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Development, maintenance and implementation of the United Nations Framework Classification for Resources: Renewable energy resources

Application of the United Nations Framework Classification for Resources to Wind Energy Resources: National Aggregation Case Studies

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Summary

This document presents case studies to exemplify the application and reporting on national wind energy resources using the United Nations Framework Classification for Resources (UNFC). UNFC is applied to all offshore wind resources in Scotland and classified into defined projects, development zones, and undeveloped areas. Within these groups, a project belongs to different classes, such as viable projects, potentially viable projects, non-viable projects, and prospective projects. The primary purpose of the case studies is to provide examples of projects with varying degrees of maturity in a country-wide reporting method.

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I. Introduction

1. The United Nations Framework Classification for Resources (UNFC) provides countries, companies, financial institutions, and other stakeholders a tool for sustainable development of mineral, petroleum, nuclear fuel, renewable energy and anthropogenic resources, as well as water and injection projects for geological storage [1]. At the core of UNFC is a project-based and principle-based approach to reporting resources. Classification of resources is based on three fundamental principles: environmental-socio-economic viability (E), technical feasibility (F) and degree of confidence (G). UNFC's incorporation of environmental-socio-economic principles aligns the framework with the challenges that society faces as it develops towards a sustainable, environmentally friendly and low-carbon future. These principles combine with technical readiness and confidence in estimates to complete a fully comprehensive analysis of a resource. The purpose is not to provide a solution in itself but to facilitate the decision making within business and government for policymaking, capital allocation and oversight of resource management.

2. To this end, the case studies in this report exemplify the application of UNFC as a means of reporting national resources. UNFC was applied to all offshore wind resources in Scotland and categorized into defined projects, development zones, and undeveloped areas. The primary purpose is to provide classification examples by presenting projects of varying degrees of maturity in a country-wide reporting method rather than to discuss the quantification methods themselves.

3. The realm of discourse, defined as the context of the quantitative evaluation and classification, is at the discretion of the reporter, provided it complies with government and applicable regulatory body regulations.

4. There are three UNFC documents referenced in this report: UNFC (2019) [1], Specifications for the application of UNFC to Wind Energy (UNFC Wind Specifications) [2], and UNFC (2009) [3]. The terminology in this report is aligned to UNFC (2019); however, it should be noted that the UNFC Wind Specifications, written prior to the publication of UNFC (2019), refer to UNFC (2009).

5. Given that no reporting template is currently offered (or enforced) as part of UNFC (2019), the application examples presented here follow a generic format - established in the publication of UNFC for application to Geothermal Energy resources [4] - solely for the purpose of consistent presentation to the public, but with no intention of making such format a mandatory template.

6. The application examples are offered as guidance and do not constitute rules of application of UNFC (2019) to wind energy.

II. Realm of Discourse of Evaluation

7. The Realm of Discourse (ROD) describes the conditions, the context, and reason for evaluating and classifying a resource [5]. The same project may be assessed differently by various reporters and for different purposes, and, consequently, resources may be classified in different ways.

8. The ROD chosen for these case studies is acting as a governmental body reporting the aggregated national offshore wind resources in Scotland. The resource evaluation and classification meet a set of unique conditions set by the reporter that may alter estimations and classifications of resources when compared to other realms of discourse. The conditions are as follows:

(i) The end goal of the report is to present a notional quantification and classification of all wind resources in Scotland; therefore, there is a greater concern for the aggerated performance, not the individual projects;

(ii) There is no consideration for potential wind energy demand, geographical or otherwise, in this report;

(iii) In the absence of meaningful economic data, the economic uncertainty of projects is reflected in the lifetime estimate of the project;

(iv) The social, technical, environmental, and economic considerations and assessment of the projects extend to the reference point of the project. If unknown, realistic assumptions are made and listed as such.

III. Quantification Method

9. To quantify the wind resources using UNFC's project-based approach, an estimate of energy produced over the project's lifetime is calculated. This relationship can be displayed graphically as the integral of estimated power output versus time. The project-specific wind resource is the power output of a given wind farm, calculated as the installed nominal capacity multiplied by the capacity factor. The remaining lifetime is the shorter of either the estimated design/project life or the economic limit of the project (measured in units of time). The resulting relationship can be written as:

Wind Resource = Total installed capacity x Remaining Lifetime x Capacity Factor

10. For projects in groups 2 and 3, a different quantification approach is typically shown in the Annex.

A. Remaining Lifetime

11. For defined projects, the main uncertainties for the wind resource estimations are the remaining lifetime and the capacity factor. The lifetime of a project could be constrained by technical, economic, regulatory or permit/license cut-offs. However, as stated in the UNFC Renewable Energy Specifications [6], unlike non-renewable sources, economic lifetime may not be an appropriate basis for the resource assessment because renewable energy is often replenished at a rate equal to or higher than consumed; thus, other project limiting factors may become more relevant than the economic limit.

12. In Scotland, and more widely in the UK, a Government-supported scheme called Contracts for Difference (CfD) is used as a mechanism to fund emerging and existing renewable technologies. Simplified, developers compete against technologies of a similar maturity for ring-fenced funding to abate the high capital expenditure and intermittency issues historically associated with renewable technologies. Successful bids - usually the developers with the lowest price per unit energy - are awarded a 15-year contract of a fixed price for the sale of energy to the grid. This predetermined price is known as the strike price.

13. Since 2015, there have been three contracts for difference rounds, with the outcome of the fourth expected in 2022. In the first allocation in 2021, offshore wind projects had a strike price of approximately £118/Mwh. However, through economy of scale, the most recent strike price was £40/Mwh.[1] This decrease has seen the levelized cost of energy (LCOE) reduced below the reference price of energy. This implies that projects are economically viable beyond the 15-year contract period; however, the project relies on the contract for security with capital funding.

14. Although the strike price of each project is known, project costs – and therefore the levelized cost of energy of the project – are unknown.[2] Due to the lack of meaningful data, a complete economic analysis cannot be performed. Instead, the quantification method used in this report reflects the economic uncertainty of projects in the lifetime of the project.

[1] Strike prices are in 2012 prices.

[2] Given the structure of the contract for difference, the Levelized Cost of Energy is below the Strike price.

B. Capacity Factor

15. The capacity factors used in this report are derived from historical data of defined projects. The capacity factor is defined as the total energy produced divided by the product of the number of hours since commissioning and the installed capacity. Otherwise put, the capacity factor is the ratio of energy produced to installed capacity i.e., the efficiency of a project. The inclusion of the capacity factor accounts for the uptime of the wind turbine, locational and intermittency factors. Known capacity factors of defined projects are used as benchmarks to estimate the capacity factor of pipeline projects based on a comparison of technical specifications and location proximity.

16. The projects outlined in the defined projects have all been subject to initial site-specific surveys as of 2020. In line with the current uptrend of capacity factors and the assumption of due diligence by developers, it is assumed that capacity factors, at a minimum, will be maintained in pipeline projects. When no direct comparisons can be made, this assumption is employed to best estimate based on a qualitative analysis of industry standards.

C. Quantifying Uncertainties for Wind Resources

17. To understand the uncertainty relating to the future wind energy production, the lifetime and capacity factor of the project are estimated with varying degrees of confidence: high, moderate and low, corresponding to the G1, G1+G2 and G1+G2+G3 values.[3]

18. **Remaining project lifetime**: In the absence of meaningful data to carry out a comprehensive economic analysis, economic viability is better inferred through publicly available information and the development status of the project(s). To this end, the ranges of the project lifetime will be used as a proxy for the economic uncertainty.

19. For projects that are the beneficiary of CfD, the low estimate of the remaining lifetime assumes that after the expiration of the contractual term (15 years), the project will not remain economically viable. On the contrary, the high estimate assumes that the remaining lifetime of the project is technically limited, and therefore the estimate is based on the manufacturer's expected technical lifetime. There are no projects where developers expected technical lifetime is equal to or less than the 15 year period of the CfD.

20. For projects that are privately funded, the lifetime of the projects is considered to be technical as per the estimations or industry standards of the manufacturer.

21. **Capacity factor:** The capacity factor is estimated using historical data [7] and, if unavailable, estimations are made using benchmarks from similar projects or industry standards.

22. Accurate estimations of lifetimes and capacity factors are challenging due to the novelty and rapid technical development of offshore wind technologies. However, emphasis is on consistency when reporting resources, allowing for the comparison of individual projects and national resources across a period of time.

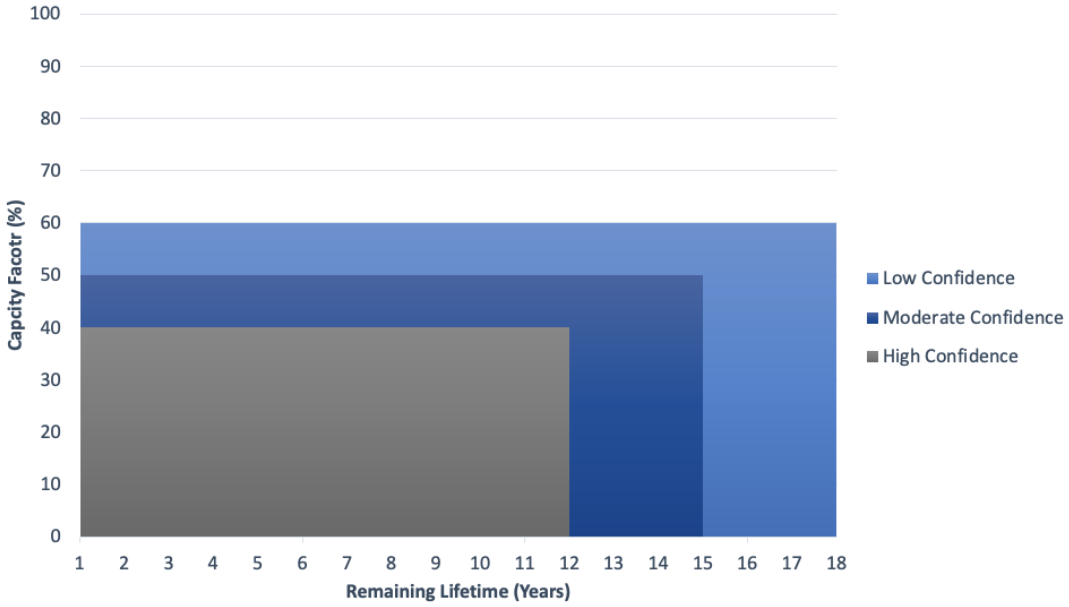
23. Given the varying degree of confidence of the input parameters listed above, the wind resource is reported in terms of low, moderate, and high estimates. The low estimate reported is the highest confidence in achieving the energy value calculated and vice versa.

