the built-up areas around Wrexham.	Areas contiguous with AONB and National Park will need further landscape and visual assessment. Proximity to built-up area around Wrexham will need further consideration, especially with regards to wind energy.
004 Mid & West Wales (Ceredigion)	Areas including all areas of greatest opportunity, where there is also grid and road access. Area of variable opportunity that contain grid and access routes included at this stage.	Proximity to Landmap visual sensory outstanding and high to the East. Proximity to National Park to the South West. Grid and access constraints may make deliverability a challenge.
005 Mid & West Wales (Powys)	Areas including all areas of greatest opportunity, where there is also grid and road access. Area of variable opportunity with particularly high wind speed also included.	Consideration of constraints in England. Proximity to Landmap visual sensory outstanding and high to the South. Grid and access constraints may make deliverability a challenge.
006 Mid & West Wales (Pembs)	Areas including all areas of greatest opportunity, where there is also grid and road access. Area of variable opportunity with particularly high wind speed also included.	Proximity to National Park. Potential impact of greenlink of future grid availability should be considered. Radar.
007 Mid & West Wales (Swansea)	Areas including all areas of greatest opportunity, where there is also grid and road access. Area of variable opportunity with high wind speed, and existing renewable generation also included.	Proximity to Landmap visual sensory outstanding and high areas. Proximity to built up area around Llanelli.
008 South East Wales	Large area, recognising varying topography, high wind speeds, good access and proximity to grid and population (and therefore energy demand). Excludes major built up areas, with the exception of Port Talbot works, given future uncertainty.	Area of heritage coast likely to be more suitable for solar than wind. Radar. Proximity to settlements. Proximity to National Park in the North.

Further assessment is required to verify each of the observations made in Table 9.

## 5.5.2 Analysis of areas of varying opportunity

All of the priority areas for refinement identified have areas of least opportunity included in them. Further detailed analysis will need to be carried out in order to refine each of the areas.

All of the priority areas for refinement identified have areas of varying opportunity included in them. The Strategic Search Areas (SSAs) from TAN 8 were mapped to compare against the priority areas for refinement. This map is available in Appendix D.

## General comments

This study has comprised a high-level desktop review, mapping the location of grid infrastructure with respect to the areas of greatest opportunity. Presence of grid infrastructure does not imply that there is capacity for connection of generation assets. Further detailed assessment will need to be undertaken in order to determine whether there is capacity for connection.

## 6 Recommendations and next steps

---

### 6.1 Conclusions

This study has provided an assessment of Wales' potential for onshore solar and wind development expressed in a spatial format that has been categorised as:

- Areas of most opportunity;
- Areas of varying opportunity; and
- Areas of least opportunity.

Spatially, these areas are not contiguous, and further assessment will be required to identify areas to take forward in a policy approach within the NDF.

It is recommended that the Welsh Government use the priority areas for refinement identified in Section 5.2 to undertake more detailed analysis to provide further evidence to inform NDF policy.

### 6.2 Next steps for NDF policy

The next stage of work should include the following activities:

1. Assessment of the fifteen priority areas for refinement in more detail, specifically undertaking the following:
  - a. Closer inspection of any areas of grey within the priority areas for refinement by determining which fixed constraints exist within each grey area and considering how barriers to development might be mitigated.
  - b. Assessment of each of the areas in terms of deliverability, including more detailed analysis of the areas in terms of:
    - Grid availability: Engage with National Grid and distribution network operators (DNOs) in order to assess the available capacity of National Grid OHLs and distribution level infrastructure in the priority areas for refinement. Assessment should include review of available capacity on existing lines and also scope for new infrastructure where limited OHLs exist.
    - Landscape and visual impacts: Undertake a landscape sensitivity assessment, for areas recommended by NRW to identify areas to analyse further.
    - Access: Assess current access and proposed road infrastructure upgrades.
    - Landownership: Assess the priority areas for refinement in terms of public or privately-owned land. This will help to identify how publicly owned land can be used to encourage local ownership.
2. Use of the outcomes of the further assessment of priority areas for refinement to inform the following:
  - a. continued dialogue with the National Grid, and the local distribution network operators, Western Power Distribution and SP Energy Networks

- to determine what is currently possible, and what could be possible to 2040. This will build on the positive dialogue and openness to considering investment in the grid on the basis of a policy objective.
- b. Further dialogue with local authorities around access, community impacts and benefits, and local authority targets.
3. Following further assessment, it is anticipated that areas of search could be identified for inclusion in the draft NDF. However, this additional assessment will help to identify whether this remains preferable to a criteria-based approach.
  4. Should areas of search form part of the NDF consultation, Welsh Government should consider putting out a call for sites, which would highlight sites to assess under a further criteria based assessment. This could be confidential to assist with point 4.

### 6.3 Guidance for local planning authorities and regional planning

The analysis undertaken thus far has been focussed on large-scale development at a national scale (10MW and above), in order to inform the NDF.

However, the tool has been designed to enable appropriate functionality and assessment using additional constraints, included as overlay layers. Along with further refinement exercises, this could be used to support further assessment at the regional and local level.

Local authorities are required to set objectives for use of their land and policies for implementing these objectives within their LDPs. A sustainability appraisal of their plan must be undertaken. The tool could therefore be useful for local authorities when developing their LDPs particular with regards to setting targets for renewable energy.

Further assessment may be required at a local or regional level, in particular for smaller scale generation. Any further evidence generated should feed back into future iterations of the NDF.

### 6.4 Energy Atlas

The plans are for the energy atlas to focus on regional energy planning. This should be considered in the context of SDPs. The tool could be further developed to incorporate other technologies and additional criteria, to form the basis of, and inform the development of the Energy Atlas.

# Appendix A

## Methodology

Welsh Government

**Onshore wind and solar energy  
potential assessment**

**Onshore wind and solar energy  
potential assessment methodology**

Issue | 18 January 2019

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 263184-00

**Ove Arup & Partners Ltd**  
63 St Thomas Street  
Bristol BS1 6JZ  
United Kingdom  
[www.arup.com](http://www.arup.com)

**ARUP**

# Contents

---

	Page
<b>1 Introduction</b>	<b>1</b>
1.1 Project background and purpose	1
1.2 Purpose of this document	1
<b>2 Overview of proposed approach and key steps</b>	<b>2</b>
2.1 Overview of approach	2
2.2 Step 1: Define high risk areas	3
2.3 Step 2: Define low risk and medium risk areas	6
2.4 Step 3: Overlay grid infrastructure	9
2.5 Step 4: Define resource availability	14
<b>3 Options for development of the approach</b>	<b>17</b>
3.1 Level of detail – decisions made	17
3.2 Percentage coverage	20
3.3 Energy output calculation methodology – decisions made	21
<b>4 Summary</b>	<b>22</b>

## Tables

Table 1: Constraints applied to define the high risk areas for onshore wind and solar energy development.

Table 2: User-variable constraints applied to create user defined high risk areas, which are added to the high risk base layer

Table 3: Overlay layer User-variable constraints applied to create user defined high risk areas, which are added to the high risk base layer

Table 4: Wind turbine assumptions

Table 5: Solar panel assumptions

Table 6: Method for calculating energy output of a given area

Table 7: Toolkit level of detail – options appraisal

Table 8: Cells removed by different percentage coverage options

Table 9: Energy output calculation methodology

Table 10: Summary of decisions required, and actions taken

## Figures

Figure 1: Visual overview of the proposed approach

# 1 Introduction

---

## 1.1 Project background and purpose

The Welsh Government wish to create an approach to assessing the potential for onshore wind and solar energy development against defined constraints across Wales. The purpose of this exercise is to allow Welsh Government to assess the total onshore wind and solar energy capacity across the country, under varying constraints. A number of methods for developing the approach were considered. This document defines the method for developing the approach which will most accurately produce scenarios for the NDF and Energy Atlas, to meet the requirements to Welsh Government. A summary report and GIS shape files will be produced in conjunction with the ArcGIS output.

Two external workshops were designed and facilitated by Arup, in collaboration with the Welsh Government, to inform understanding of the key constraints according to stakeholder groups. The workshops allowed insight into the successes and limitations of previous approaches to assess solar and wind resource. Findings from the workshops have been used to inform the design of the tool. The design has also been informed through consultation with developers and experts within Arup.

The assessment will include floating solar panels but not rooftop solar panels. It will include onshore wind, but not building integrated wind turbines.

## 1.2 Purpose of this document

This document outlines the proposed methodology for developing the approach. The approach will provide Welsh Government with the evidence that it requires in order to support policy decisions. There were some areas where decisions and input from the Welsh Government were required. Such instances have been highlighted throughout, with the main decisions captured in Section 3.

- Section 2 sets out our proposed approach at a high-level.
- Section 3 assesses key options for given aspects of our approach.

## 2 Overview of proposed approach and key steps

### 2.1 Overview of approach

A visual overview of the proposed approach is given in Figure 1 and explained in full throughout the following section.

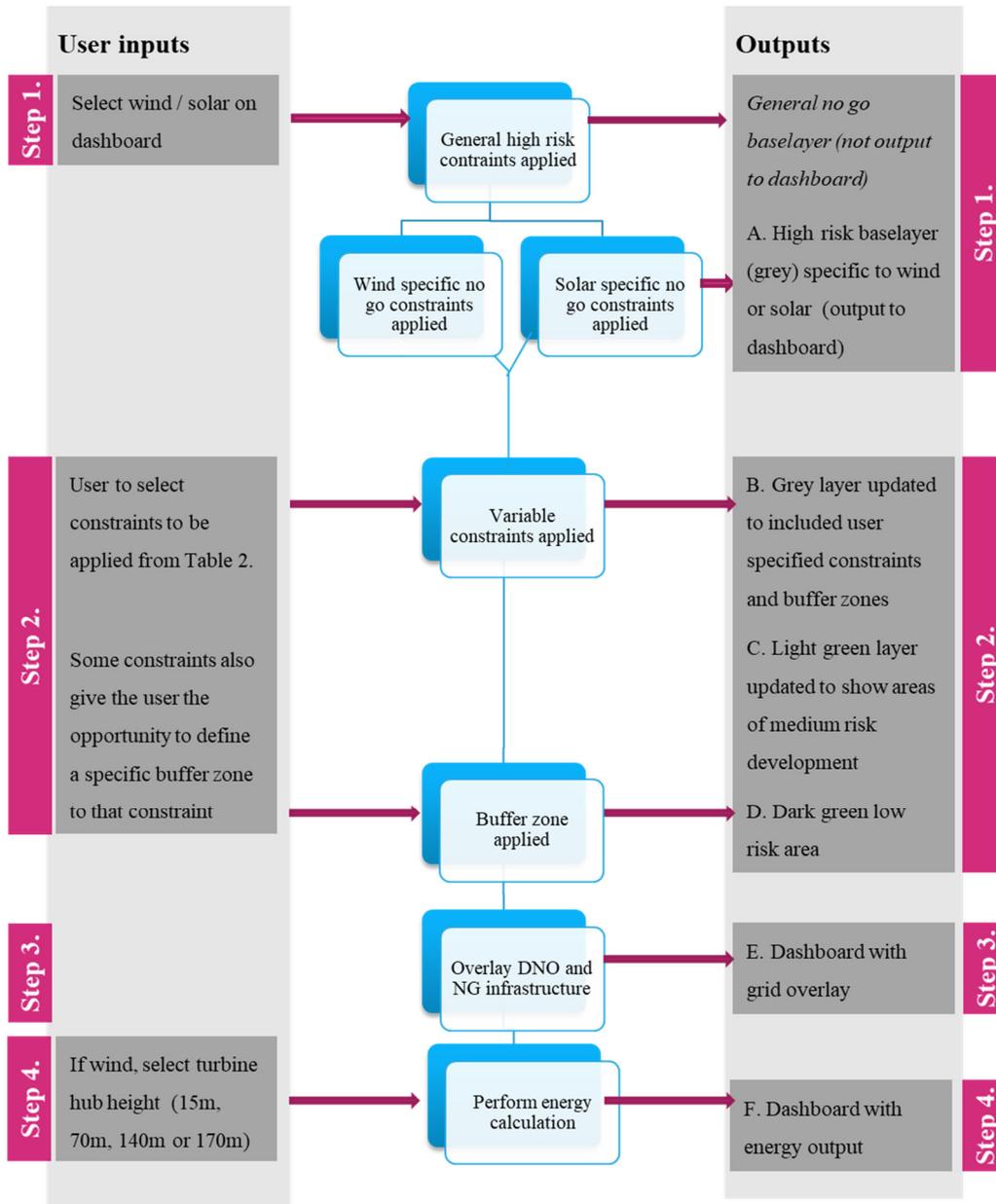


Figure 1: Visual overview of the proposed approach

## 2.2 Step 1: Define high risk areas

### 2.2.1 Inputs and methodology

Our approach will divide Wales into grid cells of 250m by 250m.

