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Renewable energy from the high seas: Geo-spatial modelling of resource potential and legal implications for developing offshore wind projects beyond the national jurisdiction of coastal States

Paul Elsner, Department of Geography, Birkbeck, University of London. Email: p.elsner@bbk.ac.uk

Suzette Suarez, Institute for the Law of the Sea and Maritime Law, University of Hamburg. Email: suzette.suarez@uni-hamburg.de

Abstract:

Offshore wind energy projects are currently restricted to the exclusive economic zones of coastal States. Recent advances in technology are raising the prospect of utilising excellent wind resources on the high seas. Using a global geo-spatial model we identify potential resource areas for this. In the *shallow water case* for bottom fixed foundations the largest locations are found on the Mascarene Plateau in the Indian Ocean and the Grand Banks in the North Atlantic. The *deep water* case for floating platforms identifies the largest regions on the Grand Banks/Flemish Cap and Rockall Bank/Hatton Ridge, both in the North Atlantic. The overall legal framework for wind energy projects on the high seas is the United Nations Convention in the Law of the Sea. Flag states will play a central regulatory role for high seas wind energy developments. There is the danger that flags of convenience might evolve and unduly undercut environmental and safety standards that are in place for projects on the territorial sea and EEZ. Such abuse of high seas freedom could compromise the UNCLOS principle of 'due regard'. Marine spatial planning approaches and the establishment of cooperative mechanisms, led by the IMO, could safeguard against such potential misappropriation.

Keywords

Offshore wind energy, geospatial resource modelling, law of the sea, high seas, UNCLOS

1. Introduction

The oceans have vast potentials for the generation of renewable energy. A number of approaches with varying levels of technological maturity are available, including wave and tidal energy (Roberts et al., 2016; Thomas, 2008), ocean thermal energy conversion (Masutani and Takahashi, 2001), and offshore wind (Rodrigues et al., 2015). Amongst these examples, offshore wind energy is the most mature and cost-effective technology

(Castro-Santos et al., 2017). This is reflected in the diffusion and success of offshore wind projects in the past decades. Offshore wind energy is now an important central pillar in the energy systems of a number of countries. Globally, 14.4 GW of offshore wind capacity had been installed by the end of 2016, with the UK (5.1 GW), Germany (4.1 GW) and China (1.6 GW) being the biggest markets (Global Wind Energy Council, 2016).

The offshore wind industry sector has undergone a dramatic development in the past two decades. Early projects were initiated in Northern Europe in the 1990s with small capacities of single digit MW, water depths of no more than 10 m and distance from shore of a few kilometres. This was succeeded by more substantial developments in the 2000s and 2010s with increasingly larger capacities, deeper water depths and greater distances to shore. Modern offshore wind projects now commonly have capacities of several hundred MW (Rodrigues et al., 2015) and are located at water depths of up to 50 m and distances of more than 120 km away from shore. Future developments are expected to push the limits even further (WindEurope, 2017). For example, the UK Crown Estate identified the Dogger Bank area at the outer limit of their exclusive economic zone (EEZ) as one of the development zones in its latest tendering competition for offshore wind developments (The Crown Estate, 2012).

The above described dynamic transition of offshore wind energy from an experimental stage to large-scale industrial sized power projects is reflected by the increasing awareness of the specific legal complexities of this technology in the energy law discipline. It is noteworthy that wind energy was already an inherent theme right from the start of the emergence of Energy Law is discipline in its own right. The subject defining paper of Bradbrook (Bradbrook, 1996) highlights legal challenges associated with the construction and operation of wind turbines, but only in the onshore context. Less than two decades later offshore wind energy is not only acknowledged as well by the same author but also recommended to be the preferential form of wind energy generation due to its lower conflict potential (Bradbrook, 2012).

A highly relevant technical development in offshore wind technology is the recent introduction of floating platforms that make it possible to access the wind resources that have been unavailable due to their water depth. The most prominent example is the first commercial floating platform project "Hywind" off the coast of Scotland. In its first three month of operation it reached a CF of 65% (Equinor, 2018).

The economic competitiveness of offshore wind energy has improved dramatically in recent years. This was driven by technological advances such as larger turbines, growing installation experience and economies of scale. Lower capital and operational expenditure costs led to a sharp fall of contracts for difference (CFDs) prices that European governments awarded to wind energy developers in the year 2017. A number of those license terms were only half the CFDs awarded in tenders a few years earlier (Appleyard, 2017). Offshore wind energy is therefore rapidly becoming a competitive renewable energy technology.

All current offshore wind energy projects have in common that they are located within the territorial sea or within the exclusive economic zone (EEZ) of a coastal State, which may be up to 200 nm from the coastline. As the territorial sea is part of a coastal State's territory, offshore wind parks located therein are under the complete jurisdiction and control of the coastal state. Although the EEZ is not part of the territory of the coastal State, under the United Nations Convention in the Law of the Sea (UNCLOS), the generation of wind energy within the EEZ (Art. 56) as well as the construction, maintenance, and removal of any offshore wind installation or structure, are under the exclusive jurisdiction and control of the coastal State (Art. Art. 60 of UNCLOS), subject only to the navigation safety rules established by the relevant international organizations.

This means that that in the territorial sea and the EEZ, project developers have to operate in the specific legal framework of the respective coastal State, including planning permission, licensing procedures, compliance to environmental regulations and the connection to the respective national grid network. To date, relevant State practice relating to offshore wind parks in the territorial sea and on the EEZ is found mainly among four North Sea EU coastal States: Germany, the United Kingdom, the Netherlands and Denmark. A critical factor which drove the development of offshore wind projects in these jurisdictions is the EU 20-20-20 energy policy established in 2009, aiming for 20% reduction in EU greenhouse gas emissions from 1990 levels and a 20% increase in renewable energy resources in the share of EU energy consumption by 2020(Kanellakis et al., 2013).