24. In Figure I, three arbitrary lifetimes (12, 15 and 18 years) and capacity factors (40%, 50% and 60%) have been selected to represent estimations of high (G1), moderate (G1+G2) and low confidence (G1+G2+G3), respectively.

[3] The reader is referred to UNFC (2019) and UNFC Wind Specifications documents for further details.

Figure I

Quantifying the energy output over the lifetime of the project in accordance with UNFC's principles of reporting



25. This graph illustrates the G1, G2 and G3 values. The grey area represents the high confidence (low estimate; G1) of the total energy output over the lifetime of the project. The moderate confidence (G1+G2) is represented as the addition of the grey and dark blue areas on the graph. Similarly, the high estimate (low confidence; G1+G2+G3) is the collective areas coloured grey, dark blue and blue.

D. Reference Point

26. The reference point is a key component of the project definition that must be defined. It is the point at which the cumulative quantities of wind energy products are measured or estimated and will typically be the point of sale or consumption, which will depend on the legal stature or contract terms [6].

E. United Nations Framework Classification for Resources (2019)

27. UNFC (2019) classifications are performed using the E, F and G Categories and Sub-categories. Throughout the classification process, there is a generic reference to 'project elements' when classifying along the E axis, in particular when assigning an E1 or E2 classification. To easily differentiate between these two categories, E1 has all project elements in place, and E2 is missing one or more, although it is expected to be in place in the foreseeable future. Project elements can be defined as per the UNFC Renewable Energy Specifications and Wind Specifications [2]:

- Access to the source
- Access to market
- Authorization/entitlement
- Economic case
- Social and environmental considerations.

28. The UNFC Renewable Energy Specifications and Wind Specifications describe how the various project elements need to be considered when classifying the resource as per the UNFC numerical codes and the E, F and G axes. If there is insufficient information relating

to one or multiple project elements, then this is explicitly stated and reflected in the classification.

29. In accordance with the E-axis Categories, economic assumptions shall be based on current market conditions and realistic assumptions of future market conditions [2]. Further, current market conditions and realistic assumptions of future market conditions should include policy support mechanisms for wind energy but shall not assume that such mechanisms will become more beneficial in the future unless already specified in the regulation.

30. Expanding on the above projects that are economically viable through government subsidies may benefit from having more than one classification. For the period of the contractual term, the project may be classified as E1.2. A second classification, and in turn, a second project, would be classified as E1.1 or E3, depending on the OPEX of the project and the reference price of energy at the end of the contractual period (i.e., does the project remain economically viable?). Another possibility is an extension of government subsidies beyond the current contractual term, resulting in no change to the classification.

31. To address this, the decision rule employed in this report is that if a project is a beneficiary of a CfD, it will be classified accordingly, with prior consideration for the contractual length.[4] This may not be an appropriate ROD for other organizations; however, for the purpose of aggregating national resources, this is deemed a suitable condition to employ.

IV. Results

32. The Annex includes the resource quantification of the E-F-G project and project classification for all offshore wind projects in Scotland, grouped as Group 1: Defined projects, Group 2: Development Zones, and Group 3: Undeveloped Areas. Within these groups, a project belongs to different classes; viable projects, potentially viable projects, non-viable projects, and prospective projects.

33. Table 1 shows the outcome of the quantification and classification exercise on a per-project and/or per group basis.

[4] Economic uncertainty is reflected in lifetime uncertainty.

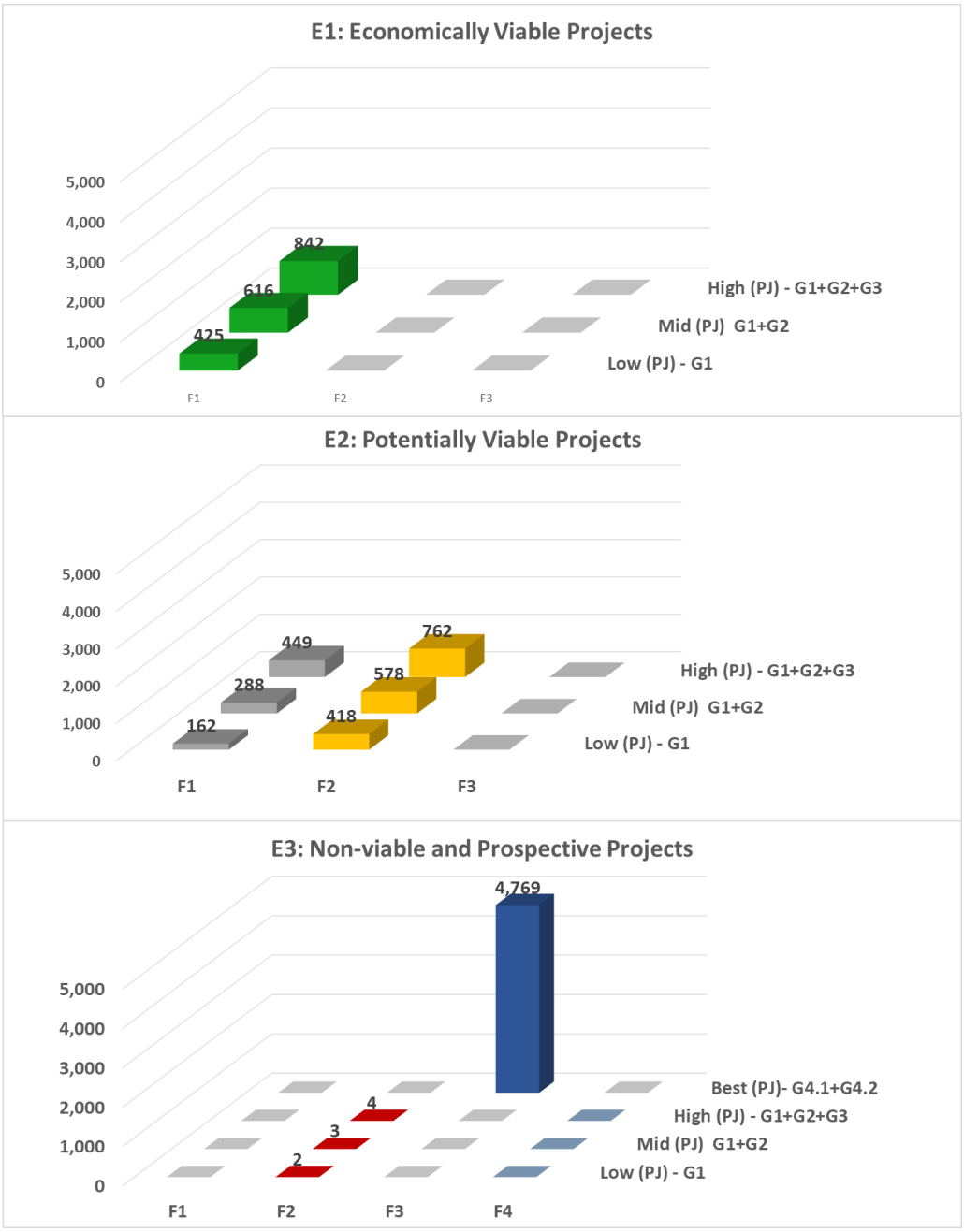
Table 1
Summary of projects/groups as per the aforementioned classification and quantification methods

Project/Group	*Number of turbines*	*Installed capacity (MW)*	*Distance from offshore (km)*	*Area (km^2)*	*Development Status*	*Funding*	*E*	*F*	*Low (PJ) G1*	*Mid (PJ) G1+G2*	*High (PJ) G1+G2+G3*
Beatrice	84	588	13	133	Operational	Private	1.1	1.1	134	171	213
Moray East	100	950	22	950	Under construction	Subsidy	1.2	1.2	180	270	375
Moray West	85	850	22	225	Consent granted	Not Secured	2	2.1	214	271	335
Dounreay Tri	2	10	9	25	Consent granted	Not Secured	3.3	2.2	2	3	4
Hywind Scotland Pilot Park	5	30	25	15	Operational	Private	1.1	1.1	8	10	12
Aberdeen Offshore Wind Farm (EOWDC)	11	93	3	20	Operational	Private and Grant	1.2	1.1	19	23	27
Kincardine	6	50	15	24	Under construction	Private	1.1	1.2	13	16	20
ForthWind Offshore Wind Demonstration Project Phase 1	2	30	2	2	Consent granted	Subsidy	2	2.1	4	8	12
ForthWind Offshore Wind Demonstration Project Phase 2	7	53	2	9	Early concept	Not Secured	2	2.1	10	15	21
Inch Cape	180	1000	15	150	Consent granted	Private	2	2.1	189	284	394
Neart na Gaoithe	64	448	16	105	Consent granted	Subsidy	1.2	1.2	64	113	177
Seagreen - Alpha and Beta	114	1140	30	400	Consent granted	Subsidy	2	1.3	162	288	449
Marr Bank and Berwick Bank (Formally Seagreen 2 and 3)	NA	4100	38-77	1440	Early concept	Not Secured	3.2	3.1	776	1,164	1,616
Robin Rig	56	168	13	18	Operational	Private	1.1	1.1	8	14	19
Project/Group	*Number of turbines*	*Installed capacity (MW)*	*Distance from offshore (km)*	*Area (km^2)*	*Development Status*	*Funding*	*E*	*F*	*Low (PJ) G4.1*	*Mid (PJ) G4.1+G4.2*	*High (PJ) G4.1+G4.2 +G4.3*
Category 2 Development Zones (various undefined projects)	NA	NA	varies	varies	Early concept	Not Secured	3.2	3.1	1803	3606	5409
Category 3 Undeveloped Areas (various undefined projects)	NA	NA	varies	varies	Early concept	Not Secured	3.3	4.1	141,000	185,000	230,000

V. Summary of Wind Resources

34. Figure II is a graphical representation of offshore wind resources in Scotland with the omission of undeveloped quantities. It shows the outcome of the project aggregation based on the E-F-G classification outcome of the aggregation of the projects. Undeveloped quantities are omitted to avoid distortion of the graph.

Figure II
Graphical representation of offshore wind resources in Scotland with the omission of undeveloped quantities



Note: Depicted: viable projects (green), potentially viable projects (yellow), non-viable projects (red), prospective projects (blue), and other combinations.

35. Table 2 also presents the aggregation of the projects on the basis of development status as it is customary practice in the wind energy sector. Please note that the project status is slightly different from the so-called UNFC classes (Refer back to status classes).