Cells will then be categorised according to whether they contain any fixed constraints, user defined constraints or no constraints. In all cases, if a cell contains above 50% of a constraint, the approach will flag it as containing that constraint.

The application of some constraints would cause an area to be unsuitable for any scale of onshore wind and solar development. These constraints, summarised in Table 1, will be used to establish a base layer of high risk areas for wind and solar development.

Table 1: Constraints applied to define the high risk areas for onshore wind and solar energy development.

Category	Fixed constraint	Wind/Solar	Criteria	Copyright	Reference
Environmental	Ramsar	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Renewable Toolkit
	World Heritage Sites	Both	Exclude all	Designated Historic Asset GIS Data, The Welsh Historic Environment Service (Cadw), 24/08/2018, licensed under the Open Government Licence	Renewable Toolkit
	Special Protection Areas (SPAs)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Renewable Toolkit
	Special Areas of Conservation (SACs)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Renewable Toolkit
	candidate Special Areas of Conservation (cSACs)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Renewable Toolkit
	Ancient Woodland	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Workshop input

	Area of Outstanding Natural Beauty (AONB)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Workshop input
	National Parks	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Workshop input
	Conservation Areas	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Renewable Toolkit
Infrastructure	NATS specified Communication Systems	Both	Exclude 600m around	NATS specified communication systems (communication with Alasdair Auld)	Discussion with NATS
	Airports and Runways	Both	Exclude 1km around	Airport locations identified from <a href="http://lle.gov.wales/map">http://lle.gov.wales/map</a>	Workshop input
	Urban Regions	Both		Contains OS data © Crown copyright and database right (2018)	Workshop input

At this stage, the user will be required to select between wind or solar development.

## 2.2.2 Outputs

The approach will then output a map highlighting the high risk areas specific to the technology that the user has chosen. This is Output A in Figure 1.

## 2.3 Step 2: Define low risk and medium risk areas

### 2.3.1 Inputs and methodology

The user will then be required to select the constraints that they would like to apply from the list in Table 2. The application of these constraints would cause the area to also be highlighted as a high risk for wind and solar development, Output B in Figure 1.

Table 2: User-variable constraints applied to create user defined high risk areas, which are added to the high risk base layer

Category	Fixed constraint	Wind/Solar	Criteria	Copyright	Reference
Terrain	All Inland Waters	Wind	OS Vector Map Local All inland water	© Crown copyright and database rights [2018] Ordnance Survey 0100031673	Workshop input
	Inland Waters (excluding rivers and canals)	Solar	OS Mastermap Where not reservoir and static water	© Crown copyright and database rights [2018] Ordnance Survey 0100031673	Workshop input
Environmental	Woodland	Both	OS Vector Map Local Feature Des includes coniferous woodland, coniferous woodland and shrub, mixed woodland, mixed woodland and shrub, broadleaf woodland, broadleaf woodland and shrub	© Crown copyright and database rights [2018] Ordnance Survey 0100031673	Workshop input
	Peat deeper than 45cm	Both	Exclude all	© Crown copyright: Welsh Government	Developer input on variability. Depth defined by dataset
	Special Site of Scientific Interest (SSSI)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Workshop input
	Predictive Agricultural Land Classification (ALC)	Both	Category 1 and 2	© Crown copyright. Mapping derived from soils data © Cranfield University (NSRI) and for the Controller of HMSO 2017. © Crown copyright 2017, the Met Office. Contains OS data © Crown copyright and database right 2017. Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved.	Arup experience

	National Nature Reserve (NNR)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Workshop input
	LandMap Visual Sensory	Both	High and Outstanding	Contains Natural Resources Wales information © Natural Resources Wales and database right	Workshop input
	Open Access	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Arup experience
	Historic Landscape	Both	Exclude all	This report is based on Cadw Historic Assets Data. ©Crown Copyright. Cadw.	Arup experience
	Regionally Important Geological and Geomorphological Sites (RIGS)	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and database right	Client input
	Geo Parks	Both	Fforest Fawr	licensed under the Open Government Licence	Client input
	UNESCO Biosphere	Both	Exclude all	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	Client input
Infrastructure	Allocated Major Developments	Both	Buffer based on size attributes	Arup identified sites (NDF)	Client input
	NATS navigation Aids and Air Ground Air Communication	Wind	Exclude all	NATS Geographical guidance	Discussion with NATS

The remaining areas will be defined as follows:

- If a constraint is potentially applicable to the area but has not been selected by the user, then it will be defined as medium risk and highlighted light green.
- If there are no identified constraints applicable to the area, the area will be defined as low risk and highlighted dark green.

### 2.3.2 Outputs

The approach will then output areas for potential development (medium risk) highlighted light green, Output C in Figure 1. These will be areas that contain a variable constraint which has not been selected by the user. These light green areas will be flagged according to their category.

The approach will also output areas of greatest potential highlighted dark green (Output D in Figure 1). These are areas which contain no fixed or variable constraints.

## 2.4 Step 3: Overlay grid infrastructure

### 2.4.1 Inputs and methodology

There will be additional layers available as optional overlays. These overlay layers will not impact the identified areas of potential but will allow the user to consider further constraints as well as identify which locations have the best capabilities for connecting to the grid.

The user will not be required to input any data at this stage. Input datasets to the approach are detailed in Table 3:

Table 3: Overlay layer User-variable constraints applied to create user defined high risk areas, which are added to the high risk base layer

Type of overlay layer	Overlay Layer	Wind/Solar	Criteria	Buffer (KM)	Copyright	Zoom Overlay Visible at (1: )
Transmission infrastructure	National Grid Cable National Grid Substations National Grid OHL	Both	All	-	© National Grid UK	2,000,000
Distribution infrastructure	WPD GM Substations	Both	11, 33, 66, 132 kV	-	© Western Power Distribution	500,000
	SPEN Substations	Both	Substation Grid, Substation Primary, Substation Super Grid	-	© SP Energy Network	500,000
Infrastructure	Existing Wind Turbine Sites	Both	REPD Wales, Onshore Wind, Operational and Under Construction	-	© Crown copyright	2,000,000
	Existing Solar Farm Sites	Both	REPD Wales, Solar Photovoltaics, Operational and Under Construction	-	© Crown copyright	2,000,000
	Road Network	Both	All	-	© Crown copyright and database rights [2018] Ordnance Survey 0100031673	750,000
	Rail Network	Both	All	-	Contains OS data © Crown copyright and database right (2018)	750,000
	Radar Sweep 20m	Wind	All	-	NATS Geographical guidance	1,000,000
	Radar Sweep 80m	Wind	All	-	NATS Geographical guidance	1,000,000
	Radar Sweep 180m	Wind	All	-	NATS Geographical guidance	1,000,000
	Radar Sweep 200m	Wind	All	-	NATS Geographical guidance	1,000,000

	Active Travel Routes	Both	National Trail Wales Coastal Path Sustran National Route Sustran NCN Link Sustran Regional Route	-	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	500,000
	Listed Buildings	Both	All	-	© Crown copyright	250,000
	Existing Buildings	Both	OS Vector map Local All Buildings	-	© Crown copyright and database rights [2018] Ordnance Survey 0100031673	100,000
Environmental	LandMap Geological	Both	High and Outstanding	-	Contains Natural Resources Wales information © Natural Resources Wales and database right	1,000,000
	LandMap habitats	Both	High and Outstanding	-	Contains Natural Resources Wales information © Natural Resources Wales and database right	1,000,000
	Flood Zone 2	Both	All	-	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Some features of this information are based on digital spatial data licensed from the Centre for Ecology & Hydrology © NERC (CEH). Defra, Met Office and DARD Rivers Agency © Crown copyright. © Cranfield University. © James Hutton Institute. Contains OS data © Crown copyright and database right 2015. Land & Property Services © Crown copyright and database right.	750,000
	Flood Zone 3	Both	All	-	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Some features of this information are based on digital spatial data licensed from the Centre for Ecology & Hydrology © NERC (CEH). Defra, Met Office and DARD Rivers Agency © Crown copyright. © Cranfield University. © James Hutton Institute. Contains OS data © Crown copyright and database right 2015. Land & Property Services © Crown copyright and database right.	750,000
	Slope (Steep, Very Steep)	Both	Steep where gradient is between 15° and 25°.	-	licensed by OS to the Licensor under the PSMA Member Licence	500,000

			Very Steep where gradient is greater than 25°			
Scheduled Ancient Monument	Both	All	-	© Crown copyright	2,000,000	
Registered Parks	Both	All	-	© Crown copyright	2,000,000	
Tranquil Area	Both	All	-	Contains Natural Resources Wales information © Natural Resources Wales and database right	2,000,000	
Ramsar	Solar	-	5	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000	
	Wind	-	30		2,000,000	
Special Protection Area (SPA)	Solar	-	5	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000	
	Wind	-	30		2,000,000	
Special Area of Conservation (SAC)	Solar	-	5	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000	
	Wind	-	30		2,000,000	
Candidate Special Area of Conservation (cSAC)	Solar	-	5	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000	
	Wind	-	30		2,000,000	
World Heritage	Solar	-	2	Designated Historic Asset GIS Data, The Welsh Historic Environment Service (Cadw), 24/08/2018, licensed under the Open Government Licence	2,000,000	
	Wind	-	20		2,000,000	
Conservation Area	Solar	-	2	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000	
	Wind	-	20		2,000,000	
	Solar	-	2		2,000,000	

	National Park	Wind	-	20	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000
	Area of Outstanding Natural Beauty (AONB)	Solar	-	2	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000
		Wind	-	20		2,000,000
	Site of Special Scientific Interest (SSSI)	Solar	-	2	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000
		Wind	-	10		2,000,000
	National Nature Reserve	Solar	-	2	Contains Natural Resources Wales information © Natural Resources Wales and Database Right. All rights Reserved. Contains Ordnance Survey Data. Ordnance Survey Licence number 100019741. Crown Copyright and Database Right.	2,000,000
		Wind	-	10		2,000,000

## 2.4.2 Outputs

The approach will output selected constraints and DNO/ National Grid infrastructure to the map.