The four North Sea EU pioneering coastal States initially relied on existing regulations including energy, construction, environmental, crown estate lease legislations and extended their application to the new offshore activity. A specific legal regime with respect to siting, consent/approval, construction, and operations, however gradually developed for the offshore wind industry in these North Sea jurisdictions (Müller and Roggenkamp, 2015).

Yet, many excellent offshore wind resources are located beyond the world's EEZ, on the high seas (Capps and Zender, 2010). The above described advances of a maturing offshore wind energy sector make it now appear realistic that in the near-future offshore wind projects could technically and commercially be viable on the high seas. Such scenario has been theoretically envisaged in the context of their proposed global grid electricity network (Chatzivasileiadis et al., 2014, 2013). However, the location of potential high seas offshore wind parks was indicative only and remained on the conceptual level.

The goal of this paper is two-fold. First, this paper will investigate the potential of offshore wind projects in more detail by developing a spatially explicit model that identifies suitable areas that have very good to excellent technical potential for offshore wind energy projects. Second, the legal framework applicable to offshore wind parks on the high seas will be assessed. For the generation of wind energy on the high seas, some fundamental legal issues will have to be considered within the high seas legal regime, which is different from the territorial and EEZ regimes.

The remainder of this paper is organised as follows: Section 2 describes the set-up of the geospatial model to identify high seas areas that might have promising potential for offshore wind energy developments and section 3 presents core results of this analysis.

Section 4 introduces UNCLOS and offshore wind parks on the high seas. This is followed by section 5 that discusses the legal framework that will apply when offshore wind energy projects on the high seas would be developed. Section 6 provides discussion and the conclusions will be made in section 7.

2. Identifying suitable high seas areas for offshore wind energy projects.

To identify high seas areas that may have promising potential for offshore wind energy development, a spatially explicit GIS-model was developed. The design was guided by previous similar studies which identified wind energy potential of resource areas such as the North Sea (Baldock and Jacquemin, 2009; Veum et al., 2011) or the Mediterranean Sea

(Soukissian et al., 2017). Other researchers focused on specific coastal EEZ, e.g. the UK (Cavazzi and Dutton, 2016), India (Nagababu et al., 2017), and the U.S. (Musial et al., 2016).

The global ocean wind power potential was assessed by Capps and Zender (2010) by using a seven year data from QuickSCAT satellite data series. They referenced this to the cut-in and cut-out wind speeds of three turbine models with a capacity between 3 MW and 5 MW at 80 m hub height and three water depth limits (<45 m, <60 m, <200 m). This parameterisation reflected the technological State of art at the end of the first decade of this century. Political boundaries and spatial resource allocation in respect to national territories and legal regimes were not considered (Capps and Zender, 2010).

To frame the discussion in this paper and to provide the platform for legal analysis, we undertook our own assessment to identify potentially suitable wind energy areas on the high seas. This was motivated by the need to reflect recent technical advances in the offshore wind energy sector and to test if the high seas – from a technical point of view – have any significant potential for the development of offshore wind energy projects and where these areas are located.

2.1 Data and Methodology

2.1.1 Wind data and wind speed

Satellite-based microwave ocean wind speed data are well suited for the investigation of long-term wind conditions (Hasager, 2014). The central wind speed information for our revised global suitability model was data from the Blended Sea Winds (BSW) data set of the NOAA National Centers for Environmental Information (NCEI). It combines observation of a number of satellite missions and provides 6-hourly wind speed estimates at 10 m above sea level. The data has a resolution of a 0.25° to 0.25° grid over ice-free oceans between 65°S and 65°N (Zhang et al., 2006).

A 11 year time series of monthly average wind speeds between January 1995 to December 2005 was adopted to reflect the inter-annual wind speed variability. BSW wind speed estimates were upscaled to an assumed hub height of 100 m, using the logarithmic wind profile function (Masters, 2004; Soukissian et al., 2017):

$$v_h = v_{10} \frac{\ln\left(\frac{h}{z_0}\right)}{\ln\left(\frac{10}{z_0}\right)} \qquad (1)$$

where v_h is the wind speed at hub height h, v_{10} is the wind speed at reference height 10 m above sea level, and z_0 (meters) is the surface roughness length, for which the established open sea surface roughness coefficient of 0.0002 m was adopted (Nagababu et al., 2017; Soukissian et al., 2017).

Fig. 1 outlines the global distribution of wind speed data modelled for 100 m hub. It can be seen that there is substantial spatial variation, with a general trend of having the strongest wind speeds with >11 m/s at latitudes between 40° and 60° North and South. Generally low wind speed of <7 m/s can be observed in the tropical regions, with a number of clusters of stronger wind speeds.