Table 2
Summary of quantification in terms of development status

Development Status	*Low (PJ) G1*	*Mid (PJ) G1+G2*	*High (PJ) G1+G2+G3*	*% of total[a] (using mid estimate)*
Operational	169	217	271	0.1%
Under construction	192	286	394	0.1%
Consent granted	635	966	1,371	0.5%
Early concept	2,588	4,784	7,045	2.5%
Undeveloped	141,215	184,769	229,643	96.7%
				100.0%

[a] Rounding error.

Annex

Project Classification and Resource Quantification

I. Group 1: Defined Project

A. Northeast Region

Beatrice Offshore Windfarm

Project Location: Approximately 13km from the Caithness Coast

Date of Evaluation: June 2020

Development Status: Fully Commissioned as of June 2019

Quantification Method: Based on production history

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 84

Installed Capacity: 588 MW

Area:133 km^2

Project Summary

1. Beatrice offshore wind farm is Scotland's largest operating wind farm, located 13km from the Caithness Coast in the northeast of Scotland. The joint venture between SSE Renewable (40% stake), Transmission Capital Partners (35%) and Red Rock Power Ltd.(25%) is fully commissioned with 84 turbines and a combined installed capacity of 588MW. The project has received a loan from the European investment bank [8].

2. An initial application was submitted for 144-277 turbines, which was granted in principle before the Crown Estate granted seabed exclusivity to the then development partnership of SSE Renewables and SeaEnergy in 2009. The development began in the same year, with the consent application submitted in 2012. The project was subject to public concern, with objections being lodged [9]. The most commonly cited concerns were: a major hazard to shipping, disturbance to the natural marine environment, financially unviable after subsidies are withdrawn (with some citing the oil and gas industry as a favourable alternative), and the 'unacceptable visual intrusion'. Despite the objections, the UK Government approved the application in 2014 following a comprehensive assessment.

Quantification

Reference point: Blackhillock Substation.

Project lifetime: The lifetime of the project is deemed technical lifetime, which is not defined by developers. The industry standard of 20-25 is applied.

Capacity Factor: The capacity factor estimate is based on the limited historical data (6 months of data from June-December 2019).

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	18	40	134
Moderate	20.5	45	171
High	23	50	213

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	Fully commissioned as of 2019, indicating all project elements are in place. The project received a loan from the European Investment Bank (EIB) - the largest international public bank. The loan strategy from EIB is to invest in higher-risk projects based on positive externalities; without a loan of this nature, the project is likely unfeasible. In spite of this, this is considered a private loan, and the project is economically viable without subsidy, justifying the E1.1 classification.
Sub-category	***UNFC (2019) definition***	
E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions.	

F Category classification and subclassification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	Fully Commissioned as of June 2019, with production taking place.
Sub-category	***UNFC (2019) definition***	
F1.1	Production is currently taking place.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.1; F1.1; G1	134	Based on a capacity factor of 40% and a project lifetime of 18 years.
E1.1; F1.1; G2	38 (G1+G2 = 134+38 = 171[a])	Based on a capacity factor of 45% and a project lifetime of 20.5 years.
E1.1; F1.1; G3	42 (G1+G2 +G3 = 134+38+42 = 213[a])	Based on a capacity factor of 50% and a project lifetime of 23 years.

[a] Rounding error.

Moray East offshore wind farm

Project Location: Approximately 22km off the coast in the Moray Firth

Date of Evaluation: June 2020

Development Status: In construction; final commissioning expected April 2022

Quantification Method: Estimates based on Beatrice Wind Farm

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 100

Installed Capacity: 950MW

Area: 295 km^2

Project Summary

3. Moray offshore windfarm (East), also known as Moray East offshore wind farm, is a development in the Outer Moray Firth, 22km off the coast of Scotland. The project is led by Moray Offshore Windfarm East (MOWEL), a joint venture of EDP Renewables (57%), Engie (23%), and Diamond Generating Europe (DGE, 20%). The development is split into three projects: Telford Offshore Wind Farm, Stevenson Offshore Wind Farm, and MacColl Offshore Wind Farm, for a combined capacity of 950MW, less than the 1,116MW consented for in 2016.

4. In 2017, the project was a successful participant in the UK's second contract for difference auction, with the onshore work beginning in 2018. The transmission infrastructure will include the installation of three offshore substations transmitting to an onshore substation, which is planned to be developed southwest of Aberdeenshire, to deliver the electricity generated by the wind farm to the national grid.

Quantification

Reference point: Onshore substation in New Deer, Aberdeenshire.

Economic lifetime: Cfd won in allocation round two for 950MW of installed capacity [10].

Technical lifetime: Technical lifetime is not defined by developers. The industry standard of 20-25 is applied.

Capacity Factor: The site is located in an area of proven output; Beatrice has a recorded capacity factor of 49.2% in its short lifetime to date; however, with consideration for seasonal energy generation, the moderate estimation of 45% will be used.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	15	40	180
Moderate	20	45	270
High	25	50	374

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	There is a reasonable assumption that there will be no impediments to the project reaching full commissioning, as expected, in April 2022 - given all project elements are in place. The project won a second-round contract for difference auction; therefore, it is the beneficiary of a government subsidy. After the contractual period has expired, reclassification is necessary based on technical factors of production and market conditions.
Sub-category	***UNFC (2019) definition***	
E1.2	Development is not environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions but is made viable through government subsidies and/or other considerations.	

F Category classification and subclassification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	Construction began in 2018, with full commissioning expected in 2022.
Sub-category	***UNFC (2019) definition***	
F1.2	Capital funds have been committed, and implementation of the development is underway.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.2; F1.2; G1	180	Based on a capacity factor of 40% and a project lifetime of 15 years.
E1.2; F1.2; G2	90 (G1+G2 = 180+90 = 270)	Based on a capacity factor of 45% and a project lifetime of 20 years.
E1.2; F1.2; G3	105 (G1+G2+G3 = 180+90+105 = 375)	Based on a capacity factor of 50% and a project lifetime of 25 years.

Moray West

Project Location: Approximately 22.5km off the coast of Wick in Moray Firth

Date of Evaluation: June 2020

Development Status: Consent Granted

Quantification Method: Estimations based on Beatrice Wind Farm

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: up to 85

Installed Capacity: 850MW

Area: 225km^2

Project Summary

5. Moray offshore windfarm (West), also known as Moray West offshore venture, is situated in the Outer Moray Firth, 22.5km off the coast of Scotland. The project is in planning as part of the ongoing development of the Moray Firth, where Beatrice and Moray East are in operation and construction, respectively. EDPR Offshore Espana, which has sole ownership of the project, has consent for up to 85 turbines and an installed capacity of around 850MW.

6. The initial application was submitted in 2010; however, due to ongoing works in the area, the project was put on hold before consent was authorized in 2019. A detailed survey campaign across the whole project during 2019 will be used for modelling and design work during 2020.

7. In the lead up to construction, further detailed surveys will be needed to finalize construction plans with further environmental surveys to inform the next planning stages that will commence in late 2020.

8. The offshore export cable circuits will come ashore to the east of San End Bay on the Aberdeenshire Coast prior to onward transmission to the recently upgraded Blackhillock

Substation (via a new substation at Whitehillock to step up voltage). A similar transmission route as the currently operating Beatrice offshore windfarm.

Quantification

Reference point: Blackhillock Substation

Project lifetime: The lifetime of the project is deemed technical lifetime, which is not defined by developers. The industry standard of 20-25 is applied.

Capacity Factor: With no comparable regional projects, industry standards were used.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	20	40	214
Moderate	22.5	45	271
High	25	50	335

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	The area is still undergoing surveying to advise the technical plans, which, once finalized, will be submitted for approval to the Scottish Ministers with little chance of refusal. Funding is not yet in place; it hopes to secure a contract for difference in the next auction round (2021) or identify an alternative route to market. Once funding is secured and technical plans approved, then promotion to E1 is advised.

Sub-category	***UNFC (2019) definition***
N/A	No sub-categories defined

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F2	The technical feasibility of a development project is subject to further evaluation.	Work is currently undergoing to finalize the design/selection of the wind turbines however are likely to be selected in the foreseeable future. Once the final selection of the turbine is confirmed, promotion to F1 is advised.

Sub-category	***UNFC (2019) definition***
F2.1	Project activities are ongoing to justify development in the foreseeable future.

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E2; F2.1; G1	214	Based on a capacity factor of 40% and a project lifetime of 20 years.
E2; F2.1; G2	57 (G1+G2 = 214+57 = 271)	Based on a capacity factor of 45% and a project lifetime of 22.5 years.
E2; F2.1; G3	64 (G1+G2 +G3 = 214+57+64 = 335)	Based on a capacity factor of 50% and a project lifetime of 25 years.

B. North Region

Dounreay Tri

Project Location: 9km off Dounreay, Caithness County

Date of Evaluation: June 2020

Development Status: Consent Granted

Quantification Method: Estimation based on industry standards

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 2

Installed Capacity: 10MW

Area: 25km^2

Project Summary

9. Dounreay Tri floating demonstration wind farm, consisting of two 5MW turbines, is being developed by Hexicon AB in the Scottish territorial waters 9km off Dounreay, Caithness County.

10. The proposed project aimed to put Scotland at the forefront of developing innovative deepwater technologies. Hexicon uses a single platform to house multiple turbines, and it is anchored with eight mooring lines. This utilization of the platform has many advantages, including less use of sea area, cost reduction for mooring, towing and maintenance, and fewer inter-array cables.

11. Construction began in March 2017; however, the project failed to meet the original expected commissioning date of summer 2018 and is now stagnant due to funding issues. Hexicon, who have had prior success with the technology in South Korea, have removed all information from their website stating, 'The project is currently on hold, but there is a strong commitment of the project's key suppliers to re-start the project at the earliest possible.'

Quantification

Reference point: The point of reference is the substation or switchgear which will be installed near the Dounreay Substation.

Project lifetime: The lifetime of the project is deemed technical lifetime, which is not defined by developers. The industry standard of 20-25 is applied.

Capacity Factor: Derived from industry standards as no data for direct comparison is available.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	20	30	2
Moderate	22.5	40	3
High	25	50	4

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E3	Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future, or evaluation is at too early a stage to determine environmental-socioeconomic viability.	Economic case: The project is currently on hold due to a lack of funding. This project may be assigned an E2 classification; however, due to the prolonged delay and lack of information currently publicly available, E3.3 is a suitable classification.
Sub-category	***UNFC (2019) definition***	
E3.3	On the basis of realistic assumptions of future conditions, it is currently considered that there are no reasonable prospects for environmental-socio-economic viability in the foreseeable future.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F2	Preliminary studies of a defined project provide sufficient evidence of the potential for development and that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.	Construction began in 2017 with a full development plan and remains technically feasible on the basis of previous success in South Korea. However, the project is currently on hold after a long period of delay due to a lack of funding, with no resolution expected in the foreseeable future.
Sub-category	***UNFC (2019) definition***	
F2.2	Project activities are on hold and/or were just as development may be subject to significant delay.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E3.3; F2.2.; G1	2	Based on a capacity factor of 30% and a project lifetime of 20 years.
E3.3; F2.2; G2	1 (G1+G2 = 2+1 = 3)	Based on a capacity factor of 40% and a project lifetime of 22.5 years.
E3.3; F2.2; G3	1 (G1+G2 +G3 = 2+1+1 = 4)	Based on a capacity factor of 50% and a project lifetime of 25 years.