## 2.5 Step 4: Define resource availability

### 2.5.1 Inputs and methodology

If assessing wind potential, the user will be required to select either a turbine of hub height 15m, 70m, 140m or 170m. The data in Table 4 will then be used to calculate the total available wind resource.

Table 4: Wind turbine assumptions

	Small turbine <sup>1</sup>	Small-medium turbine <sup>2</sup>	Medium-large turbine <sup>3</sup>	Large turbine <sup>4</sup>
	Largest turbine not requiring EIA assessment		Average of commercially available turbine	Largest commercially available turbine
Hub height (m)	15	70	140	170
Rotor diameter (m)	7.2	53	82	160
Capacity factor (%)	27	31	35	38

It is assumed that a spacing of five diameters by seven diameters is required per turbine<sup>56</sup>.

An air density of 1.225kg/m<sup>3</sup> was also assumed<sup>7</sup>.

If assessing solar, no further user input will be required and the data given in Table 5 will be used.

<sup>1</sup> Reference:

[www.energysavingtrust.org.uk/sites/default/files/reports/choosing%20a%20wind%20turbine\\_0.pdf](http://www.energysavingtrust.org.uk/sites/default/files/reports/choosing%20a%20wind%20turbine_0.pdf)

<sup>2</sup> Reference: <https://www.enercon.de/en/products/ep-1/e-53/>

<sup>3</sup> Reference: <https://www.enercon.de/en/products/ep-2/e-82/>

<sup>4</sup> Reference: Reference: <https://en.wind-turbine-models.com/turbines/1719-general-electric-ge-4.8-158>

<sup>5</sup> <http://www.na-paw.org/Mitchell/Mitchell-Wind-Turbine-Separation-Distances.pdf>

<sup>6</sup> TAN8 suggests a wind turbine spacing between three and ten diameters and so this assumption is in-keeping with TAN 8 guidance <https://gov.wales/topics/planning/policy/tans/tan8/?lang=en>

<sup>7</sup> Standard ISA density of air at 15°C and standard pressure.

Table 5: Solar panel assumptions

	Solar Panel
Area required for 1MW rated power (m <sup>2</sup> /MW) <sup>8</sup>	24,000
Area of panel (m <sup>2</sup> ) <sup>9</sup>	2
Percentage of site area covered by panels (%)	80
Panel efficiency (%) <sup>10</sup>	22
Performance ratio (%) <sup>11</sup>	85

The approach will then calculate two resource availability values for the map specific to the technology type chosen using the calculation methodology given in Table 6.

1. Total available resource – the approach will sum the energy output for dark green (low risk) and light green (medium risk) areas of the map but will exclude high risk areas.
2. Low risk available resource – the approach will sum the energy outputs for the dark green areas of the map.

Table 6: Method for calculating energy output of a given area

Wind	Solar
<p><b>Nomenclature</b></p> <ul style="list-style-type: none"> <li>• A = Rotor swept area (m<sup>2</sup>)</li> <li>• A<sub>c</sub> = Area of GIS cell (m<sup>2</sup>)</li> <li>• CF = Capacity factor</li> <li>• D = Rotor diameter (m)</li> <li>• E = Energy (MWh)</li> <li>• N = number of turbines</li> <li>• V = Wind velocity (m/s)</li> <li>• ρ = Density of air (kg/m<sup>3</sup>)</li> </ul>	<p><b>Nomenclature</b></p> <ul style="list-style-type: none"> <li>• A = Area of GIS cell (m<sup>2</sup>)</li> <li>• C = Percentage coverage (%)</li> <li>• E = Energy output (MWh/year)</li> <li>• I = Global incident irradiance (W/m<sup>2</sup>) (annual average)</li> <li>• N = number of grid cells</li> <li>• PR = Performance ratio (%)</li> <li>• η = Efficiency (%)</li> </ul>
<p><b>1. Calculate number of turbines per cell</b></p> $N = \frac{A_c}{35D^2}$	<p><b>1. Calculate energy output for the cell</b></p> $E = I \times (N \times C \times A) \times \eta \times PR \times 8760$
<p><b>2. Calculate rotor swept area</b></p>	<p><b>2. Calculate the total energy for low risk and medium risk developments</b></p>

<sup>8</sup> <https://gov.wales/docs/desh/publications/151021renewable-energy-toolkit-en.pdf>

<sup>9</sup> This was taken as an average from datasets for the Jinko Solar JKM330PP-72-A, BYD P6C-36 Series-4BB and the Canadian Solar CS6U- 315

<sup>10</sup> <https://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market/>

<sup>11</sup> <https://photovoltaic-software.com/principle-ressources/how-calculate-solar-energy-power-pv-systems>

Wind	Solar
$A = \frac{\pi D^2}{4}$	
<p><b>3. Calculate energy output for the cell</b></p> $E = CF \times \left(\frac{1}{2} \rho A V^3\right) \times N \times 8760$ <p>Note that CF will vary depending on the user selected turbine size.</p>	
<p><b>3. Calculate the total energy for low risk and medium risk developments</b></p>	

### 2.5.2 Outputs

Energy output of wind or solar resource will be output for all the identified low risk and medium risk areas on the map. This is Output F in Figure 1. Note, that this will be exclusive of existing wind and solar energy output.

## 3 Options for development of the approach

---

A number of decisions were required for the development of the approach and were set out in previous versions of this report. A summary of the decisions made is included below.

### 3.1 Level of detail – decisions made

The level of detail and variability within the approach was dependent on the intended end user and primary purpose. Welsh Government have indicated that the primary purpose of this exercise is to identify the most appropriate areas for development under the NDF and so the level of detail of the approach has been selected to align with this.

Table 7 outlines the various options for level of detail presented to Welsh Government where green text describes advantages of a given option and red text describes disadvantages. Option 2A was selected as the preferred option and therefore the approach will allow the user to select medium risk constraints individually and will determine whether a cell contains a given constraint depending on the percentage of the cell covered by that constraint. The user will be able to select buffer zones for some constraints. The only deviation made from this option in the approach is that presence of road and rail networks will automatically lead to a cell being excluded rather than these cells being assessed on a percentage coverage basis.

Table 7: Toolkit level of detail – options appraisal

	<b>Percentage cover</b> If a cell contains above a defined percentage of a given constraint, then the approach will register the cell as containing that constraint	<b>On/off</b> If a cell contains even a small amount of a constraint (such as a road passing through the cell) then the approach will register the cell as containing that constraint
<p>1. High detailed design</p> <p>All constraints can be selected individually</p> <p>All buffers have a sliding scale</p>	<p>Option 1A</p> <p>More accurate estimation of potential energy output</p> <p>Allows various scenarios to be modelled to a high degree of accuracy</p> <p>Would require an intense amount of programming and processing power</p> <p>Potentially beyond the capabilities of the proposed approach and therefore usability negatively impacted</p> <p>Extremely slow and would require option to select options and then run processes separately for energy outputs to be given therefore not providing a dynamic approach</p> <p>This option would be beneficial for Welsh Government to calculate total resource. It would have the capability for a variety of different options to be explored, however, it would take significant amounts of time for results from each option to be outputted. This option is likely to be too slow for developers and community groups to use.</p>	<p>Option 1B</p> <p>Fairly accurate estimation of solar and energy resource to be made</p> <p>Would allow various scenarios to be modelled to a fairly high degree of accuracy</p> <p>Would require a high amount of programming and processing power</p> <p>Granular data – if you change one buffer, it might not have any impact on the energy output calculated</p> <p>Potentially at the edge of the capabilities of the proposed approach decreasing speed therefore impacting usability</p> <p>This option would be less beneficial to Welsh Government compared with the Option 1A as the accuracy of the output would be compromised. It is likely to be too slow for developers and community groups to use.</p>
<p>2. Medium detailed design</p> <ul style="list-style-type: none"> <li>All medium risk constraints can be selected individually</li> <li>For some relevant constraints the user is given a few static options for the buffer zone</li> </ul>	<p><u>Preferred Option</u></p> <p>Option 2A</p> <ul style="list-style-type: none"> <li>Medium speed and processing time</li> <li>Medium user input</li> </ul>	<p>Option 2B</p> <ul style="list-style-type: none"> <li>Medium speed and processing time</li> <li>Medium user input</li> <li>This option is likely to underestimate amount of resource as whole boxes will be blocked off even if the constraints selected cover just 1% of the grid cell.</li> </ul>

	<b>Percentage cover</b> If a cell contains above a defined percentage of a given constraint, then the approach will register the cell as containing that constraint	<b>On/off</b> If a cell contains even a small amount of a constraint (such as a road passing through the cell) then the approach will register the cell as containing that constraint
	<b>This option would be beneficial to Welsh Government as it would allow them to explore various combinations of constraints. It could also be used by developers and community groups to estimate resource in a particular area.</b>	<b>This option would be beneficial to Welsh Government as it would allow them to explore various combinations of constraints. It could also be used by developers and community groups to estimate resource in a particular area.</b>
<p>3. Low detailed design</p> <ul style="list-style-type: none"> <li>Constraints are grouped into categories and the user can define whether each of the categories is turned on or off</li> <li>The user can define whether the buffer zone for each of the given categories is on or off</li> </ul>	<p><b>Option 3A</b></p> <ul style="list-style-type: none"> <li>This option will be the fastest of Options 1A, 2A and 3A</li> <li>Limited option choices may compromise relevance</li> </ul> <p>This option would have a high degree of usability for users wishing to estimate resource availability and site comparison. It therefore may be suitable for community groups or for Welsh Government if wishing to make resource estimations for pre-determined scenarios. However, the limited user control may make this option difficult for developers to use.</p>	<p><b>Option 3B</b></p> <ul style="list-style-type: none"> <li>This will be the fastest of all six options</li> <li>Limited option choices may compromise relevance</li> <li>This option is likely to underestimate amount of resource as whole boxes will be blocked off</li> </ul> <p>This option would be beneficial for community groups or for Welsh Government wishing to make resource estimations for pre-determined scenarios and would enable fast, high-level comparisons to be made for comparison between sites. However, the limited user control may limit the usefulness of this option for any users requiring a more detailed approach.</p>

## 3.2 Percentage coverage

Various options for percentage coverage were considered. The smaller the assumed percentage coverage, the larger the area that will be included in the high risk area. Testing to indicate the most suitable option for percentage coverage has been undertaken on a grid of 500m x 500m cells.

Table 8 shows the number of cells removed by different options for percentage cover. The larger the area left after cell exclusion, the slower the processing time for the tool will be.

Table 8: Cells removed by different percentage coverage options

Percentage coverage (%)	Grid squares left after cells with given percentage coverage removed	Total area left after cell exclusion (m <sup>2</sup> ) – Based on 500m x 500m cell	Approximate percentage of Wales considered to be low risk for development
Base case (Total grid cells and area in Wales)	86,875	21,718,750,000	n/a
25	41,920	10,480,000,000	48%
50	51,770	12,942,500,000	60%
75	60,467	15,116,750,000	70%
100	85,902	21,475,500,000	99%

The 50% percentage coverage option will be applied. This means that any cells covered by more than 50% of a given constraint will be identified as containing that constraint. The only exceptions to this will be for road and role networks which will be identified as containing the constraint if any part of the cell is affected.