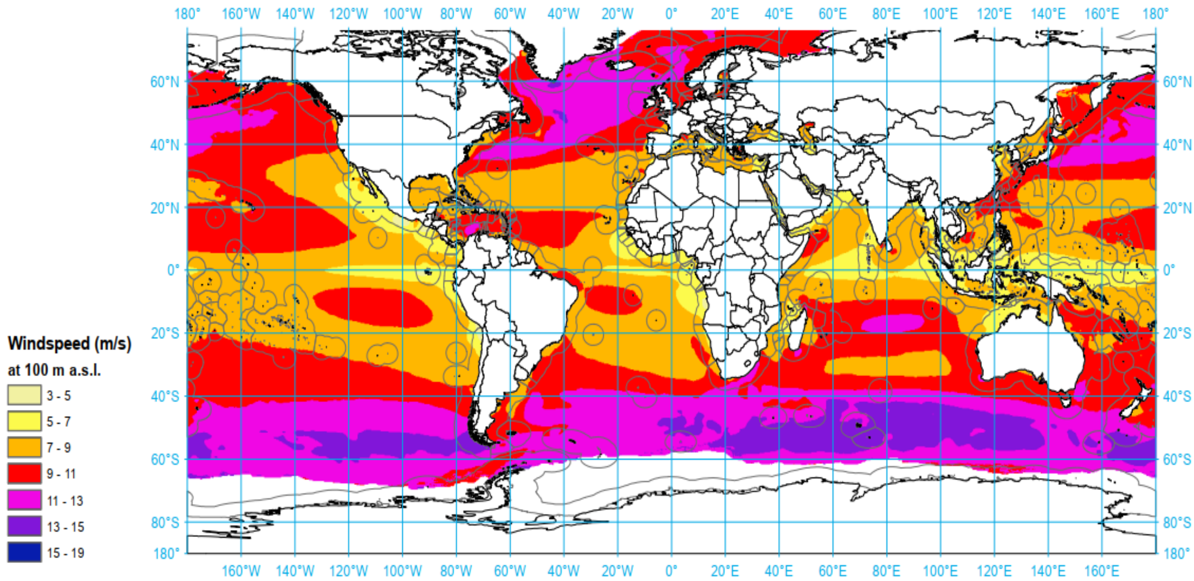

Fig. 1. Long-term annual average wind speed distribution at 100 m above sea level. Data upscaled from a *Blended Sea Wind* 11 year time series between 1995 and 2005.

In the context of this study it was assumed that suitable sites for offshore wind energy developments on the high seas should exhibit a minimum average annual wind speed of at least 7.5 m/s at 100 m hub height. This limit was adopted as well by Dvorak et al. (2010). Other studies used lower limits, e.g. 4.5 m/s at 10 m (Soukissian and Papadopoulos, 2015), 6.5 m/s at 80 m (Schallenberg-Rodríguez and García Montesdeoca, 2018), or 7.0 m/s at 100 m (Musial et al., 2016). Our threshold of 7.5 m/s can therefore be considered conservative.

2.1.2 Bathymetry and EEZ data

The data on water depth was sourced from the GEBCO_2014 data set of the General Bathymetric Chart of the Oceans (GEBCO) project. The spatial resolution is 30 arc-second data which is equivalent to approximately 920 m at the equator. It currently represents the best global bathymetry data set (Weatherall et al., 2015). Fig. 2 illustrates that the bathymetry at most coastlines drops very quickly to depths of several thousands of metres. The mean global water depth is -2,270 m. The delineation of the coastal EEZ data was determined using geospatial data from the *Flanders Marine Institute* Marine Regions data depository (Claus et al., 2017, 2014).

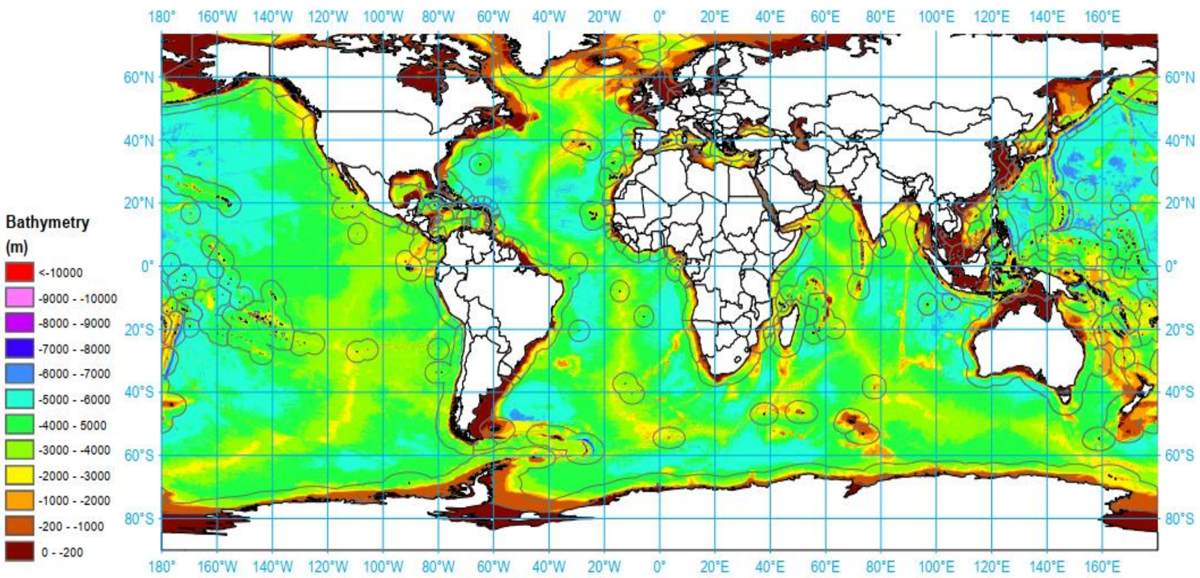

Fig. 2. Global bathymetry. Grey lines outline the respective Exclusive Economic Zones of coastal States.

Two depth levels were considered for this study. In the *shallow water case*, a maximum water depth of 50 m was allowed. This represents the technological standard in which offshore wind turbines are bottom mounted (GWEC, 2017; IRENA, 2016). In the *deep water case*, the maximum water depth was 1000 m. This is assuming the operational availability of floating platforms. Such a concept is currently subject of intense development and research. The first commercial floating wind farm project started in 2017 of the Scottish coast (New Energy Update, 2018). The maximum water depth for the Hywind floating platform concept is 1000 m.

2.2 Wind energy modelling

To estimate the technical resource capacity of the identified high seas areas, we adopted an approach of Musial et al. (Musial et al., 2016; U.S. Department of Energy (DOE), 2015) who assumed an array power density of 3 MW/km^2, including wake losses and setbacks. We further assumed that a suitable offshore wind energy area should have at least a size of 100 km^2 to make it commercially viable.