C. East Region

Hywind Scotland Pilot Park

Project Location: Approximately 25km off the coast of Aberdeenshire.

Date of Evaluation: June 2020

Development Status: Fully commissioned as of October 2017

Quantification Method: Estimation based on production history

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 5

Installed Capacity: 30MW

Area: 15 km^2

Project Summary

12. Hywind Scotland pilot park is the world's first integrated energy storage system to be connected to a floating offshore wind farm. The joint venture between Equinor (75%) and Masdar (25%) is situated approximately 25km off the coast of Peterhead and is comprised of five 6MW wind turbines for a total installed capacity of 30MW. Equinor and Masdar have privately funded the pilot project that has been operational since 2017.

13. The Hywind concept has been demonstrated and verified through five years of operation of the 2.3 MW Hywind Demo during which the prototype has performed beyond expectations. The pilot park aims to demonstrate cost-efficient and low-risk solutions for commercial-scale wind parks. By removing the conventional bottom-fixed design, floating wind allows for wind turbines to be placed almost anywhere the water depth in excess of 60m, thus gaining access to stronger, more consistent wind resources.

14. Storage for Hywind is also unconventional. The onshore Project infrastructure comprises an underground cable approximately 1.5 km in length and a small switchgear yard facility close to the Peterhead Grange substation. The electricity generated from the wind farm is transmitted to landfall, where, as of June 2018, it is stored in a 1MW battery system on the coast at Peterhead. The electricity is then exported to the national grid when required. The purpose is to harmonize production and demand, thus providing a more reliable and valuable power supply.

Quantification

Reference point: The reference point is the transmission for the Peterhead substation to the national grid

Project lifetime: *Technical lifetime* - the technical lifetime of the wind turbine is expected to be 20-25 years. The remaining lifetime is calculated using the range minus time since commissioning (3 years).

Capacity Factor: The lifetime capacity factor, based on 1.5 years of data, was found to be 53.8%, with a capacity of 55.3% in the last year, the highest of any project in the UK.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	17	48	8
Moderate	19.5	52	10
High	22	56	12

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	Fully commissioned as of 2017, indicting all project elements are in place. The project is privately funded by Equinor and Masdar; therefore, the project is economically viable without the aid of government subsidy.
Sub-category	***UNFC (2019) definition***	
E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	Fully Commissioned as of October 2017.
Sub-category	***UNFC (2019) definition***	
F1.1	Production is currently taking place.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.1; F1.1; G1	8	Based on a capacity factor of 48% and a remaining project lifetime of 17 years.
E1.1; F1.1; G2	2 (G1+G2 = 8+2 = 10)	Based on a capacity factor of 52% and a remaining project lifetime of 19.5 years.
E1.1; F1.1; G3	2 (G1+G2 +G3 = 8+2+2 = 12)	Based on a capacity factor of 56% and a remaining project lifetime of 21years.

Aberdeen Offshore Wind Farm (EOWDC)

Project Location: Approximately 3km off the coast of Aberdeenshire.

Date of Evaluation: June 2020

Development Status: Fully commissioned as of summer 2018

Quantification Method: Estimation based on production history

Estimation type: Deterministic

Water Depth: 60m

Number of turbines: 11

Installed Capacity: 93.2MW

Area: 20km^2

Project Summary

15. The European Offshore Wind Deployment Centre (EOWDC) is located off the coast of Aberdeen. The project consists of a commercial offshore wind farm (Aberdeen offshore wind farm) with an installed capacity of 93.2MW and associated facilities for research, testing and training. The wind project received approval from the Scottish Government in March 2013 after being subject to objections for more than two years. The offshore site investigation work was complete by April 2016, and offshore construction began in October 2016. The project was awarded a European Union Grant of 40 million Euros under the European Energy Programme for Recovery.

16. Aberdeen Offshore Wind Farm Limited (AOWFL) was awarded the rights by the Crown Estate in August 2010 to develop the wind power project. The consent application for a standard wind farm with 11 turbines was submitted in August 2011. The application was later altered to build a demonstration wind power project instead of with new generation turbines technologies, complemented by research and testing facilities at the site. A key component to the success of the project was the new foundation type of three-legged jacket with suction buckets allowing for a more efficient installation.

Quantification

Reference point: The transmission to the grid occurs at Blackdog Substation.

Project lifetime: *Technical lifetime*- The technical lifetime of the wind turbine is expected to be 20-25 years.

Capacity Factor: The capacity factors estimates are derived from the historical data of the project, with an average capacity factor of approximately 39% to date.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	18	36	19
Moderate	20.5	38	23
High	23	40	27

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	The project was commissioned in 2018, indicating all project elements are in place. The project received a 40 million euros grant from the European Union, considered a subsidy; therefore, E1.2 is a suitable classification.
Sub-category	***UNFC (2019) definition***	
E1.2	Development is not environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions but is made viable through government subsidies and/or other considerations.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	Fully commissioned as of June 2018.
Sub-category	***UNFC (2019) definition***	
F1.1	Production is currently taking place.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.2; F1.1; G1	19	Based on a capacity factor of 36% and a project lifetime of 18 years.
E1.2; F1.1; G2	4 (G1+G2 = 19+4 = 23)	Based on a capacity factor of 38% and a project lifetime of 20.5 years.
E1.2; F1.1; G3	4 (G1+G2 +G3 = 19+4+4 = 27)	Based on a capacity factor of 40% and a project lifetime of 23 years.

Kincardine

Project Location: 15 kilometres off the coast, south of Aberdeen

Date of Evaluation: June 2020

Development Status: Under construction; Full commission expected in 2020

Quantification Method: Estimation based on industry standards

Estimation type: Deterministic

Water Depth: 60 -100m

Number of turbines: 6

Installed Capacity: 50MW

Area: 24km^2

Project Summary

17. Kincardine offshore wind farm, developed by Cobra Wind, is set to become the world's largest floating offshore wind farm. The 50MW installed capacity will consist of five 9.6MW turbines and the already operational 2MW demonstrator turbine. The pilot-scale demonstrator turbine was commissioned in October 2018 and confirmed the feasibility of a commercial-scale project which is scheduled to reach full capacity by 2020.

18. In 2020, Cobra secured a 380 million loan from French bank Natixis SA. This was awarded after green credentials were confirmed by the Climate Bonds Initiative [11].

Quantification

Reference point: The reference point is landfall at Redmoss Substation.

Project lifetime: *Technical lifetime* - The technical lifetime of the wind turbine is expected to be 20-25 years.

Capacity Factor: The demonstrator turbine was commissioned and confirmed the feasibility of the commercial scale site. However, due to the smaller scale of the project, the capacity factor data is not a true reflection of the larger-scale project; therefore, the capacity factor was taken from industry standards.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	20	40	13
Moderate	22.5	45	16
High	25	50	20

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	Although the project is set to become fully operationally by 2020, partial completion and extraction have confirmed all project elements are in place.
Sub-category	***UNFC (2019) definition***	
E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	The partial operation has confirmed the feasibility of the project. Once complete, the project should be promoted to F1.1.
Sub-category	***UNFC (2019) definition***	
F1.2	Capital funds have been committed, and implementation of the development is underway.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.1; F1.2; G1	13	Based on a capacity factor of 40% and a project lifetime of 20 years.
E1.1; F1.2; G2	3 (G1+G2 = 13+3 = 16)	Based on a capacity factor of 45% and a project lifetime of 22.5 years.
E1.1; F1.2; G3	4 (G1+G2 +G3 = 13+3+4 = 20)	Based on a capacity factor of 50% and a project lifetime of 25 years.

ForthWind Offshore Wind Demonstration Project Phase 1

Project Location: 1.5km off the coast of Kirkcaldy Bay

Date of Evaluation: June 2020

Development Status: Consent Granted

Quantification Method: Estimations based on industry standards

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 2

Installed Capacity: 30MW

Area: $2km^2$

Project Summary

19. ForthWind, the offshore demonstration, is situated in shallow waters approximately 1.5km off the coast of Lavenmouth. In phase one, CIERCO intends to install two new 'pre-commercial' turbines to validate the technical and operational ability of the new offshore wind turbine technology on fixed foundations.

Quantification

Reference point: The reference point will be on landfall at a substation located at the Fife Energy Park.

Economic lifetime: Cfd won in allocation round three for 12MW of installed capacity [12].

Technical lifetime: Technical lifetime is not defined by developers. The industry standard of 20-25 is applied.

Capacity Factor: The capacity factor was derived from industry standards; however, due to the novel nature of the technology, there is no direct comparison.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	15	30	4
Moderate	20	40	8
High	25	50	12

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	The project is in the process of finalizing consent and licensing. Given the project successfully won a third-round contract for difference auction, it is likely that the project will be viable in the foreseeable future.
Sub-category	***UNFC (2019) definition***	
N/A	No Sub-categories defined	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F2	The technical feasibility of a development project is subject to further evaluation.	The project has been deemed technically feasible in order to receive capital funds commitment (via the contract for difference auction) which would result in an F1.2 classification. However, all parties, including the government, should be committed to development. Given not all licenses have been granted yet, F2.1 is a suitable classification until government commitment is confirmed.
Sub-category	***UNFC (2019) definition***	
F2.1	Project activities are on hold and/or were just as development may be subject to significant delay.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E2; F2.1; G1	4	Based on a capacity factor of 30% and a project lifetime of 15 years.
E2; F2.1; G2	3 (G1+G2 = 4+3 = 8[a])	Based on a capacity factor of 40% and a project lifetime of 20 years.
E2; F2.1; G3	4 (G1+G2+G3 = 4+3+4 = 12[a])	Based on a capacity factor of 50% and a project lifetime of 25 years.

[a] Rounding error.