### 3.3 Energy output calculation methodology – decisions made

Two different options were presented to developers for calculating wind and solar potential for a given area. The comparative strengths (green) and weaknesses (red) of each method are given in Table 9. Following response from developers, Method 2 has been identified as the most appropriate approach.

Table 9: Energy output calculation methodology

	Wind	Solar
<p><b>Method 1</b></p> <p>Based on device assumed rated power (as suggested by Renewable Energy Toolkit)</p>	<ul style="list-style-type: none"> <li>Consistent with Renewable Energy Toolkit</li> <li>Gives a more accurate indication of the wind energy resource available given the current capabilities of wind energy technology</li> <li>Considers the variation of capacity factor for different wind speeds making energy outputted more accurate if the turbine installed has similar characteristics to that used in the approach.</li> <li>This method is based on the technical capabilities of solar power today and does not take into technological improvements</li> <li>The wind energy outputted using this method is not heavily influenced by the wind speed in that area</li> </ul>	<ul style="list-style-type: none"> <li>Consistent with Renewable Energy Toolkit</li> <li>Gives a more accurate indication of the solar energy resource available given the current capabilities of solar energy technology</li> <li>This method is based on the technical capabilities of solar power today and does not take into technological improvements</li> <li>The solar energy outputted using this method is not influenced at all by the solar irradiation in that area</li> </ul>
<p><b>Method 2</b></p> <p>Based on unconstrained resource</p>	<p><b><u>Preferred option</u></b></p> <ul style="list-style-type: none"> <li>This method gives a more accurate representation of the overall wind energy resource for Wales without being limited by current technical capabilities</li> <li>This method may overestimate the wind resource available for a site making it an unreliable approach for developers</li> </ul>	<ul style="list-style-type: none"> <li>This method gives a more accurate representation of the overall solar energy resource for Wales without being limited by current technical capabilities</li> <li>This method may overestimate the solar resource available for a site making it an unreliable approach for developers</li> </ul>

## 4 Summary

In a previous report to the Welsh Government, it was highlighted that the decisions outlined in Table 10 were required. The action taken to address each of these is summarised within the table.

Table 10: Summary of decisions required, and actions taken

Decision required	Action taken
3. A decision was required regarding the cell size which should be used for the cell size.	Cells of 250m by 250m have been used in this iteration of the approach.
4. A decision was required to determine whether cells containing constraints should be eliminated on a presence/absence or percentage covered basis.	The decision was made to treat the cells on a percentage coverage basis with the exception of rail and road networks which will be assessed on an on/off basis.
5. A decision was required regarding whether user variable constraints can be switch on and off individually or whether they can be categorized by group.	Variable constraints should be selected individually by the user rather than split into groups.
6. A decision was required to determine the degree that a user can vary the buffer zones for each constraint.	AONB, National Park and existing building constraints will have buffer zones applied.
7. A decision is required regarding the calculation method to be used to calculate energy output.	Calculation Method 2 will be used following feedback from developers.

## **Appendix B**

Summary of constraints used to  
assess potential scenarios

## B1 Summary of underpinning fixed assumptions – wind and solar

The list of fixed constraints below were used to create scenarios for discussion and assessment at the second stakeholder workshop. Some of these constraints were moved to the variable category after discussion at the workshop.

Table 10: Fixed constraints applied to all scenarios

Fixed constraint	Criteria	Wind/solar
Inland waters	All identified are excluded	Wind only
Inland waters	Exclude rivers and canals in this level of assessment	Solar only
Global designations (Ramsar / World heritage)	Excluded	Both
European designations (SPAs, SACs and cSACs)	Excluded	Both
Woodland	Ancient woodland excluded	Both
Rail network	Excluded	Both
Road network (Principal and secondary)	Excluded	Both
NATS, CAA and MoD exclusion zones	Exclude 600m around NATS specified communication systems Exclude Airports and runways. MoD to send data on the following: - MoD estate - Assessment undertaken by their radar engineer based on the maximum turbine height provided to them by Arup.	Wind only
NATS, CAA and MoD exclusion zones	Exclude 600m around NATS specified communication systems	Solar only
Listed buildings	Exclude	Both
Existing buildings	Exclude	Both
Scheduled Ancient Monuments	Exclude	Both
Existing wind turbine sites	Exclude	Wind only
Existing solar farm sites	Exclude	Both

## B2 Summary of underpinning variable assumptions – wind

These constraints were used to create scenarios for discussion and assessment at the second stakeholder workshop. The list was further refined to create a preferred scenario and a final list of constraints.

Constraint	Scenario 1 - Minimum constraint, maximum output	Scenario 2 - Low constraint, high output	Scenario 3 - High constraint, low output	Scenario 4 - Maximum constraint, minimum output
Slope gradient	Above 25° slope angle excluded	Above 15° slope angle excluded	Above 15° slope angle excluded /	Above 5° slope angle excluded
Flood areas	Not selected	Zone 2 flood zones applied	Zone 2 flood zones applied	Zone 2 / 3 flood zones applied
Woodland* * Ancient woodland excluded in high-risk zone	Not selected	Not selected	Selected	Selected
Peat	Not selected	Not selected	Selected	Selected
Active travel routes	Not selected	Not selected	Selected	Selected
SSSI	Not selected	Not selected	Selected	Selected
Agriculture Land Classification (ALC)	Not selected	Not selected	Selected	Selected
AONB	Selected with no buffer zone	Selected with 0 - 5 km buffer	Selected with 5 – 11km buffer	Selected with 11 – 20km buffer
National Nature Reserves (NNR)	Not selected	Not selected	Selected	Selected
National parks	Selected with no buffer zone	Selected with 0 - 5 km buffer	Selected with 5 – 11km buffer	Selected with 11 – 20km buffer

Constraint	Scenario 1 - Minimum constraint, maximum output	Scenario 2 - Low constraint, high output	Scenario 3 - High constraint, low output	Scenario 4 - Maximum constraint, minimum output
Outstanding/high areas in LANDMAP	Not selected	Not selected	Selected	Selected Landmap geological high and outstanding Landmap habitat outstanding Landmap visual sensory high, outstanding and medium
Registered parks	Not selected	Not selected	Selected	Selected
Open access	Not selected	Not selected	Selected	Selected
RIG sites	Not selected	Not selected	Selected	Selected
Tranquil areas	Not selected	Not selected	Selected	Selected
NATS radar sweep	Not selected	Not selected	Selected	Selected
500m buffer around existing buildings	Not selected	Not selected	Selected	Selected
Historic landscapes	Not selected	Not selected	Selected	Selected
Special Landscape Areas (SLAs)	Not selected	Not selected	Selected	Selected

## B3 Summary of underpinning variable assumptions – solar

These constraints were used to create scenarios for discussion and assessment at the second stakeholder workshop. The list was further refined to create a preferred scenario and a final list of constraints.

<b>Constraint</b>	<b>Scenario 1 - Minimum constraint, maximum output</b>	<b>Scenario 2 - Low constraint, high output</b>	<b>Scenario 3 - High constraint, low output</b>	<b>Scenario 4 - Maximum constraint, minimum output</b>
Slope gradient	Above 25° slope angle excluded	Above 15° slope angle excluded	Above 15° slope angle excluded	Above 5° slope angle excluded
Flood areas	Not selected	Zone 2 flood zones applied	Zone 2 flood zones applied	Zone 2 / 3 flood zones applied
Woodland* * Ancient woodland excluded in high-risk zone	Not selected	Not selected	Selected	Selected
Peat	Not selected	Not selected	Selected	Selected
Active travel routes	Not selected	Not selected	Selected	Selected
SSSI	Not selected	Not selected	Selected	Selected
Agriculture Land Classification (ALC)	Not selected	Not selected	Selected	Selected
AONB	Not selected	Not selected	Selected	Selected

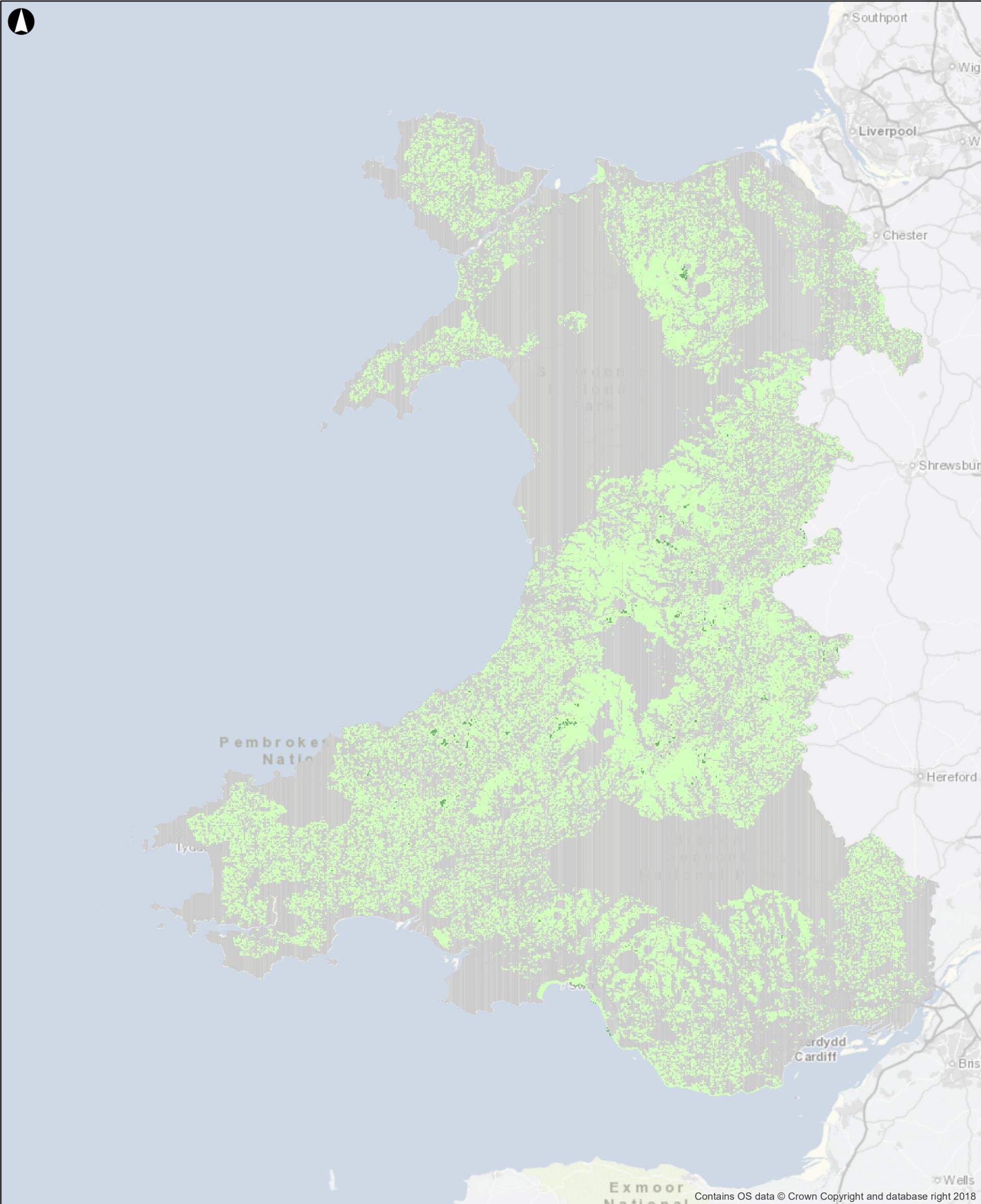
<b>Constraint</b>	<b>Scenario 1 - Minimum constraint, maximum output</b>	<b>Scenario 2 - Low constraint, high output</b>	<b>Scenario 3 - High constraint, low output</b>	<b>Scenario 4 - Maximum constraint, minimum output</b>
National Nature Reserves (NNR)	Not selected	Not selected	Selected	Selected
National parks	Not selected	Not selected	Selected with no buffer zone	Selected with 7km buffer zone
Outstanding/high areas in LANDMAP	Not selected	Selected Visual sensory high and outstanding	Selected Landmap visual sensory high, outstanding and medium	Selected Landmap geological high and outstanding Landmap habitat outstanding Landmap visual sensory high, outstanding and medium
Registered parks	Not selected	Not selected	Selected	Selected
Open access	Not selected	Not selected	Selected	Selected
RIG sites	Not selected	Not selected	Selected	Selected
Tranquil areas	Not selected	Not selected	Selected	Selected
Marine Nature Reserves (MNR)	Not selected	Not selected	Selected	Selected
Historic landscapes	Not selected	Not selected	Selected	Selected