To estimate the potential annual electricity production at specific sites, a Weibull probability density function of wind speed was assumed (Andrews and Jelley, 2007; Masters, 2013) and then using an empirical function to determine turbine capacity factor (CF) (Dvorak et al., 2010; Jacobson and Archer, 2012; Masters, 2004; Yue and Yang, 2009):

$$CF = 0.087 \times V_{avg}(^{m}/_{s}) - \frac{P_{rated}(kW)}{D^2(m)} \quad (2)$$

where P_{rated} denotes the power output of the reference turbine (kW), v_{avg} the mean annual wind speed (m/s), and D (m) is the diameter of the turbine blades. We assumed a hub height of 100 m and used the Vestas V164-8MW turbine with a rated capacity of 8 MW and blade diameter of 164 m as reference turbine. This model has been on the market since 2016 and was adopted as an example of operational technology on the commercial market at the end of this decade. Cut-in wind speed is 3.5 m/s, full-rated capacity is achieved at 13 m/s and cut-out wind speed is 25 m/s (Fig. 3).

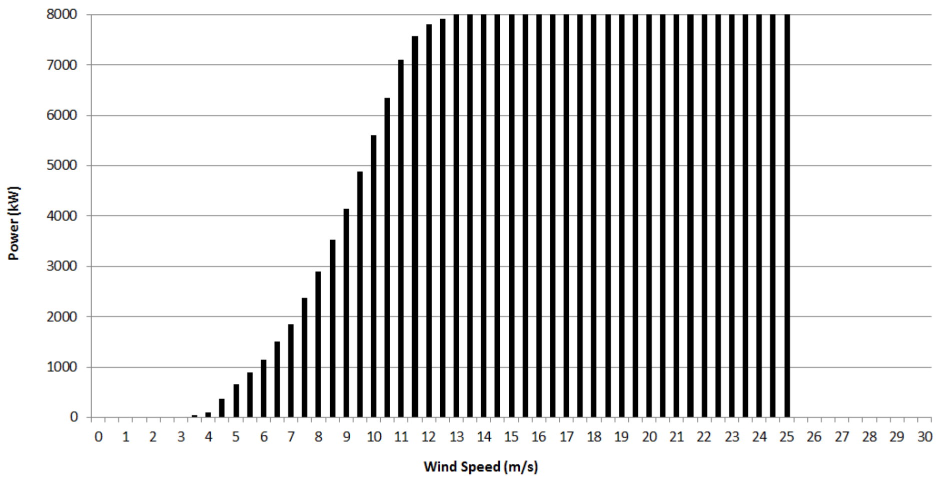

Fig. 3. Power curve of reference turbine Vestas V164-8MW with a rated capacity of 8 MW.

3. Model Results

Our spatially explicit global model identified a substantial number of high seas areas with significant technical wind energy potential for both scenarios. For pragmatic reasons we will focus the presentation of our results on the largest resource areas, as they represent the large majority of the global potential: nearly 90% of the *shallow water* potential and approximately 60% of the *deep* water is aggregated in the respective five largest areas. Their locations are displayed in Fig. 4 (*shallow water* case) and Fig. 5 (*deep water* case). Tables 1 and 2 present more detailed resource information for each of those locations.

The shallow water case identified overall an area of 16231 km^2 that could potentially be suitable for offshore wind development with bottom foundations. This translates to a technical capacity of 48.7 GW with an annual energy generation capacity of approximately 209 TWh. The largest one is on the Mascarene Plateau in the Indian Ocean which represents two third of the shallow water high seas technical potential. The Grand Banks in the North Atlantic account for approximately 17%. This is complemented by three seamounts: The Lena Tablemount and two to date unnamed seamounts, here labelled "Tablemount A" and Tablemount B" (see Fig. 4 and Table 1).

Both the seabed of the Mascarene Plateau (joint submission by the Seychelles and Mauritius) and of the Flemish Cap area (submission by

Canada) are claimed as extended continental shelf under UNCLOS article 76. No continental shelf claim has been submitted for the identified seamounts. The legal regime of the continental shelf under UNCLOS is separate from the legal regime of the EEZ and from the highs seas legal regime (Suarez, 2008). We will address the implications of this in more detail later in this paper (see section 5.4).

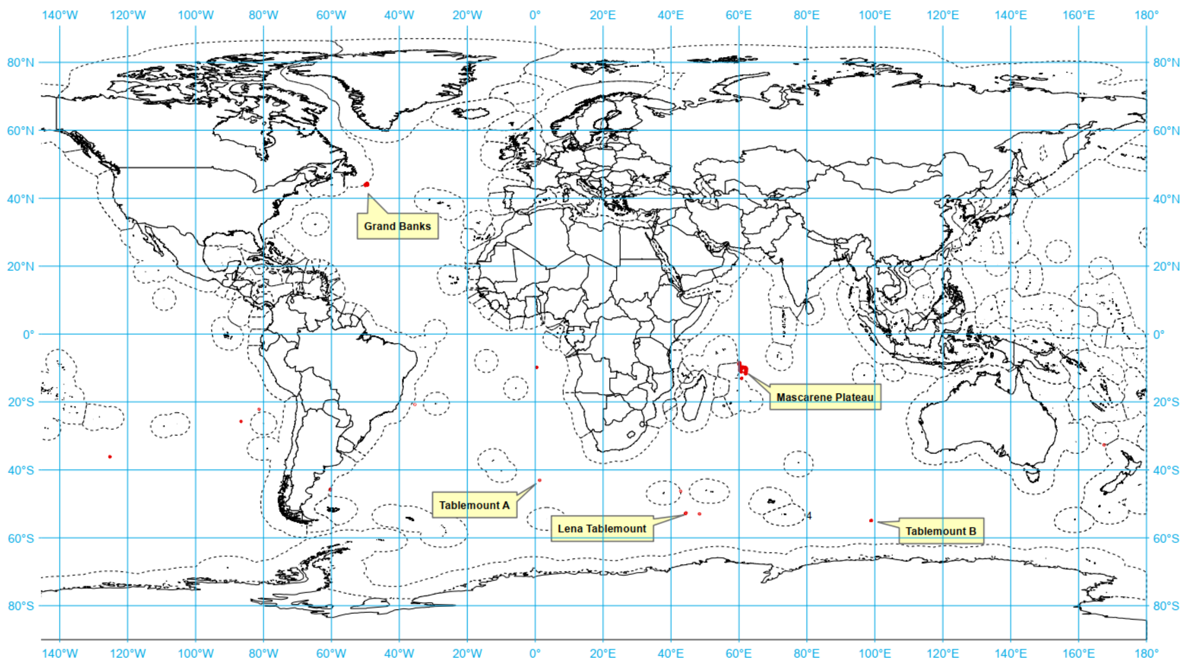

Fig. 4. Regions with wind energy potential for the *shallow water* case (<50 m water depth), outlined in red. The largest five areas are labelled.