ForthWind Offshore Wind Demonstration Project Phase 2

Project Location: 1.5km off the coast of Kirkcaldy Bay

Date of Evaluation: June 2020

Development Status: Early planning/concept

Quantification Method: Estimations based on industry standards

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 7

Installed Capacity: 53 MW

Area: 9 km^2

Project Summary

20. Phase 2 of the ForthWind floating wind development is in the early planning stage with; currently, no consent is authorized. CIERCO hopes to continue their development of floating wind technology in the shallow waters of Kirkcaldy Bay - to allow for the technology to achieve commercial readiness - before the expansion into deeper waters.

Quantification

Reference point: Reference point will be on landfall at the substation with the transmission to the national grid

Project lifetime: *Technical lifetime* - the technical lifetime of the wind turbine is expected to be 20-25 years.

Capacity Factor: The capacity factor was taken from industry standards; however, due to the novel nature of the technology, there is no direct comparison.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	20	30	10
Moderate	22.5	40	15
High	25	50	21

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	The project is yet to have consent granted; however, given the capital commitment and progress of phase one, it is assumed that the project will become viable in the foreseeable future.
Sub-category	***UNFC (2019) definition***	
N/A	No Sub-categories defined	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F2	The technical feasibility of a development project is subject to further evaluation.	Preliminary studies have taken place. Further studies are currently in development, i.e. phase one, which will provide additional data to confirm feasibility.
Sub-category	***UNFC (2019) definition***	
F2.1	Project activities are ongoing to justify development in the foreseeable future.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E2; F2.1; G1	10	Based on a capacity factor of 30% and a project lifetime of 20 years.
E2; F2.1; G2	5 (G1+G2 = 10+5 = 15)	Based on a capacity factor of 40% and a project lifetime of 22.5 years.
E2; F2.1; G3	6 (G1+G2 +G3 = 10+5+6 =21)	Based on a capacity factor of 50% and a project lifetime of 25 years.

Inch Cape

Project Location: 15km off the Angus Coast

Date of Evaluation: June 2020

Development Status: Consent Granted

Quantification Method: Estimations based on industry standards

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: Up to 180

Installed Capacity: 1000MW

Area: 150km^2

Project Summary

21. Inch Cape is a proposed project approximately 15km from the coast the Angus Coast. Consent has been granted in principle for both onshore and offshore construction of up to 72 turbines, with an estimated installed capacity of 1,000MW, in summer 2019 by the Scottish Government. The project is being developed by SeaEnergy Renewables, which was involved in the pioneering instalment of the Beatrice Demonstrator project.

Quantification

Reference point: The reference point will be the connection to the National Grid at Cockenzie, East Lothian.

Project lifetime: *Technical lifetime* - the technical lifetime of the wind turbine is expected to be 20-25 years.

Capacity Factor: The capacity factor was taken from industry standards; there is no direct comparison.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	20	30	189
Moderate	22.5	40	284
High	25	50	394

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	Most project elements are in place; however, some, specifically consent and licenses, are not. It is reasonable to assume that the project elements will be in place in the foreseeable future.
Sub-category	***UNFC (2019) definition***	
N/A	No Sub-categories defined	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F2	The technical feasibility of a development project is subject to further evaluation.	A preliminary project outline has been published; however, work is currently ongoing to confirm the feasibility of the project, i.e. specific design aspects.
Sub-category	***UNFC (2019) definition***	
F2.1	Project activities are ongoing to justify development in the foreseeable future.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E2; F2.1; G1	189	Based on a capacity factor of 30% and a project lifetime of 20 years.
E2; F2.1; G2	95 (G1+G2 = 189+95 = 284)	Based on a capacity factor of 40% and a project lifetime of 22.5 years.
E2; F21.1; G3	110 (G1+G2 +G3 = 189+95+110 = 394)	Based on a capacity factor of 50% and a project lifetime of 25 years.

Neart na Gaoithe

Project Location: 15.5 km off the Fife Coast

Date of Evaluation: June 2020

Development Status: Consent Granted

Quantification Method: Estimations based on industry standards

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 64

Installed Capacity: 448 MW

Area: 105 km^2

Project Summary

22. Neart na Gaoithe is a project consented to 15.5km from the Fife Coast with a proposed installed capacity of 448MW after securing a contract for the difference from the Scottish government. The application for sixty-four 7MW turbines was granted by Marine Scotland in 2014. The project was then subject to a Judicial Review of the Scottish Ministers after concerns were raised by the Royal Society for the Protection of Birds (RSPB). This caused a significant delay until 2017 when the Supreme Court ruled in favour of the original decision to grant consent. The project is expected to be fully commissioned by 2023; however, construction has yet to begin.

Quantification

Reference point: Onshore grid connection is at Crystal Rig onshore wind farm near Dunbar, East Lothian.

Economic lifetime: Cfd won in allocation round one [13].

Technical lifetime: Developers estimate the operational lifetime to be 25 years [14].

Capacity Factor: The capacity factor was taken from industry standards; there is no direct comparison in close proximity.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	15	30	64
Moderate	20	40	113
High	25	50	177

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	The project has consent granted and all project elements in place; however, construction is yet to begin. It is reasonable to assume that no impediments will prevent the project from commissioning as expected in 2023. The project won the first-round contract for difference auction; therefore, it is the beneficiary of a government subsidy. After the contractual period has expired, reclassification is necessary based on technical factors of production and market conditions.

Category	*UNFC (2019) definition*	*Reasoning for Classification*
Sub-category	***UNFC (2019) definition***	
E1.2	Development is not environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions but is made viable through government subsidies and/or other considerations.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	The development plan is in place and funding committed (F1.2 classification); however, construction has not begun. Once commissioned, the project should be promoted to F1.1.
Sub-category	***UNFC (2019) definition***	
F1.2	Capital funds have been committed, and implementation of the development is underway.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.2; F1.2; G1	64	Based on a capacity factor of 30% and a project lifetime of 15 years.
E1.2; F1.2; G2	64 (G1+G2 = 64+49= 113)	Based on a capacity factor of 40% and a project lifetime of 20 years.
E1.2; F1.2; G3	49 (G1+G2+G3= 64+49+64 = 177)	Based on a capacity factor of 50% and a project lifetime of 25years.

Seagreen - Alpha and Beta

Project Location: 27km and 38km from the Angus coastline

Date of Evaluation: June 2020

Development Status: Consent Granted

Quantification Method: Estimations based on industry standards

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 114

Installed Capacity: 1140 MW

Area: 400km^2

Project Summary

23. Seagreen Alpha and Beta are currently being developed in unison 27km and 38km, respectively, from the Angus coastline. The wind farms will collectively have an installed capacity of 1140MW produced from 114 turbines after an amendment was approved by Scottish Ministers in August 2018. Seagreen Wind Energy, a wholly-owned subsidiary of SSE, secured a contract for difference, agreeing on a favourable price for approximately

500MW, 43% of the estimated production per year for 15 years. This dependency on the contract for difference is reflected in the economic life of the project.

Quantification

Reference point: The reference point will be the connection to the National Grid at Tealing Substation, North of Dundee.

Economic lifetime: Cfd won in allocation round three for 454MW [12]. This covers phase 1 (alpha) installed capacity.

Technical lifetime: Developers estimate the operational lifetime to be 25 years [14].

Capacity Factor: The capacity factor was taken from industry standards as there is no direct comparison in close proximity.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	15	30	162
Moderate	20	40	288
High	25	50	449

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future.	Most project elements are in place; however, the amendments to the project are pending. Once authorized, the project should promote to E1.2 as it is the beneficiary of a contract for difference.
Sub-category	***UNFC (2019) definition***	
N/A	No Sub-categories defined.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	The maturity of the project would be classified as F1.2 as all plans are in place and funds have been committed. However, due to the pending amendments, construction has not started; therefore, the project is classified as F1.3.
Sub-category	***UNFC (2019) definition***	
F1.3	Studies have been completed to demonstrate the technical feasibility of development and operation. There shall be a reasonable expectation that all necessary approvals/contracts for the project to proceed to development will be forthcoming.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E2; F1.3; G1	162	Based on a capacity factor of 40% and a project lifetime of 15 years.
E2; F1.3; G2	126 (G1+G2 = 162+126 = 288)	Based on a capacity factor of 45% and a project lifetime of 20 years.
E2; F1.3; G3	162 (G1+G2+G3 = 162+126+162 = 449[a])	Based on a capacity factor of 50% and a project lifetime of 25 years.

[a] Rounding error.

Marr Bank and Berwick Bank (Formally Seagreen 2 and 3)

Project Location: 38km and 77km from the coast in the Outer Firth and Forth

Date of Evaluation: June 2020

Development Status: Early planning/concept

Quantification Method: Estimations based on industry standards

Estimation type: Deterministic

Water Depth: 60m-100m

Number of turbines: Unknown

Installed Capacity: 4,100MW

Area: 1440km^2

Project Summary

24. Marr and Berwick Bank has the potential to be Scotland's largest wind farm with a total installed capacity of 4,100MW. The project remains in the very early planning stage, with only the initial geological surveys having been completed. SSE intends to commission several surveys in the coming years to investigate different socio-environmental issues.

Quantification

Reference point: The reference point will be on landfall at the substation with the transmission to the national grid.

Project lifetime: *Technical lifetime* - The technical lifetime of the wind turbine is expected to be 20-25 years.

Capacity Factor: The capacity factor was taken from industry standards; however, due to the novel nature of the technology, there is no direct comparison.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	20	30	776
Moderate	22.5	40	1164
High	25	50	1616

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E3	Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future, or evaluation is at too early a stage to determine environmental-socio-economic viability.	The project is in the early planning phase; therefore, project elements cannot be defined and/or assessed due to insufficient evidence.
Sub-category	***UNFC (2019) definition***	
E3.2	Environmental-socio-economic viability cannot yet be determined due to insufficient information.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F3	The technical feasibility of a development project cannot be evaluated due to limited data.	The project is in the early planning place with ongoing work to determine the maturity/feasibility of the project.
Sub-category	***UNFC (2019) definition***	
F3.1	Site-specific studies have identified a potential development with sufficient confidence to warrant further testing.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E3.2; F3.1; G1	776	Based on a capacity factor of 30% and a project lifetime of 20 years.
E3.2; F3.1; G2	388 (G1+G2 = 776+388 = 1164)	Based on a capacity factor of 40% and a project lifetime of 22.5 years.
E3.2; F3.1; G3	442 (G1+G2+G3 = 776+388+442 = 1616)	Based on a capacity factor of 50% and a project lifetime of 25 years.

D. Southwest

Robin Rig

Project Location: Approximately 12.5km off the coast in the Solway Firth

Date of Evaluation: June 2020

Development Status: Fully commissioned as of April 2010

Quantification Method: Estimation based on production history

Estimation type: Deterministic

Water Depth: <60m

Number of turbines: 56

Installed Capacity: 168MW

Area: 18km^2

Project Summary

25. Robin Rigg is Scotland's first offshore wind farm, completed in 2010. It was one of Scotland's largest offshore wind farms with a current installed capacity of 168MW (56 x 3MW turbines).