<b>Constraint</b>	<b>Scenario 1 - Minimum constraint, maximum output</b>	<b>Scenario 2 - Low constraint, high output</b>	<b>Scenario 3 - High constraint, low output</b>	<b>Scenario 4 - Maximum constraint, minimum output</b>
Special Landscape Areas (SLAs)	Not selected	Not selected	Selected	Selected

## **B4**      **Maps of scenarios**

---

### **B4.1**      **Scenarios 1 to 4 for wind and solar**



Contains OS data © Crown Copyright and database right 2018

**Legend**

- Most Opportunity
- Varying Opportunity
- Least Opportunity

F1	2018-12-10	FH		
Issue	Date	By	Chkd	Appd

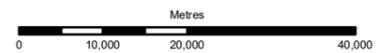
# ARUP

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
Client

**Welsh Government**

Job Title  
**Assessment of onshore wind and solar energy potential**



**Scenario 1 -  
Least Constrained  
Scenario Wind**

Scale at A3

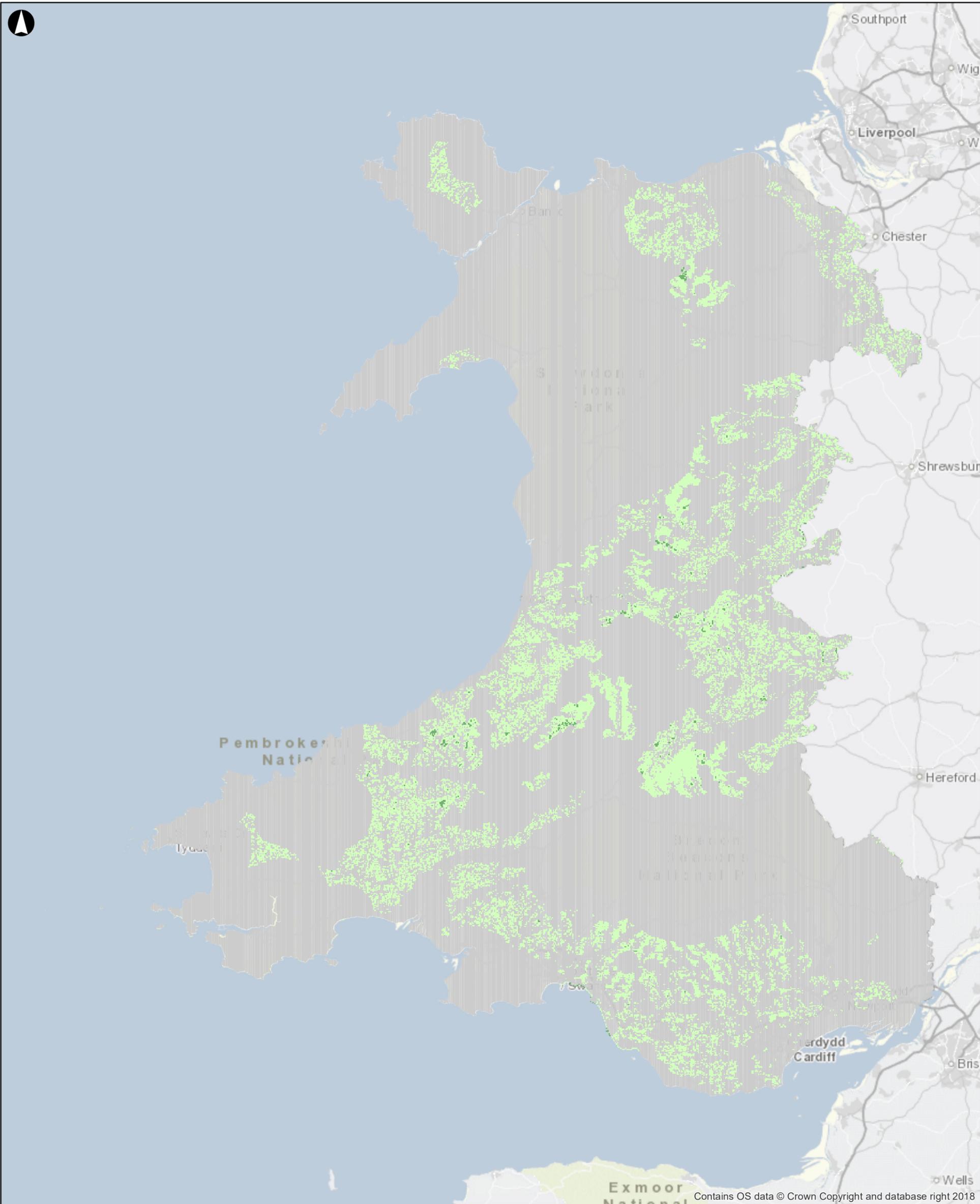
**1:840,000**

Job No  
**263184**

Drawing Status  
**For Issue**

Drawing No  
**004**

Issue  
**F1**



Contains OS data © Crown Copyright and database right 2018

**Legend**

- Least Constrained
- Constrained
- Highly Constrained

F1	2018-12-10	FH	BL	
Issue	Date	By	Chkd	Appd

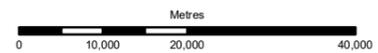
# ARUP

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
Client

**Welsh Government**

Job Title  
**Assessment of onshore wind and solar energy potential**



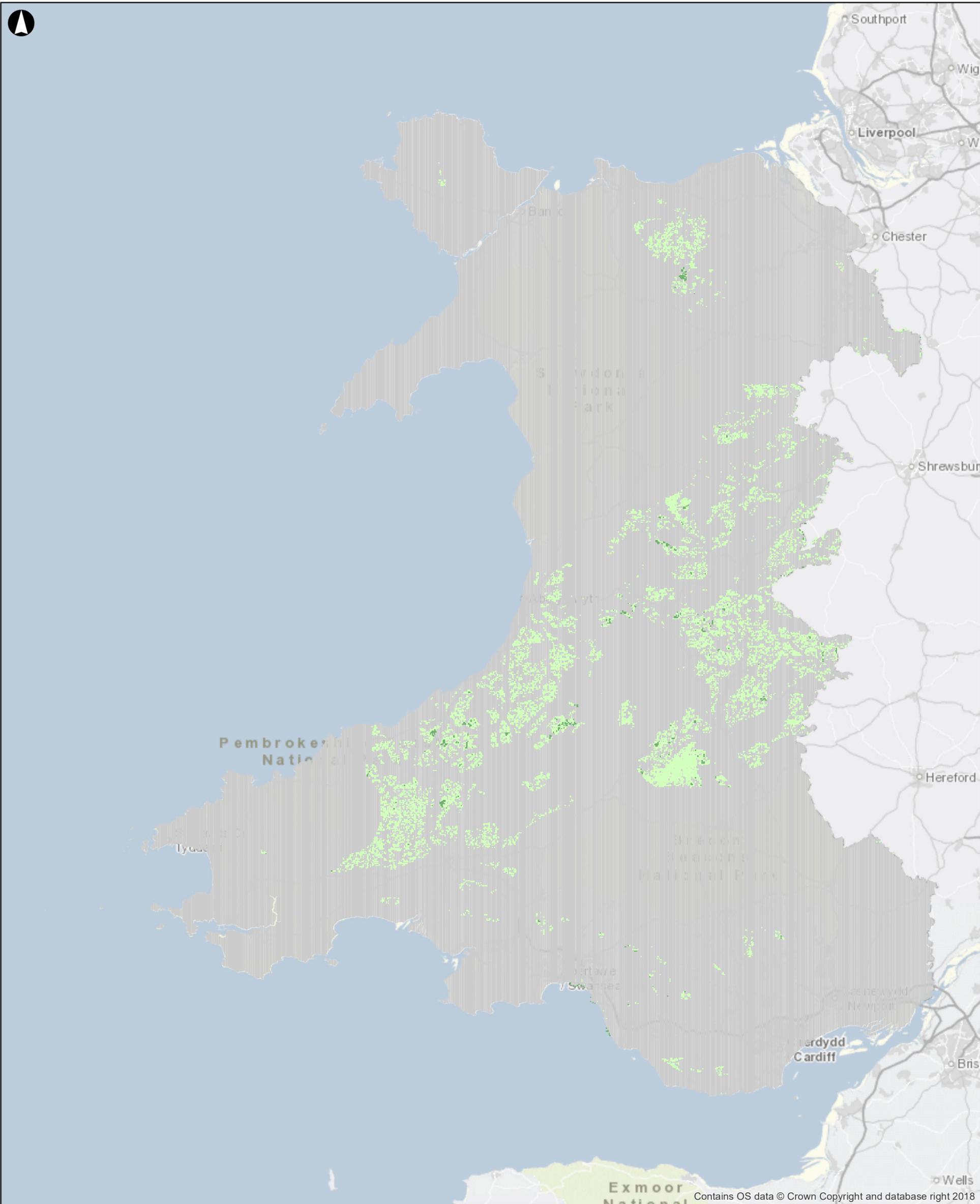
**NDF Scenario 2  
WIND**

Scale at A3

**1:840,000**

Job No <b>263184</b>	Drawing Status <b>For Issue</b>
-------------------------	------------------------------------

Drawing No <b>006</b>	Issue <b>F1</b>
--------------------------	--------------------