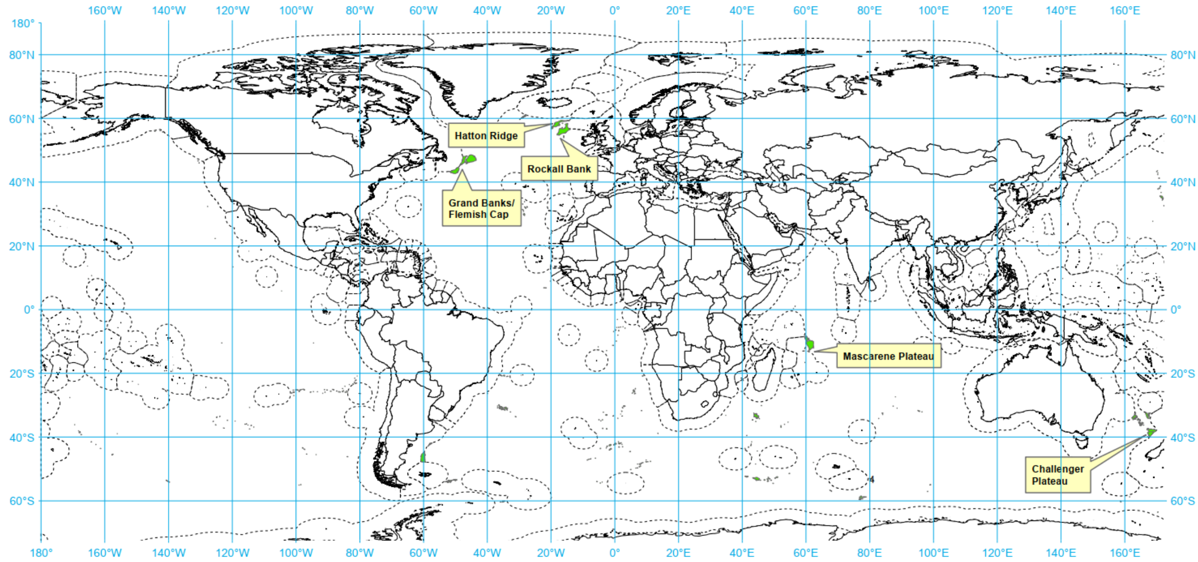

Fig. 5. Regions with wind energy potential for the *deep water* case (<1000 m water depth), outlined in green. The five largest areas are labelled.

Table 1

The five largest areas with offshore wind energy potential on the high seas in the *shallow water* case, i.e. having water depths of <50 m.

Feature	**Size (km^2)**	**Wind Speed at 100 m**	**Technical Capacity**	**Annual Energy Production**	**Extended Continental Shelf**
Mascarene Plateau	10712	8.4 - 9.5 m/s	32.1 GW	141.6 TWh	Yes (joint submission of Seychelles and Mauritius, confirmed)
Grand Banks	2791	8.9 m/s	8.4 GW	35.1 TWh	Yes (Canada, claimed)
Lena Tablemount	381	13.7 m/s	1.1 GW	8.6 TWh	No
Unnamed Tablemount A	228	12.5 m/s	0.68 GW	4.7 TWh	No

Unnamed Tablemount B	227	13 m/s	0.68 GW	4.9 TWh	No

The model for the *deep water* case assumes the operational availability of floating turbines which increases the maximal allowable water depth to 1000 m. The effect of this is a 35-fold growth of suitable wind energy areas on the high seas. A total of approximately 480 000 km^2 were identified where offshore wind energy technically could be developed on the high seas. This would allow the installation of approximately 2250 GW of capacity which could generate 7300 TWh of energy per year.

Table 2

The five largest areas with offshore wind energy potential on the high seas in the *deep water* case, i.e. having water depths of <1000 m.

Feature	Size (km^2)	Wind Speed at 100 m	Technical Capacity	Annual Energy Production	Extended Continental Shelf
Grand Banks/ Flemish Cap	90413	8.9 – 10.7 m/s	271.2 GW	2025.3 TWh	Yes (Canada, claimed)
Mascarene Plateau	70161	8.3 – 9.5 m/s	210.5 GW	928.1 TWh	Yes (joint submission of Seychelles and Mauritius, confirmed)
Rockall Bank	40720	12 m/s	122.2 GW	799.6 TWh	Yes (claimed by Denmark/Faroe Islands,

					Iceland, Ireland, UK)
Challenger Plateau	35504	9.8 – 10.1 m/s	106.5 GW	534.6 TWh	Yes (New Zealand, confirmed)
Hatton Ridge	21055	12.1 m/s	63.2 GW	418.4 TWh	Yes (overlapping claims by Denmark/Faroe Islands, Island, Ireland, UK)

The location of the five largest areas are outlined and labelled on Fig. 5 and their properties detailed in Table 2. The largest area is Grand Banks/Flemish Cap region in the North-West Atlantic, which is part of a claim as extended continental shelf by Canada. This is followed by the Mascarene Plateau in the Indian Ocean, an area that has been confirmed as joint extended continental shelf to Seychelles and Mauritius.

Rockall Bank and Hatton Ridge in the Eastern Atlantic are two other areas with a substantial offshore wind energy potential. It should be noted that their seabed is subject to four overlapping claims as extended continental shelf (see Table 2). The seabed of the Challenger Plateau area in the Tasman Sea has been confirmed as part of the extended continental shelf pertaining to New Zealand.