26. The first application to develop Robin Rigg was originally submitted to the Scottish ministers by Solway Offshore and Offshore Energy Resources in June 2002, with section 36 consent being granted in March 2003.

27. MT Højgaard designed, supplied and installed the monopile foundations for the turbine sand substations. When first commissioned, the farm had a capacity of 174MW; however, due to failures during the installation, two units had to be decommissioned in 2015 at the high cost of £25 million.

28. The power generated by the turbines is transmitted to offshore substations by subsea cables before on-ward transmission ashore near Seaton.

Quantification

Reference point: The reference point is the transmission for the onshore substation to the national grid.

Project lifetime: *Technical lifetime* - The project has an operational lifetime of 20 years. Estimation for the remaining lifetime of the project will consider this the high estimation due to the infancy of the technology when commissioned.

Capacity Factor: Lifetime capacity factor, based on eight years of data, was found to be 35.1%, with a capacity of 34.6% in the last year.

Estimate	*Lifetime (Years)*	*Capacity Factor (%)*	*Energy estimate over project lifetime (PJ)*
Low	5	32	8
Moderate	7.5	34	14
High	10	36	19

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC-2009 definition*	*Reasoning for Classification*
E1	Development and operation are confirmed to be environmentally-socially-economically viable.	Fully Commissioned as of April 2010, demonstrating that all project elements are in place and is the beneficiary of a contract for difference.
Sub-category	***UNFC (2019) definition***	
E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F1	The technical feasibility of a development project has been confirmed.	Fully Commissioned as of April 2010.
Sub-category	***UNFC (2019) definition***	
F1.1	Production is currently taking place.	

UNFC (2019) Classification Wind Resources

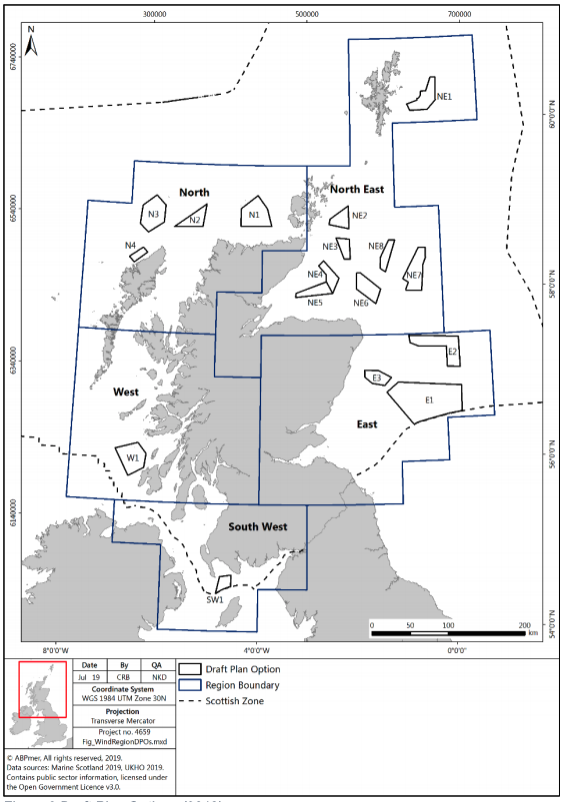
Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E1.1; F1.1; G1	8	Based on a capacity factor of 32% and a project lifetime of 5 years.
E1.1; F1.1; G2	5 (G1+G2 = 8+5 = 14[a])	Based on a capacity factor of 34% and a project lifetime of 7.5 years.
E1.1; F1.1; G3	6 (G1+G2+G3 = 8+5+6 = 19)	Based on a capacity factor of 36% and a project lifetime of 10 years.

[a] Rounding error.

II. Group 2: Development Zones

29. In 2019, the Scottish Government released the most up to date plan for offshore wind energy to identify areas suitable to host commercial-scale offshore wind projects [15]. The plan develops the public engagement from previous sectoral marine planning exercises released in 2011 and 2013 prior to the final draft released in 2020. Given the classification metrics in UNFC, these areas contain immature notional projects that can be classified as such.

Figure III
Marine Scotland draft plan potential areas [15]



A. Methodology

30. With the aid of the areas outlined in the draft sectoral marine plan, this report quantifies and classifies the notional projects in accordance with UNFC. The Scottish Government states that it is "not appropriate to detail the precise nature of the technology due to the rapid development of deep-water technologies". By remaining technology-neutral, the draft plan is contrary to the notional project-based approach this report seeks to implement. However, the quantification method used - calculating potential output from an

area by using a known power output per unit area as a scalar - is adopted as means of quantification for this report.

B. Quantification

31. The draft plan adopts a method of appraisal of outlining the areas and assigning a maximum deployment scenario for the area. This is then scaled using the average power density of offshore wind farms (5MW/km^2) to calculate the realistic development as a percentage of the area (Table 3). It is noted that the draft plan has a total maximum deployment of 10 GW and a minimum of 3GW.

Table 3
Summary of maximum realistic development scenarios as reported by Marine Scotland [15]

Region	DPO	Total DPO Area (km²)	Realistic maximum development scenario for DPO (GW)	Realistic development as percentage of total DPO Area	Regional Low Scenario (GW)	Regional Medium Scenario (GW)	Regional High Scenario (GW)
East	E1	3816	3	16%			
	E2	1287	2	31%			
	E3	474	1	42%			
	Sub-total	**5577**	**6**		**1**	**2**	**3**
North East	NE1	776	2	52%			
	NE2	464	1	43%			
	NE3	339	1	59%			
	NE4	440	1	45%			
	NE5	496	1	40%			
	NE6	699	2	57%			
	NE7	1027	3	58%			
	NE8	401	1	50%			
	Sub-total	**4641**	**12**		**1.5**	**3**	**4.5**
North	N1	1163	2	34%			
	N2	560	2	71%			
	N3	1106	2	36%			
	N4	200	1	100%			
	Sub-total	**3030**	**7**		**1**	**2**	**3**
West	W1	1107	2	36%			
	Sub-total	**1107**	**2**		**0.5**	**1**	**2**
South West	SW1	292	1	68%			
	Sub-total	**292**	**1**		**0.3**	**0.6**	**1**
Total:		14646	28		4.3	8.6	13.5
Scaled back to national scenarios (GW):					**3**	**5**	**10**

32. To align the quantification method to UNFC, a project-based approach is taken. Instead of applying an average power output per unit area, the quantification method used in this report considers the water depth and location of the proposed development zone and uses the power output per unit area of a suitable comparable wind farm. If there is no suitable comparison, then the industry standard of 2MW/km^2 (average capacity factory of 40% multiplied by average power per unit area 5MW/km^2) is used. Written arithmetically, the total aggregated potential output from all development zones can be written as:

$$E_{national} = \left(\Sigma_{zones} A\left(\frac{P}{A}\right) T_x\right).G_{4.x}$$

with A= area of development zone, P/A= Power per unit area of a comparative wind farm or industry standard, T_x= low, medium and high estimations of a lifetime and G4.x= uncertainty of wind energy source defined as a percentage of the development zone that may be used.

33. The largest uncertainty for the national projects is the uncertainty in the area of the zone that may be developed ($G_{4.x}$). Barriers include but are not exclusive to:

- Opposition from individuals and/or organizations for socio-environmental reasons
- Cumulative socio-environmental factors
- Significant risk that no development will be undertaken after further investigation
- The 10GW cap by Marine Scotland.

34. Without extensive research, the ability to measure the impact of the above in a quantitative manner without site-specific assessment is not possible. Instead, reasonable qualitatively estimations can be made to assign G4.1-G4.3 values as a percentage of area:

- G4.1(low estimate) = 10% of total area
- G4.2(moderate estimate) = 20% of total area
- G4.3(high estimate) = 30% of total area.

C. Development zones

Table 4
Summary of quantification of development zones

	Region	*Water depth (m)*	*Notional project comparison*	*Area (km^2)*	*P/A*	*Low(PJ)*	*Moderate(PJ)*	*High(PJ)*
NE	**1**	>100	Hywind	776	1.1	67	135	202
NE	**2**	60-100	Hywind	464	1.1	40	80	121
NE	**3**	60-100	Hywind	339	1.1	29	59	88
NE	**4**	<60	Beatrice	440	2.2	76	153	229
NE	**5**	<60 & 60>100	Beatrice/Hywind	496	1.65	65	129	194
NE	**6**	60-100 >100	Hywind	669	1.1	58	116	174
NE	**7**	60-100 >100	Hywind	1027	1.1	89	178	267
NE	**8**	60-100 >100	Hywind	401	1.1	35	70	104
SW	**1**	<60	Robin Rigg	292	3.4	78	157	235
W	**1**	<60	Robin Rigg	1107	3.4	297	593	890
N	**1**	<60 & 60-100	Beatrice/Hywind	1163	1.65	151	303	454
N	**2**	60-100 >100	Beatrice/Hywind	560	1.65	73	146	219
N	**3**	<60 to >100	Beatrice	1106	2.2	192	384	576
N	**4**	<60 to 60-100	Beatrice	200	2.2	35	69	104
E	**1**	60-100	Hywind	3816	1.1	331	662	993
E	**2**	60-100	Hywind	1287	1.1	112	223	335
E	**3**	<60 to >100	Industry Average	474	2	75	149	224
Total						**1803**	**3606**	**5409**

UNFC (2019) Classification

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E3	Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future, or evaluation is at too early a stage to determine environmental-socio-economic viability.	Projects are currently in the exploration phase of development. The areas of search are areas of potential that may result in future projects. It is too early in the development of the project to determine the environmental-socio-economic viability.
Sub-category	***UNFC (2019) definition***	
E3.2	Environmental-socio-economic viability cannot yet be determined due to insufficient information.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F3	The technical feasibility of a development project cannot be evaluated due to limited data.	Preliminary studies have been conducted, warranting further study of the areas.
Sub-category	***UNFC (2019) definition***	
F3.1	Site-specific studies have identified a potential development with sufficient confidence to warrant further testing.	