Contains OS data © Crown Copyright and database right 2018

**Legend**

- Least Constrained
- Constrained
- Highly Constrained

F1	2018-12-10	FH	BL	
Issue	Date	By	Chkd	Appd

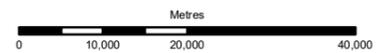
# ARUP

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
Client

**Welsh Government**

Job Title  
**Assessment of onshore wind and solar energy potential**

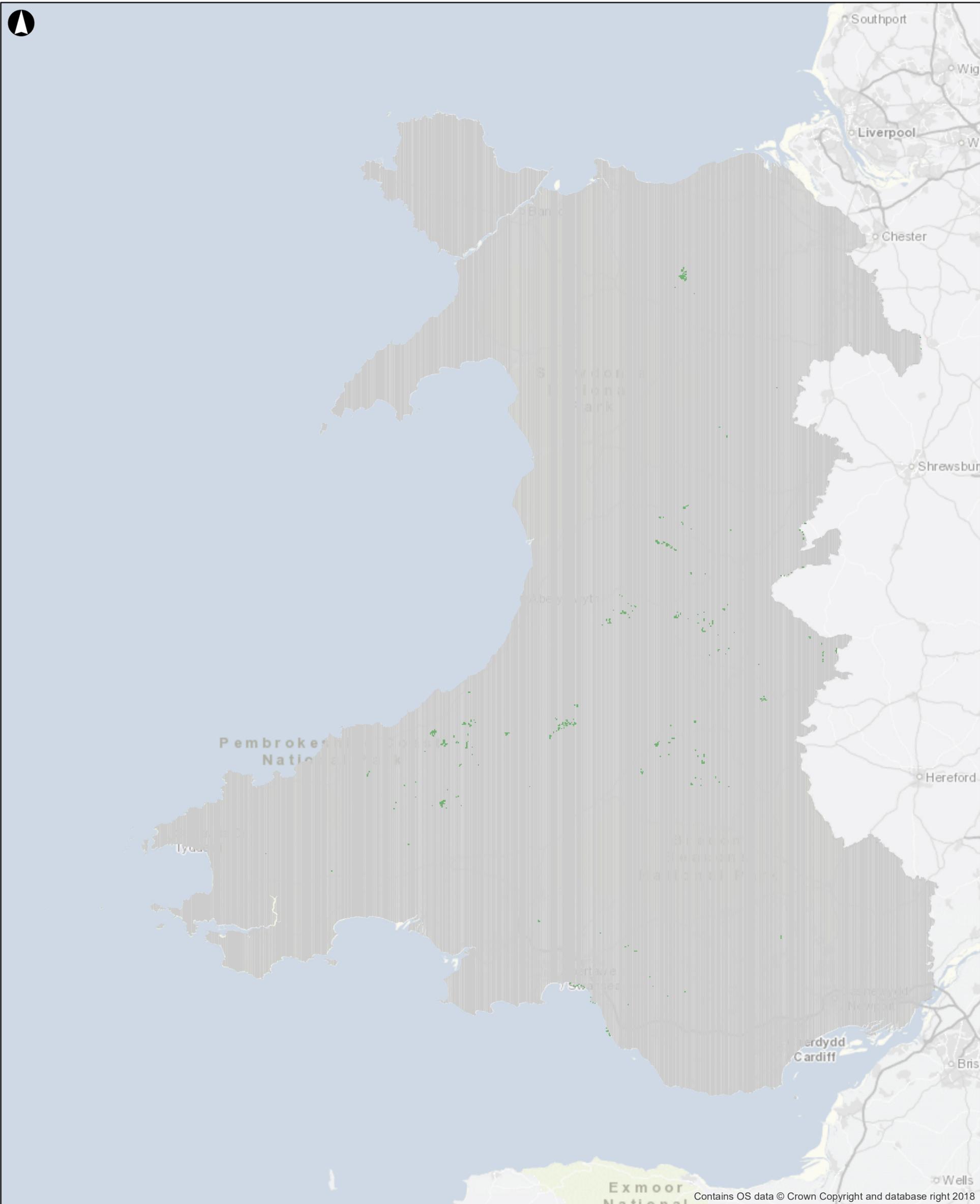


**NDF Scenario 3  
WIND**

Scale at A3

**1:840,000**

Job No <b>263184</b>	Drawing Status <b>For Issue</b>
Drawing No <b>007</b>	Issue <b>F1</b>



Contains OS data © Crown Copyright and database right 2018

**Legend**

- Most Opportunity
- Least Opportunity

F1	2018-12-10	FH		
Issue	Date	By	Chkd	Appd

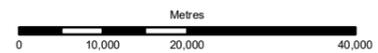
# ARUP

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
Client

**Welsh Government**

Job Title  
**Assessment of onshore wind and solar energy potential**



**Scenario 4-  
Most Constrained  
Scenario Wind**

Scale at A3

**1:840,000**

Job No

**263184**

Drawing Status

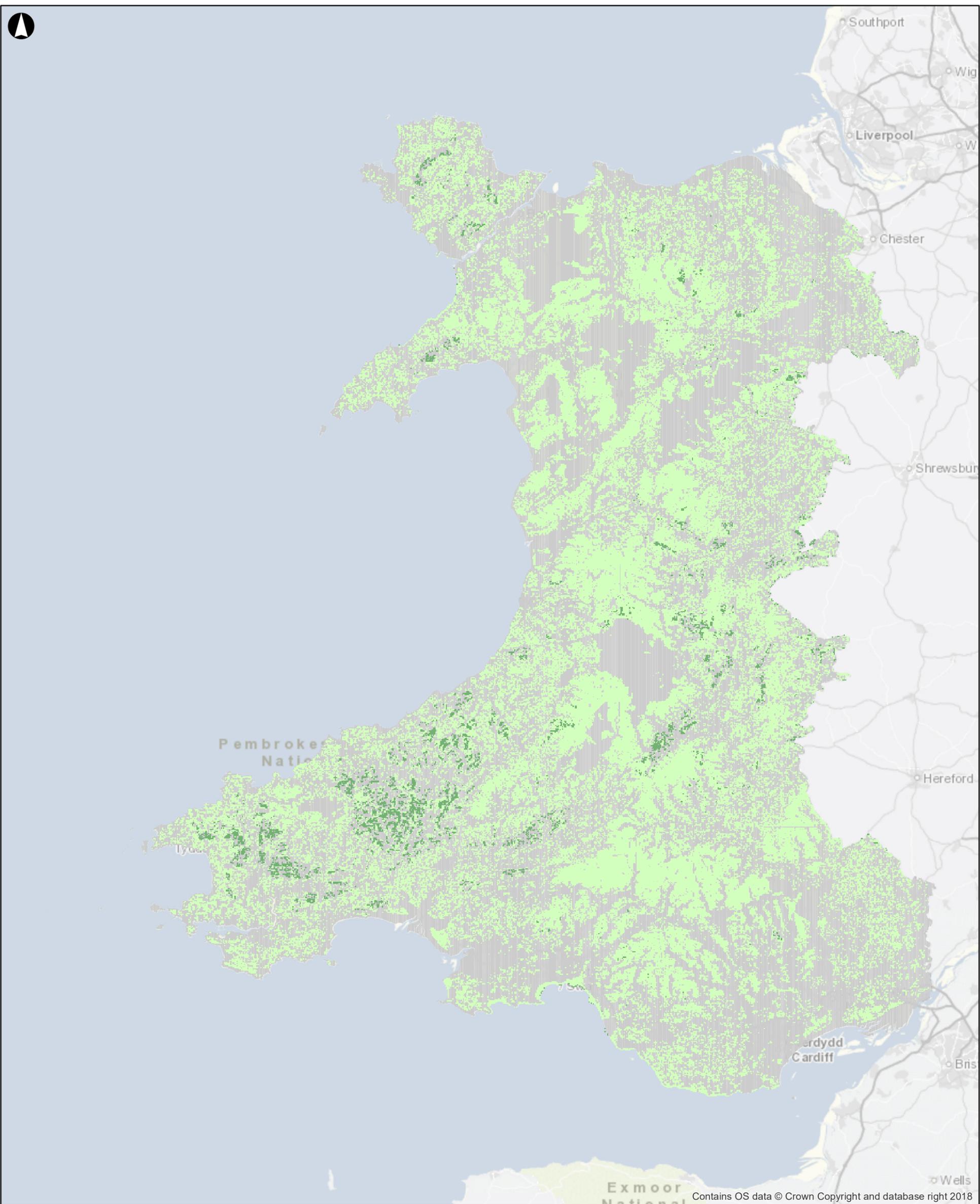
**For Issue**

Drawing No

**006**

Issue

**F1**



Contains OS data © Crown Copyright and database right 2018

**Legend**

- Most Opportunity
- Varying Opportunity
- Least Opportunity

F1	2018-12-10	FH		
Issue	Date	By	Chkd	Appd

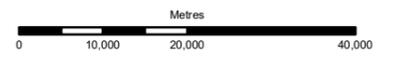
# ARUP

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
Client

**Welsh Government**

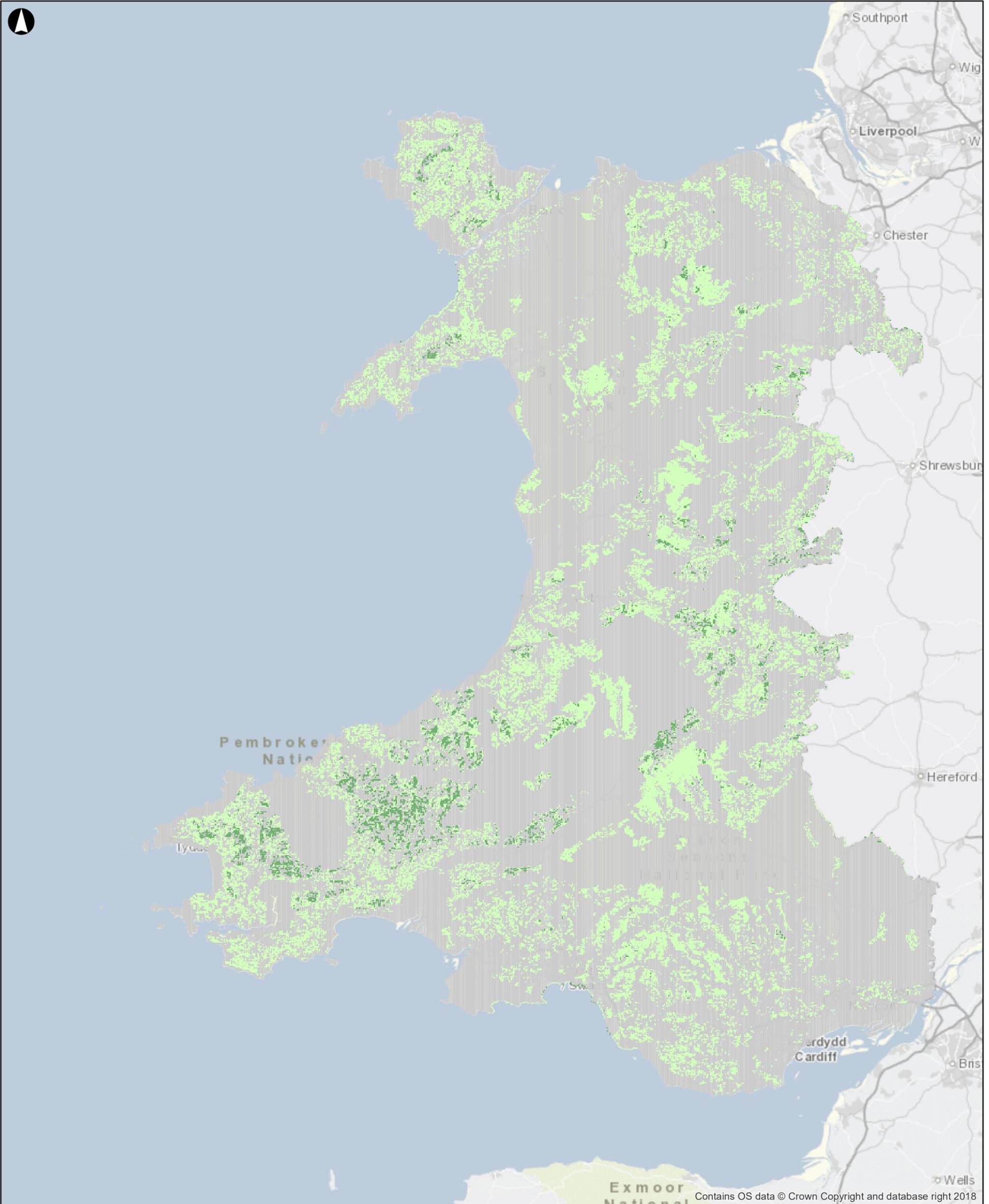
Job Title  
**Assessment of onshore wind and solar energy potential**