In summary, our model results indicate that for both scenarios a substantial technical offshore wind potential exist on the high seas. It should be noted that the seabed of the majority of the most promising areas is subject to claims of extended continental shelf under UNCLOS article 76. Only the three table mounts that were identified for the shallow water case have not been claimed and belong to the Area, which is the seafloor and subsoil that is beyond the limits of national jurisdiction and control (Art. 87.2 UNCLOS). The next sections will review in more detail which legal framework and regulations are of relevance and have to be considered if wind projects in the identified areas would be developed.

4. UNCLOS and offshore wind park on the high seas

The UNCLOS is a multilateral treaty which is generally considered the "constitution for the oceans" as it provides the fundamental legal framework for the rights, uses, and obligations of States with respect to the oceans, its resources and the marine environment (Koh, 1982). As a rule, only States parties to the treaty are bound to comply and implement the provisions of a treaty. However, it is generally acknowledged that many provisions of UNCLOS were already or have attained customary status, which means that even non-State Parties to the UNCLOS are bound to comply with them (Fitzmaurice, 2002). The legal regime of the high seas, which is the focus of this paper, is customary international law. Hence, when non-state Parties such as the U.S. or Iran undertake any economic activities or exercise any high seas freedoms on the high seas, they are obliged to do so in accordance with the high seas legal regime as codified in the UNCLOS (Fitzmaurice, 2002). Indeed, the US practice on the high seas regime confirms that it adheres to the parts of UNCLOS that are customary international law (Duff, 2006).

The nature of the high seas legal regime is different from the territorial sea and the EEZ regimes. As mentioned earlier, the territorial is part of the territory of the coastal State. The EEZ is not part of the coastal State's territory but is under the exclusive jurisdiction and control of the coastal State for certain functions and purposes as enumerated in Art. 56 of the UNCLOS. The high seas, on the other hand, cannot be appropriated by any State nor can it be subjected to the sovereign control or jurisdiction of any State. (Art. 89 UNCLOS) On the high seas, all States, whether coastal or landlocked, whether State parties or non-parties to the UNCLOS, enjoy high seas freedoms. These include, *inter alia*, the freedom of navigation, the freedom to construct and operate artificial islands, installations and structures, and the freedom of fishing (Art. 87 UNCLOS). The generation of energy from wind, currents, or waves, an activity which is explicitly mentioned as under the jurisdiction and control of the coastal State within the EEZ, is not explicitly mentioned as a high seas freedom. Whether this activity can be subsumed under the freedom of navigation of ships or freedom to construct and operate artificial islands, structures and installations will depend on how offshore wind facilities are defined: Are they ships or are they structures or installations?

The exercise of any freedom on the high seas is not absolute. High seas freedoms are tempered with corresponding responsibilities or obligations to respect the high seas freedoms of other States, to ensure maritime safety, and to protect and preserve the marine environment and to conserve resources, both living and non-living. The operation of offshore wind parks on the high seas will likewise operate within these limitations imposed on all high seas freedoms.

While UNCLOS is the starting point for determining the legal framework upon which States may undertake offshore wind park projects on the high seas, the sustainable energy legal and regulatory discourse for offshore wind activities is broader than the UNCLOS legal framework. As Heffron et al. (2018) pointed out, energy law as an academic discipline and as a regulatory matter have a set of core principles that actually straddle or may be found in different areas of law, both international and national (Heffron et al., 2018). It is beyond the scope of this paper to discuss these core principles in depth. However, we will show that some of these principles are embedded within the UNCLOS framework. It is noted that one of the core principles of energy law proposed by Heffron et al., the principle of national resource sovereignty, does not find application to resources that are generated from shared or common areas such as the high seas. This principle applies only to resources generated in areas within the sovereign jurisdiction and control of States.

5. Legal framework of offshore wind energy development on the high seas

5.1 Flag States

Unlike the jurisdictional competence in the territorial sea and the EEZ, jurisdictional competences over activities on the high seas are mainly allocated to the flag State, not to the coastal State. Flag States possesses wide discretionary latitude on the high seas; there are some limitations but these relate mainly to matters concerning safety to navigation and environmental protection. Thus, any offshore wind park project on the high seas will be governed by the flag State legal framework.

As offshore wind energy development on the high seas is still non-existent, there are no known examples of national laws that regulate offshore wind energy on the high seas. Ideally, flag States that initiate offshore wind energy development on the high seas should already possess the experience and know-how of offshore wind projects in their territorial seas or the EEZs. There are no explicit obstacles under UNCLOS that will prohibit such flag State from extending any of its current national legal and regulatory arrangements to apply to offshore wind parks on the high seas. However, a full application of current national laws that are designed for the territorial sea and the EEZ will have to take into consideration the different nuances that exist on the high seas, some of which are discussed below.

5.2 Legal status of wind parks on the high seas

With respect to floating wind parks, an uncertainty may arise with respect to their legal status on the high seas. Is the floating wind park platform a ship/vessel or an artificial island, installation, or structure? The terms "ship" and "vessel" are used interchangeably but not defined in UNCLOS. The current debate in literature relating to floating facilities swings between characterizing them on one hand as ships, particularly if and when they are ship-shaped; or regardless of shape, when they can self-navigate or self-propel or when they carry goods or people. They can also be conceptualized as artificial installation or structure, if they cannot self-propel or do not look like a standard ship or do not carry goods or people (Esmaeili, 2001).

The terms "artificial islands, installations, and structures" are mentioned in UNCLOS but are also not defined in the context of economic activities permitted to be carried out in three maritime regimes: the exclusive economic zone, the continental shelf, and the high seas. The genesis of these terms is traced to the terms "installations and other devices necessary for the exploration and exploitation of natural resources" found in article 5 of the 1958 Convention on the Continental Shelf (Esmaelli, 2001).

In the practice of States, both ships and installations or structures such as offshore floating platforms are required to be registered, with many jurisdictions assigning the task to the same agency or authority responsible for registering sea-going vessels (Esmaeili, 2001). Whether they are ships or other type of structures is a matter that remains under the discretion of flag States.