UNFC (2019) Classification Wind Resources

Classification	*Energy Quantity (PJ)*	*Supplementary Information*
E3.2; F3.1; G4.1	1803	Sum of low energy estimation
E3.2; F3.1; G4.2	1803 (G4.1+G4.2 = 1803+1803= 3606)	Additional energy for moderate estimation
E3.2; F3.1; G4.3	1803 (G4.1+G4.2+G4.1 = 1803+1803+1803 = 5409)	Additional energy for high estimation

III. Group 3: Undeveloped Areas

35. With the aid of the 2019 Offshore Wind Outlook report [16] by the International Energy Agency (IEA) and the supplementary online analysis tool, spatial analysis of the Scottish Exclusive Economic Zone (EEZ) was conducted to quantify and classify areas of technical potential. The report provides an analysis of the technical potential for offshore wind worldwide with a computational processing method. Although the quantifying and reporting method differs, the IEA first categorizes all potential waters in terms of water depth and distance from shore. This is the component of the analysis this report will benefit from before quantifying and classifying the potential with a method aligned with the UNFC's principles.

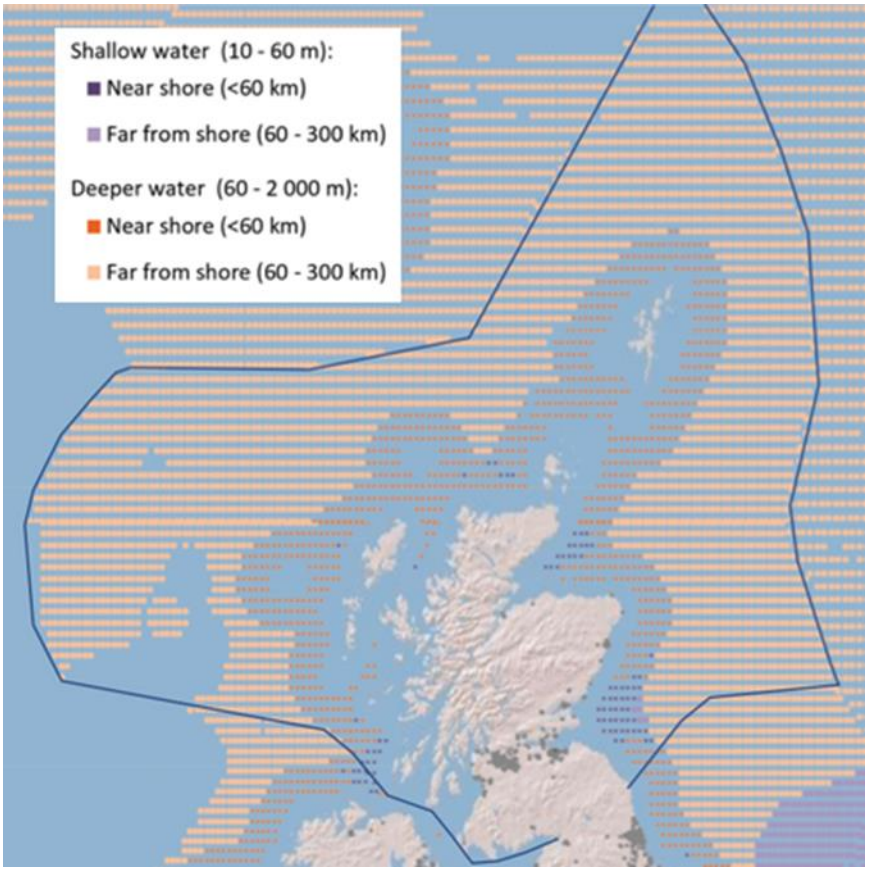
A. Methodology

IEA Categorization

36. A detailed special analysis was conducted to categorize waters in terms of water depth and distance from shore.[5] The results of the Scottish EEZ are shown in Figure IV.

[5] Regions < 12 nautical miles and areas of wind speeds <5m/s and depths >2000m are excluded.

Figure IV
Scottish Exclusive Economic Zone categorized in terms of distance to shore and water depth [16]



Quantification Method

37. The EEZ zone shown in Figure IV has been fully categorized for notional projects to be implemented. This is achieved by first calculating exclusion areas (defined below) and subtracting from the appropriate Category. When the economic exclusion zone is not absolute, it is reported with varying degrees of confidence in conjunction with the G axis of UNFC, as with the final energy potential.

38. Areas of exclusion considered in this report include the following significant socio-environmental factors:

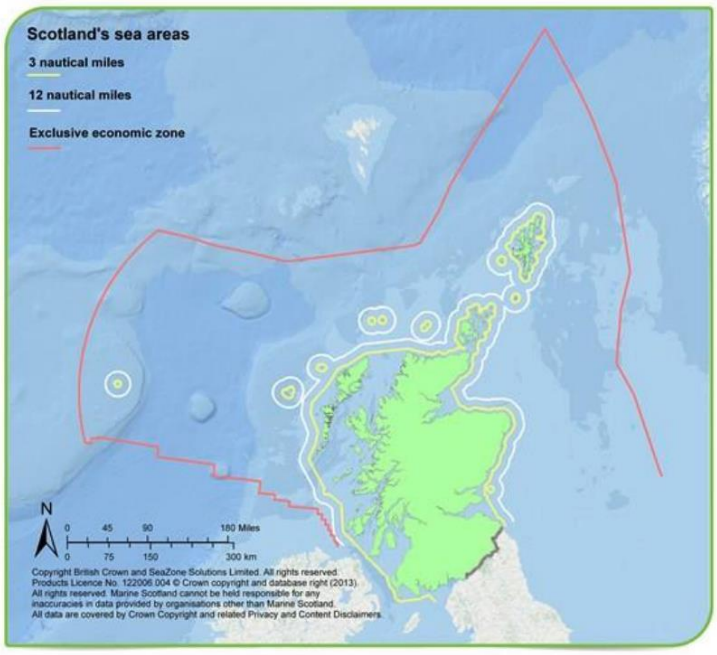
- Oil and gas infrastructure
- Maritime protected zones
- Defence
- Fisheries
- Shipping lanes
- Areas already quantified, such as all current projects and developments zones
- Areas with a water depth >2000m or within 12 nautical miles of the shore.

39. The three exclusions explicitly calculated are defence, maritime protected zones, and oil and gas infrastructure while indirectly accounting for tourism, shipping lanes and social conflicts through the omission of inshore waters.

40. Once areas have been established, as seen in the development zones, the power output per unit area can be used to estimate the energy output over the lifetime[6] of the national projects. The undeveloped product will then be treated as a singular entity when classifying.

Exclusion Zones

Figure V
Scottish Marine Limits



41. The area categorized by the IEA report is known as 'offshore waters'. This is the distance between the white line (12 nautical miles from the nearest coast) and the red line (EEZ boundary) in Figure V. Inshore waters are omitted for two reasons; firstly, wind resources closer to shore are of lesser quality when compared to those further out, and secondly, this is an area with economic activity, including, (but not limited to, fishing infrastructure, aquaculture, shipping, tourism, and, more recently, marine renewable energy generation. This blanket omission of a high traffic area, however, is not to suggest this area could not be developed.

42. The Scottish offshore waters cover an area of 372,000 km^2 [17] which is categorized into the respective regions.

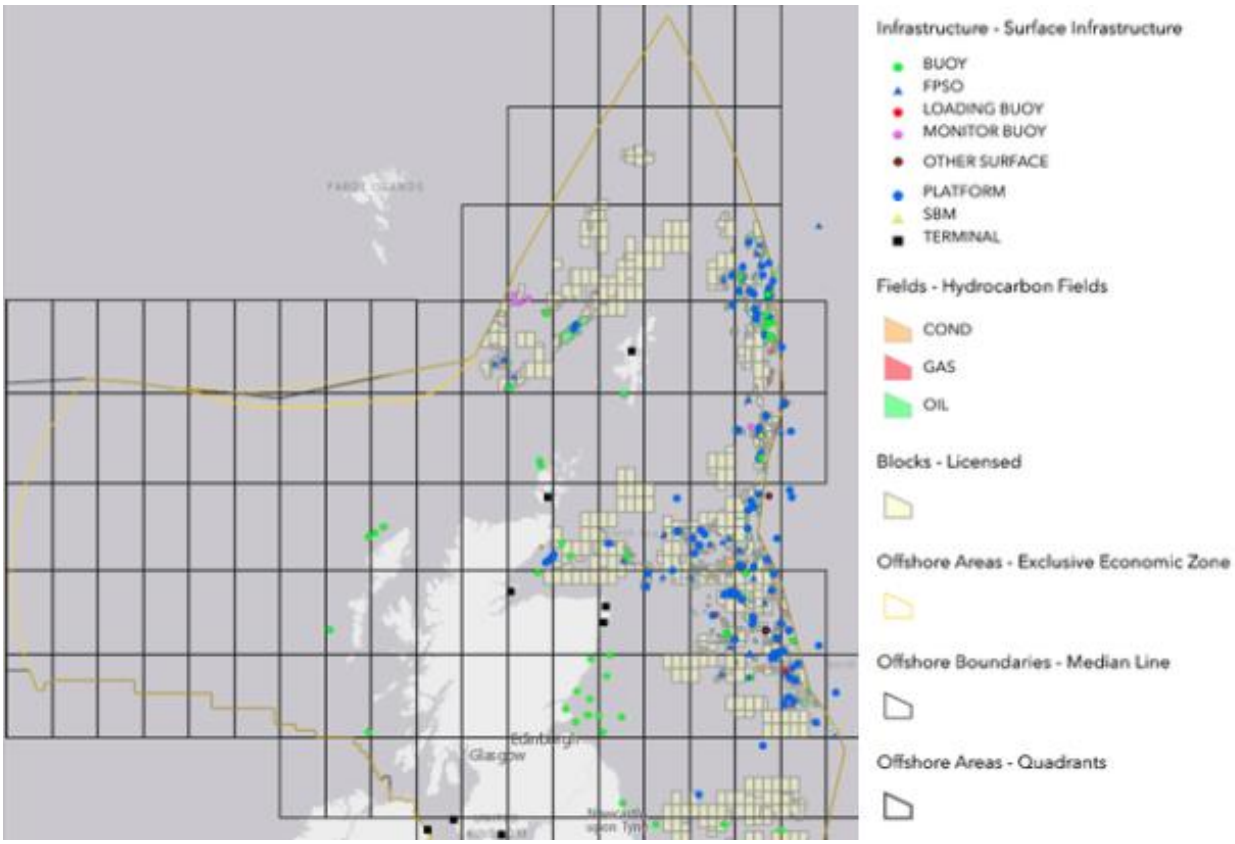
Region	*Per cent of offshore water (%)*	*Area (km^2)*
Nearshore/shallow waters	3	11,000
Far from shore/shallow waters	<1	0[a]
Nearshore/deep waters	23	85,000
Far from shore/deep waters	74	275,000

a The area is negligible and therefore is approximated to 0.

[6] A notional lifetime of 25 years is used.