**Scenario 1 - Least Constrained Scenario Solar**

Scale at A3  
**1:840,000**

Job No <b>263184</b>	Drawing Status <b>For Issue</b>
Drawing No <b>005</b>	Issue <b>F1</b>



**Legend**

- Least Constrained
- Constrained
- Highly Constrained

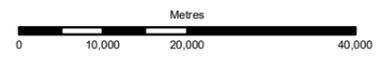
F1	2018-12-10	FH	BL	
Issue	Date	By	Chkd	Appd

# ARUP

63 St Thomas Street  
 Bristol, BS1 6JZ  
 T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
 Client  
**Welsh Government**

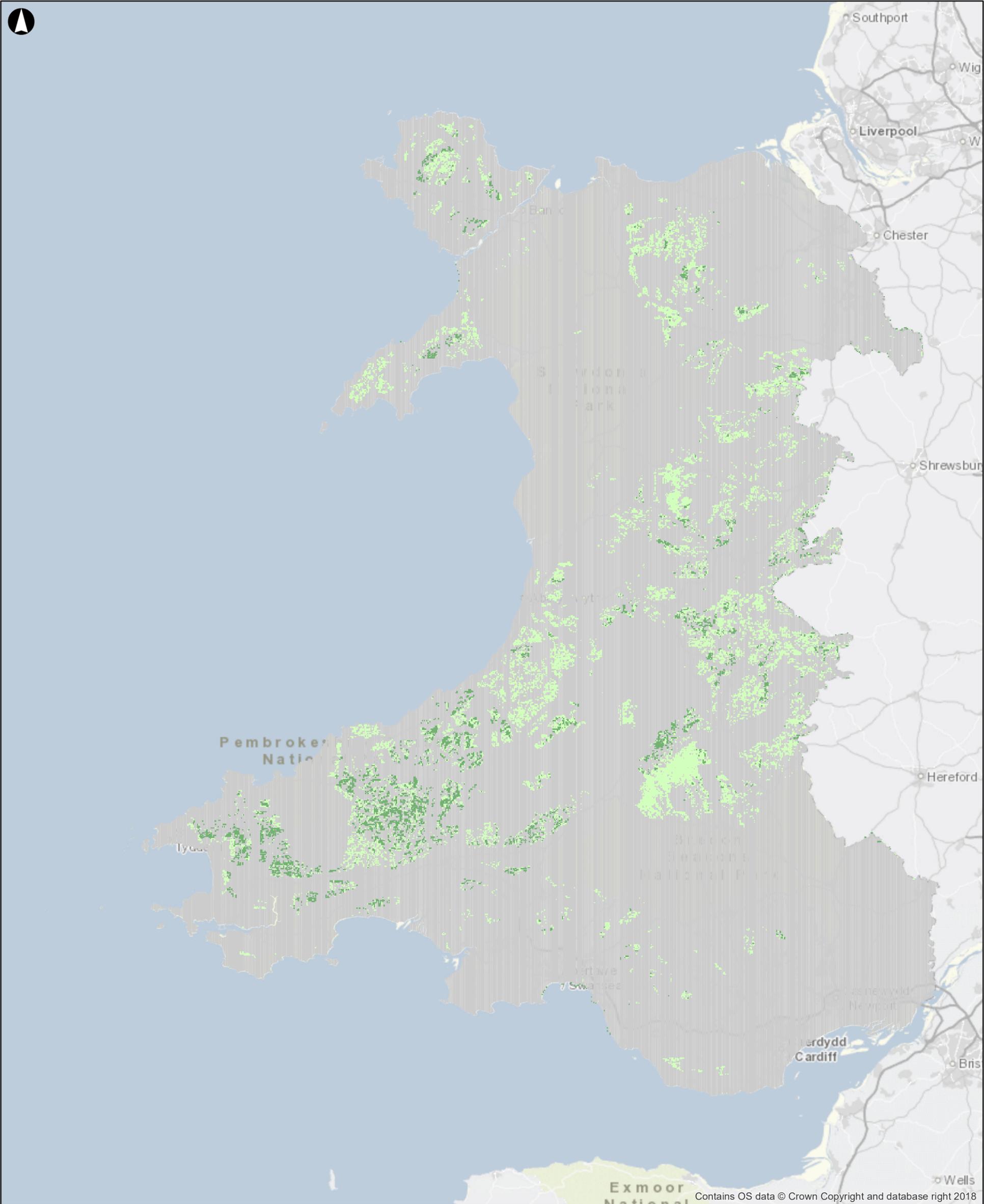
Job Title  
**Assessment of onshore wind and solar energy potential**



**NDF Scenario 2  
 SOLAR**

Scale at A3  
**1:840,000**

Job No <b>263184</b>	Drawing Status <b>For Issue</b>
Drawing No <b>002</b>	Issue <b>F1</b>



Contains OS data © Crown Copyright and database right 2018

**Legend**

- Least Constrained
- Constrained
- Highly Constrained

F1	2018-12-10	FH	BL	
Issue	Date	By	Chkd	Appd

**ARUP**

63 St Thomas Street  
Bristol, BS1 6JZ  
T +44 117 976 5432 D +44 117 988 6951

www.arup.com  
Client

**Welsh Government**

Job Title  
**Assessment of onshore wind and solar energy potential**



**NDF Scenario 3  
SOLAR**

Scale at A3

**1:840,000**

Job No  
**263184**

Drawing Status  
**For Issue**

Drawing No  
**003**

Issue  
**F1**



## Appendix C

Categorisation of constraints -  
overlay constraints

## C1 Categorisation of constraints – overlay constraints

Table 11: Categorisation of constraints – overlay constraints

Overlay	Wind/Solar/Both
National Grid Cable National Grid Substations National Grid OHL	Both
WPD GM Subs (11, 33, 66, 132 kV)	Both
SPEN Substation (Substation Grid, Substation Primary, Substation Super Grid)	Both
Existing Wind Turbine Sites	Both
Existing Solar Farm Sites	Both
Road Network	Both
Rail Network	Both
Radar Sweep 20m	Wind
Radar Sweep 80m	Wind
Radar Sweep 180m	Wind
Radar Sweep 200m	Wind
Active Travel Routes (National Trail Wales Coastal Path Sustran National Route Sustran NCN Link Sustran Regional Route)	Both
Listed Buildings	Both
Existing Buildings	Both
LandMap Geological	Both
LandMap habitats	Both
Flood Zone 2	Both
Flood Zone 3	Both
Slope (Steep, Very Steep)	Both
Scheduled Ancient Monument	Both
Registered Parks	Both
Tranquil Area	Both
Ramsar – 5km Buffer	Solar
Ramsar – 30km Buffer	Wind
Special Protection Area (SPA) – 5km Buffer	Solar

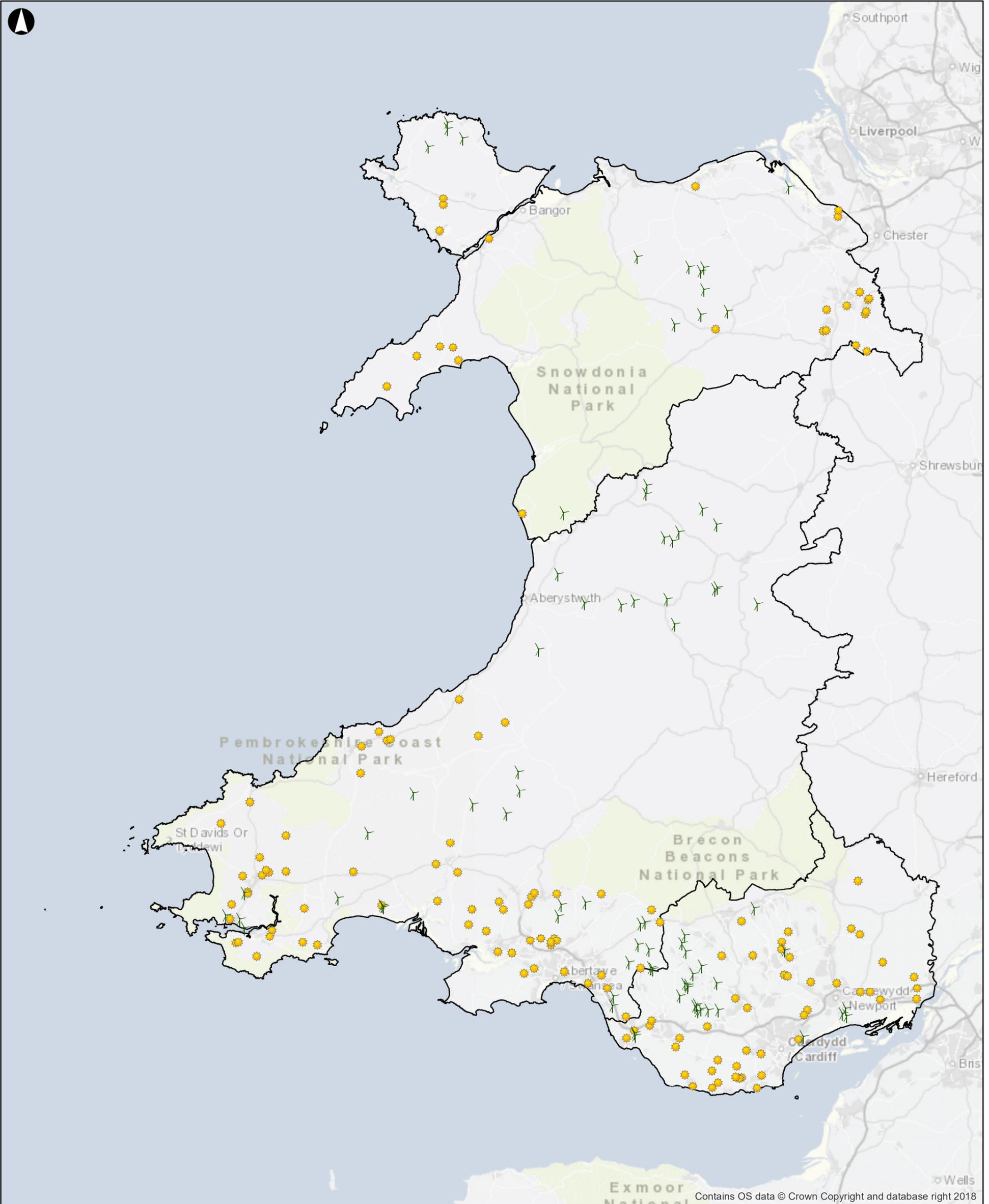
<b>Overlay</b>	<b>Wind/Solar/Both</b>
Special Protection Area (SPA) – 30km Buffer	Wind
Special Area of Conservation (SAC) – 5km Buffer	Solar
Special Area of Conservation (SAC) – 30km Buffer	Wind
Candidate Special Area of Conservation (cSAC) – 5km Buffer	Solar
Candidate Special Area of Conservation (cSAC) – 30km Buffer	Wind
World Heritage – 2km Buffer	Solar
World Heritage – 20km Buffer	Wind
Conservation Area– 2km Buffer	Solar
Conservation Area– 20km Buffer	Wind
National Park - 2km Buffer	Solar
National Park - 20km Buffer	Wind
Area of Outstanding Natural Beauty (AONB) – 2km Buffer	Solar
Area of Outstanding Natural Beauty (AONB) – 20km Buffer	Wind
Site of Special Scientific Interest (SSSI) – 2km Buffer	Solar
Site of Special Scientific Interest (SSSI) – 10km Buffer	Wind
National Nature Reserve – 2km Buffer	Solar
National Nature Reserve – 10km Buffer	Wind