To have both classifications of ships/vessels and installations/structures under national laws is not prohibited under UNCLOS. It will be for the flag State to decide whether the floating platform under its domestic laws can avail of or benefit from legal arrangements, such as financing and registration, normally given to ships under maritime and shipping laws (Shaw, 2000). One advantage of classifying a floating platform as ship under domestic laws is that the ship mortgage over the floating platform could be valid as first-ranking security interest (Sandgren, 2014).

Nevertheless, having both classifications during operations on the high seas is a legal situation not contemplated and impliedly not allowed under the UNCLOS. The two legal regimes serve different purposes. The regime of the freedom of navigation contemplates ships that are mobile whereas the regime governing installations and structures are for structures that are designed to be in one location for a period of time. A ship navigating on the high seas is governed by a different set of rules from an artificial floating structure moored on the high seas while conducting economic activities. If the floating platform operating in one location on the high seas were to be classified as a ship on the high seas, irrational consequences not contemplated by law could occur. For instance, a platform classified as a ship would be incongruously subjected to provisions applicable to ships, including the duty to render assistance on the high seas (Art. 98), and might be be subject to the arrest and boarding provisions of UNCLOS (Art. 110).

In summary, it is our position that offshore wind parks should be considered “artificial islands, installations, and structures”. From the UNCLOS perspective, no differentiation should be made between fixed and floating wind parks that are operating on the high seas.

5.3 Flags of convenience for offshore wind projects?

One potential source of uncertainty is the phenomenon of flag of convenience, which is a situation when shipping companies register in countries with a lenient regulatory framework, thus avoiding compliance with internationally accepted safety regulations and being far from the reach of flag State authorities enforcing these rules. Registering in a foreign flag is possible because, under UNCLOS, it remains the discretion of the flag State which vessel or installation it allows to fly its flag.

For ships, the main legal control which is designed to avoid such a situation is the requirement of genuine link between the flag State and the ship (Art. 91 UNCLOS). Proof of genuine link between a ship and a flag State has been interpreted in jurisprudence to refer to the acts by the flag State of effectively exercising jurisdiction and control over the administrative, technical and social matters involving ships flying its flag (Art. 94 UNCLOS) (Advisory Opinion of 2 April 2015, ITLOS Reports 2015). Thus, a flag State complies with the genuine link requirement when it can show that it effectively exercises its duties towards the vessel in order to ensure, among others, that the vessel is seaworthy and complies with all applicable rules and regulations for maritime safety as well as to ensure that the oceans are free of vessel-sourced pollutants.

Though the requirement of genuine link is not explicit between a flag State and an offshore facility registered under its flag, this is in our view implicit in Art. 87 UNCLOS (applying *mutatis mutandis* the legal regime set out in Arts. 60 and 80, UNCLOS). Under UNCLOS, it is the flag State that has exclusive jurisdiction and control over artificial islands, installations and structures it allows to be constructed and operate on the high seas. The effective exercise of the flag State of permitting the construction and operation of artificial islands, installations and structures on the high seas is the legal manifestation of the genuine link between it and the offshore platform flying its flag.

In the context of merchant shipping, genuine link has proven to be a weak regulatory mechanism since international sea-going vessels hardly go to their home ports for regular controls. In order to close this regulatory gap, the concept of Port State control, which was first conceptualized in the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, was also adopted in UNCLOS. Whenever a vessel is voluntarily at a foreign port, the authorities of that Port State are empowered to undertake controls in order to ensure that the vessel is seaworthy and in compliance with environmental standards and regulations (Art. 218 UNCLOS). The concept of Port State control is not applicable to offshore wind park structures which are stationary on the high seas for a long period of time. Thus, other than the flag State, there will be no similar additional regulatory control in existence for offshore installations and structures on the high seas. It is therefore a legal possibility that an offshore wind energy developer might register with a flag of convenience and be subjected to less strict regulations than offshore wind projects in an adjacent or neighboring EEZ.

From the framework of energy law, the problem of flag of convenience in the context of offshore wind energy development on the high seas is a problem that can be addressed within the principle of energy justice (Heffron et al., 2018). It is beyond the scope of this paper to discuss the concept of energy justice in depth. But for our purposes, we propose that the current discussion of the principle of energy justice should explicitly include the problems associated with the generation of energy from areas that are common or shared such as wind energy on the high seas. The current legal framework on the high seas limits the decision-making as well as enforcement powers solely on the flag State and this can lead to potentially disastrous consequences as shown by the flag of convenience phenomenon in the commercial shipping industry and in the fishing industry.

5.4 Issue pertaining to offshore platforms attached or mounted on the extended continental shelf

The results of our model have identified a number of suitable areas that are located on the extended continental shelf claimed by individual coastal States. The extended continental shelf is an area of the seabed and subsoil that is beyond 200 NM and in many instances, up to 350 NM from the coast (Art. 76 UNCLOS). For purposes of exclusively accessing the non-living resources, the extended continental shelf pertains to the coastal State. However, for purposes of the exercise of other freedoms of the high seas, the extended continental shelf belongs to the high seas. Can coastal States argue that they exercise control and jurisdiction over an offshore wind platform that is attached or connected to the seafloor of their extended continental shelf? In our view, there will be little room for confusion concerning the applicable legal regime. The exclusive rights of the coastal State in the extended continental shelf are clearly limited to minerals, other non-living resources of the seabed, and a specific type of living resource, the sedentary species attached to the seafloor (Art. 77.4

UNCLOS). The production of wind energy from a platform, whether floating or securely attached to the extended continental shelf, is an activity that was not contemplated to fall under the coastal State's rights to the extended continental shelf. Even if an offshore wind park is attached or secured to the seafloor of an extended continental shelf, the legal regime that therefore applies to such offshore wind parks is the regime of the high seas. This means also that potential offshore wind projects will not be affected by legal uncertainty due to overlapping continental shelf claims as could be the case for Hatton Ridge and Rockall Bank resource areas.