Oil and Gas infrastructure

Figure VI
Offshore oil and gas activity within the Scottish Exclusive Economic Zone [18]



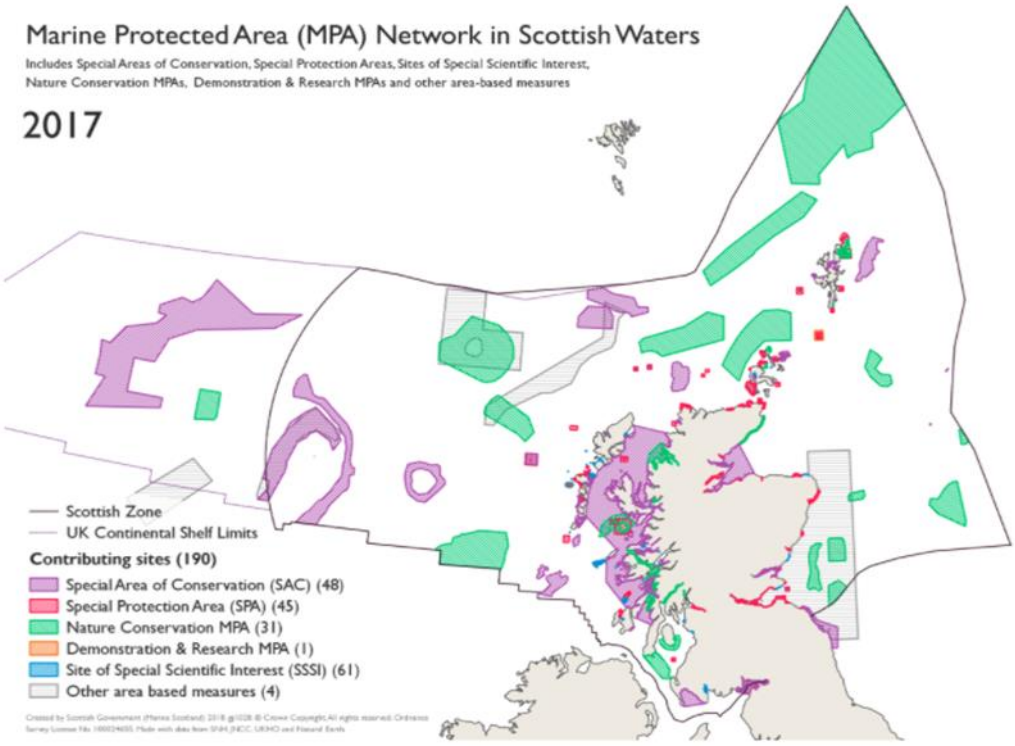
43. The impact the oil and gas sector could have on offshore wind is polarising. The lower bound is a lack of cooperation from the sector resulting in a significant proportion of projects and licensed areas excluded from potential development. The upper bound is the complete integration and cooperation of both sectors resulting in a negligible fraction of the potential area deemed undevelopable.

44. The low estimate of energy return (highest impact) will assume that any contested area will favour the oil and gas industry resulting in a large buffer zone around projects ($20km^2$) and significant areas of non-development. The high energy return will assume that a small buffer zone ($3km^2$) is required around each oil platform for access, but no non-deployment areas. This is supported by the co-existence of significant developments in the Moray Firth. The moderate (best) estimate will favour the more likely situation of partial cooperation and resolution of conflicted areas in Scottish waters resulting in a buffer zone of $10km^2$ and small areas of non-development. Estimations are quantified as the buffer area around each oil platform, approximately 90, with the addition of non-deployment areas due to oil and gas activity.

45. **Low estimate:** $20{,}000km^2$ **Moderate estimate:**$10{,}000km^2$ **High estimate:**$3{,}000km^2$

Maritime Protected Zone

Figure VII
Marine protected area (MPA) networks in Scottish Waters [19]

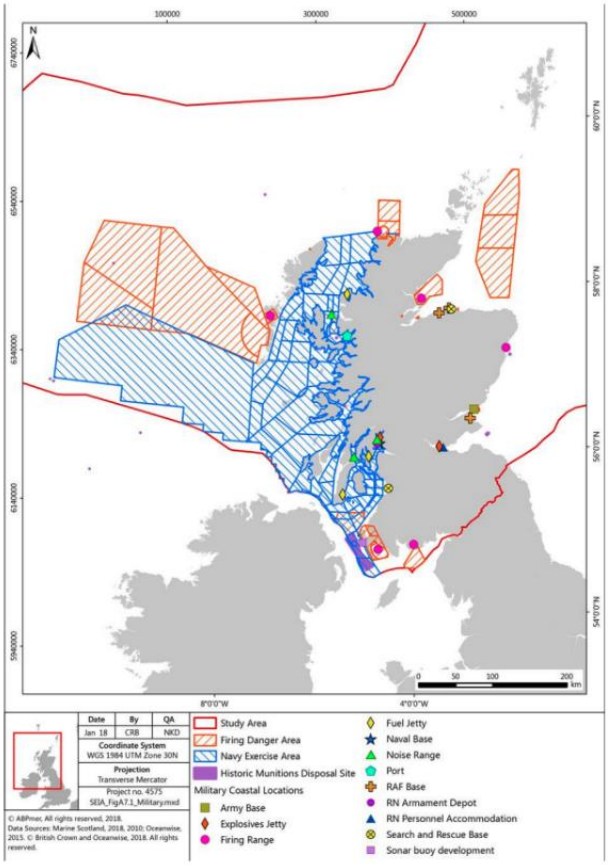


46. In offshore waters (up to 12 nautical miles from shore), 22% of waters are categorized as the following: marine protected areas, a special area of conservation and special protection. Marine protected areas are by no means fully exclusive zones. As per Marine Scotland Consenting and Licensing Guidance [17], consent can be granted for projects that pose a significant risk to the area if (a) The gain to the public is greater than the risk to the environment, (b) there is no means to proceed with the project that would significantly reduce the risk to the environment, and (c) ministers and satisfied developers will undertake measures to mitigate the risk. For reference, 22% of the offshore waters is equivalent to 82,200 km^2.

47. **Low estimate:** 10,000km^2 **Moderate estimate:**5,000km^2 **High estimate:** 0km^2

Defence

Figure VIII
Military Defence Activity in Scotland [19]



48. The primary concern with defence is the interference with radar communications and spatial overlap with training actives. Figure VIII displays potential areas of conflict with navy exercise and firing range areas. Owing to the confidential nature of the military, it is not possible to know - without the submission of plans to be accessed by the Ministry of Defence (MoD) safeguarding team - if the military interference would inhibit a project. Identifying areas of activity is possible as all information is in the public domain. However, in agreement with the Sectoral Marine Plan [15], it is not possible to know whether they are connected to offshore wind activity.

49. In the same sentiment, it is impossible to know the impact of radar interference for two reasons. Firstly, there are no standardized methods of measuring the level of interference, highlighting the need to develop tangible evidence and a set of metrics that are understood by all [18]. Secondly, without individual analysis of each proposed site, it is impossible for an outside agent to accurately quantify this. As an alternative, historical data will serve as a baseline to quantify the impact. Renewable UK reports that >50% of proposed UK offshore wind farms are rejected by the MoD safeguarding team [20]. When considering this, it should be noted that the areas of potential already omit all inshore waters where there is a high density of military activity. This technique has limitations. However, in the absence of data or recognized quantification methods, it offers an indication of the potential impact.

50. **Low estimate:** 60% **Moderate estimate:** 50% **High estimate:** 40%

B. Quantification

Exclusion Zones	*Category Impacted*	*Low (km^2)*	*Moderate (km^2)*	*High (km^2)*
Oil and Gas	**NS/DW & FS/DW**	20,000	10,000	3,000
Maritime Protected Zones	**FS/DW**	10,000	5,000	0
Defined Projects	**All**	/	2861	/
Development Zones	**NS/SW & NS/DW**	/	8532 & 5589	/
		Low (%)	***Moderate (%)***	***High (%)***
Defence	**All**	60	50	40

Category	*Area*	*Low (km^2)*	*Moderate (km^2)*	*High (km^2)*
Near shore/Shallow waters	11,000	606	757	909
Far shore/Shallow waters	0	0	0	0
Near shore/Deep waters	86,000	27,783	37,229	46,774
Far from shore/Deep waters[a]	275,000	99,383	129,229	160,174

Region	*Notional project comparison*
Near shore/Shallow waters	Beatrice
Far shore/Shallow waters	N/A
Near shore/Deep waters	Hywind
Far from shore/Deep waters	Hywind

Region	*P/A*	*Low(PJ)*[b]	*Moderate(PJ)*[a]	*High(PJ)*[a]
Near shore/Shallow waters	2.2	1,330	1,670	2,000
Near shore/Deep waters	1.1	30,600	41,000	51,400
Far from shore/Deep waters	1.1	109,000	142,000	176,000

[a] There is no direct consideration for the technical or economic viability of extracting the wind resource from this region. The low, moderate and high estimates consider varying outputs for the entire region, with consideration for the aforementioned exclusion zones. However, in the absence of a high-resolution spatial model, an estimation of the deployable area out with the above analysis would be arbitrary.

[b] Rounded to 3 significant figures.

C. United Nations Framework Classification for Resources (2019)

E Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
E3	Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future, or evaluation is at too early a stage to determine environmental-socio-economic viability.	The evaluation looks broadly at the remaining area that has no projects, i.e., out with the defined projects and areas of search. This area is in its infancy with no potential projects in place; therefore, project elements can be defined. This is an evaluation of a potential source and has been classified as the lowest maturity accordingly.
Sub-category	***UNFC (2019) definition***	
E3.3	On the basis of realistic assumptions of future conditions, it is currently considered that there are no reasonable prospects for environmental-socio-economic viability in the foreseeable future.	

F Category classification and sub-classification

Category	*UNFC (2019) definition*	*Reasoning for Classification*
F4	No development project has been identified.	The method applied quantifies potential quantities that may be produced. As above, there is no defined project(s) in place. To harness all of the potential resources, technological development (e.g. for deep waters/far from shore) is required.
Sub-category	***UNFC (2019) definition***	
F4.1	The technology necessary is under active development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project.	

D. United Nations Framework Classification of Resources (2019) Wind Resources

Classification	*Energy Quantity (PJ)*[a]	*Supplementary Information*
E3.3; F4.1; G4.1	141,000	Sum of low energy estimation
E3.3; F4.1; G4.2	43,600 (G4.1+G4.2 = 141,000+43,600 =185,000)	Additional energy for moderate estimation
E3.3; F4.1; G4.3	44,900 (G4.1+G4.2+G4.3 = 141,000+43,600+44,900 =230,000)	Additional energy for high estimation

[a] Rounded to 3 significant figures.

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