## Appendix D

### Further maps

# D1

---



Contains OS data © Crown Copyright and database right 2018

- Welsh Regions
- ☀ Existing Solar Sites
- ⚡ Existing Wind Sites

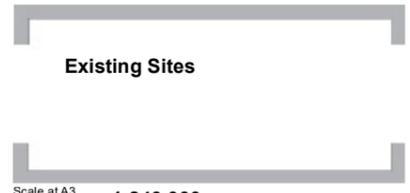
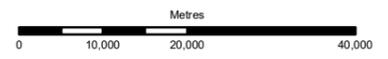
F1	2019-03-08	FH	BL	AC
Issue	Date	By	Chkd	Appd

# ARUP

63 St Thomas Street  
 Bristol, BS1 6JZ  
 T +44 117 976 5432 D +44 117 988 6951  
 www.arup.com

Client  
**Welsh Government**

Job Title  
**Energy Potential Wales**



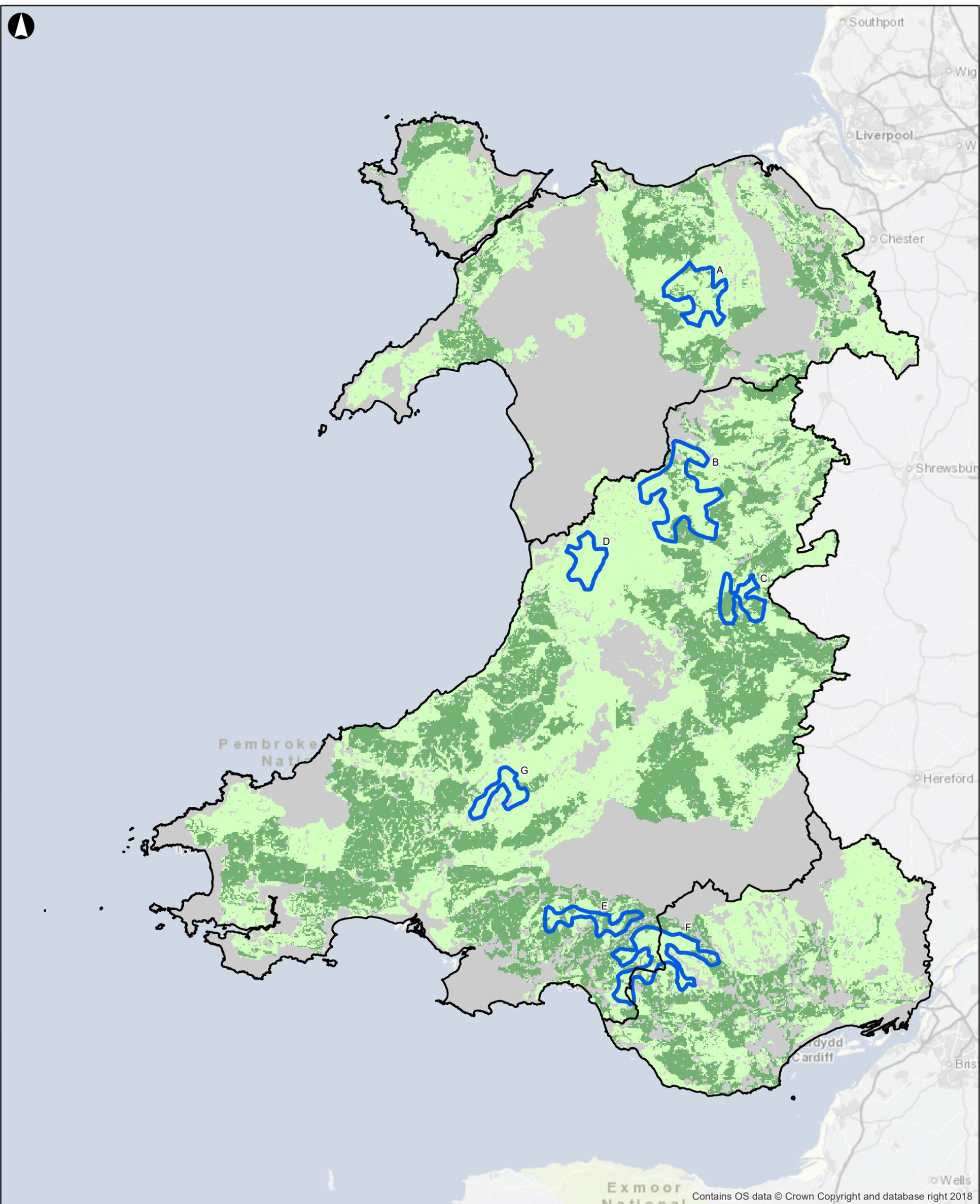
Scale at A3  
**1:840,000**

Job No  
**263184-00**

Drawing Status  
**For Issue**

Drawing No  
**D1**

Issue  
**F1**



Contains OS data © Crown Copyright and database right 2018

- Welsh Regions
- Areas of greatest opportunity
- Areas of varying opportunity
- Areas of least opportunity
- TAN8 SSA

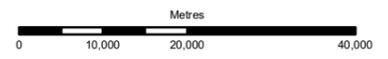
F1	2019-01-11	FH	BL	AC
Issue	Date	By	Chkd	Appd

# ARUP

63 St Thomas Street  
 Bristol, BS1 6JZ  
 T +44 117 976 5432 D +44 117 988 6951  
 www.arup.com

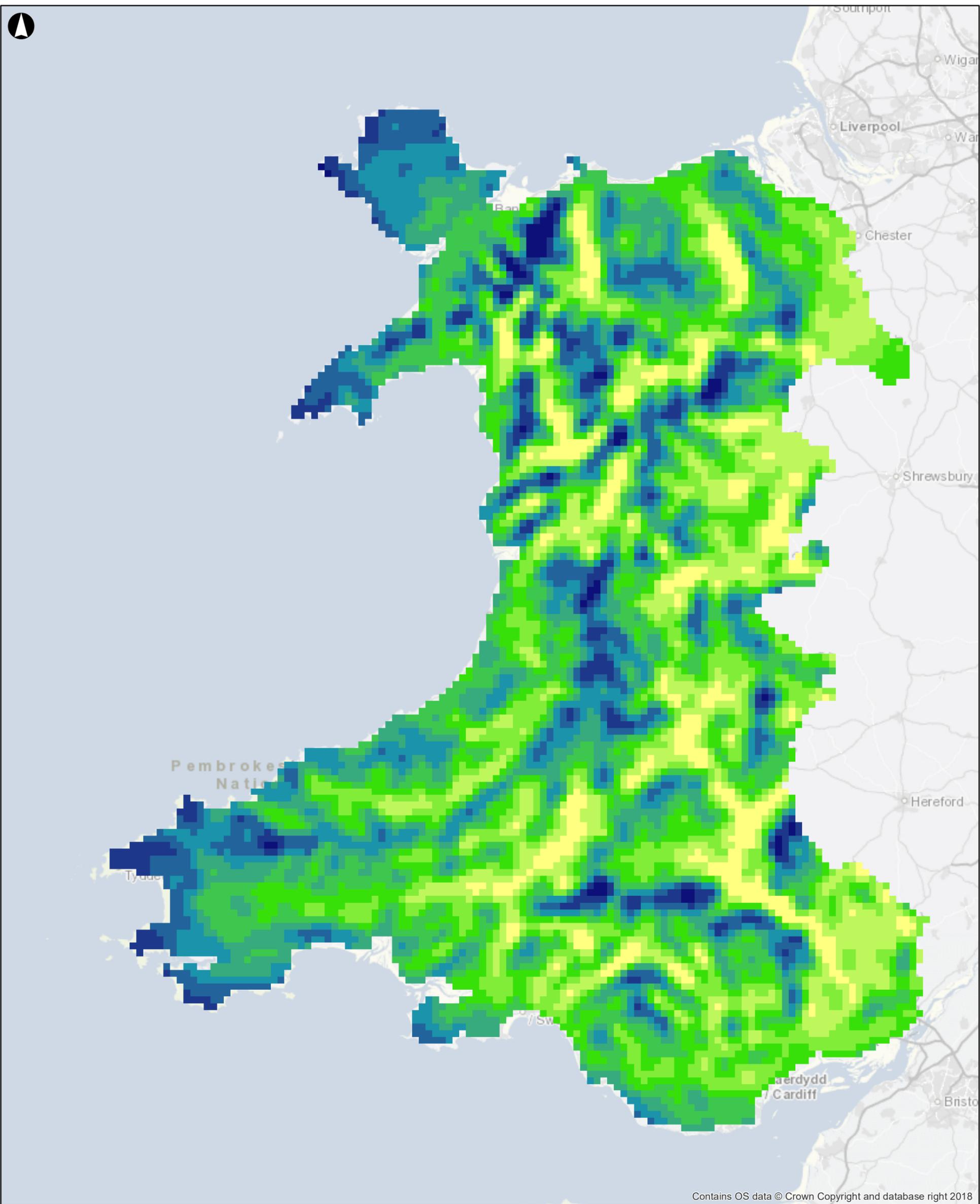
Client  
**Welsh Government**

Job Title  
**Energy Potential Wales**

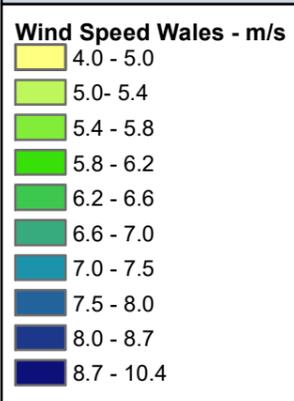


**Technical Advice Note 8  
 (Wind Preferred Scenario)**

Scale at A3	<b>1:840,000</b>
Job No	<b>263184-00</b>
Drawing Status	<b>For Issue</b>
Drawing No	<b>D2</b>
Issue	<b>F1</b>



Contains OS data © Crown Copyright and database right 2018



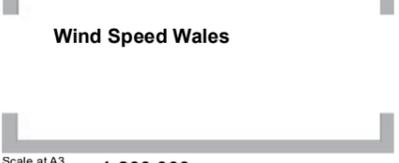
F1	2019-01-08	FH	BL	AC
Issue	Date	By	Chkd	Appd

# ARUP

63 St Thomas Street  
 Bristol, BS1 6JZ  
 T +44 117 976 5432 D +44 117 988 6951  
 www.arup.com

Client  
**Welsh Government**

Job Title  
**Energy Potential Wales**



Scale at A3	<b>1:800,000</b>
Job No	<b>263184-00</b>
Drawing Status	<b>For Issue</b>
Drawing No	<b>D3</b>
Issue	<b>F1</b>