5.5 Potential conflict of high seas freedoms

In light of the considerable area of marine space that offshore wind parks will take up and also the long duration of their operations, another source of legal uncertainty will be the potential conflict between and among high seas freedoms of other States as well as marine environment and ecosystems conservation requirements (Maes, 2008).

UNCLOS recognizes the potential conflict of uses and freedoms and requires States to have 'due regard' for the rights of other States on the high seas, and as the case may be, for the rights of the coastal States on their continental shelves and EEZs and rights of all mankind in the Area.

In a situation where more long-term fixed offshore activities on the high seas are the trend rather than the exception, the appropriateness and sufficiency of the 'due regard' principle is in doubt, because it is not a management tool but rather a settle as-you-go approach to managing conflicts of uses on the high seas.

The 'due regard' approach is clearly not in conformity with the principle of prudent, rational and sustainable use of natural resources, a principle which was mentioned in the context of shared or common energy resources (Heffron et al., 2018).

There is hence a need for a more structured management tool such as marine spatial planning for sustainable offshore wind energy on the high seas. Within marine areas under national jurisdiction and control, many coastal States are already relying on marine spatial planning tools to rationalize and manage the different and conflicting uses of the seas (Göke et al., 2018; Rodríguez-Rodríguez et al., 2016; Smith et al., 2012; Zhang et al., 2017). Marine spatial planning approaches could be appropriate in order to manage potential conflicts of uses on the high seas, but such would ideally require a regulatory authority common to all users, which will not be the case on the high seas (Maes, 2008). A regulatory authority or several regional regulatory authorities similar to regional fishing organizations should be considered. It is therefore interesting to see that marine spatial planning on areas beyond national jurisdiction is a subject of discussion at the *Intergovernmental Conference* *on an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction*. This intergovernmental conference commenced its work in April 2018 and is planning to complete the negotiation of a new binding instrument by 2020 (United Nations, 2018). In addition to addressing issues of sustainable management, mandatory marine spatial planning of uses and activities in areas beyond national jurisdiction would also be useful to address the problem of flags of convenience mentioned earlier.

5.6. Safeguarding safety of navigation

Offshore wind parks are expected to take up physical space on the high seas on a long-term basis. Their potential to adversely affect navigation and maritime traffic is therefore high. There are existing rules for safety of navigation and other maritime safety rules relevant to the offshore industry which have been established by the International Maritime Organization (IMO) but these are in the context of offshore extractive industries. For example, the IMO Resolution A.671(16) on safety zones and safety of navigation around offshore installations is intended for offshore extractive industries on the EEZ or the continental shelf and as such they do not address particular challenges that offshore wind parks present to navigation (Maritime and Coastguard Agency, 2008). In our view, although the high seas regime is mainly implemented through the flag State, it should be the international community through the IMO and not the flag State that should develop safety of navigation rules for wind park facilities on the high seas. In order for any offshore wind park facility on the high seas to thrive, the rules of safety must be applicable and common to all operators, regardless of flag.

On the other hand, we want to point out that there is less uncertainty relating to rules on navigational aids for wind turbines as these have been established by the competent international organization, the International Association of Lighthouse Authorities (IALA-AISM, 2004).

5.7 Global rules concerning protection of the marine environment against damaged caused by offshore activities on the high seas

While the generation of energy from wind resources is itself considered sustainable because it is a form of energy that is renewable, there are nevertheless some impacts on the natural environment and biodiversity. Examples for such negative impacts are underwater noise during construction that could cause avoidance behavior of marine mammals, risk and disturbance of turtles and fish from vessel movements associated with wind park construction and operation, and the disturbance of migratory bird species, including fatalities due to collisions with turbines (Bailey et al., 2014).

Any legal and regulatory framework that will govern offshore wind energy on the high seas must therefore be assessed with respect to the protection and preservation of the marine environment and resources. It is on the issue of environmental protection from damages caused by offshore activities on the high seas that the nature of UNCLOS as merely a framework convention becomes obvious. Unlike other offshore activities such as seabed activities undertaken in areas within national jurisdiction and the Area (Arts. 208, 209; 214, 215), UNCLOS does not have specific provisions for the protection of the marine environment against damage caused by offshore activities of flag States on the high seas. This is not to say that there are no rules are in place. The general obligations of States under Section 1 of Part XV will apply to flag States operating offshore wind parks on the high seas. Art. 192 states that all States have the obligation to protect and preserve the marine environment. Art. 194.1 underscores that States are under a duty to take all measures that are necessary to prevent, reduce and control pollution of the marine environment from any source, using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavour to harmonize their policies in this connection. Art. 194.5 underlines that the measures shall those necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life.

The provision under UNCLOS Section 2 of Part XV on global and regional cooperation in cases of pollution emergencies and Section 4 of Part XV on monitoring and assessment will also be relevant for offshore activities on the high seas. These two sections contain obligations of all States Parties to the UNCLOS, regardless of the location of the activities undertaken.

The duty to undertake an environmental impact assessment for activities that have the potential to cause harm to the natural environment and natural resources is recognized as a binding obligation under international law and has been confirmed in international rulings. (ITLOS Advisory Opinion of 1 February 2011) (ITLOS Reports, 2011).

For offshore wind parks located on the high seas which are registered with EU member States, the interplay of international law with relevant EU Directives which require EIA can be expected (van Leeuwen and van Tatenhove, 2010).

Our geospatial model identified Hatton Ridge and Rockall Bank as areas on the high seas with high potential for wind energy production. The EIA requirements of the 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention') will apply to any offshore wind energy development in these areas.

The flag State will also have to ensure that any EIA done will take into consideration the threats to birds and marine life in accordance with its obligations under relevant conventions to protect biodiversity, including the 1992 Convention on Biological Diversity and the 1983 Convention on the Conservation of Migratory Species of Wild Animals. From the energy law and policy perspective, the considerations of energy generation and the environment which are already required by UNCLOS and associated global treaties is haphazard. Energy generation and its impacts on the environment should be considered comprehensively and linked to the natural fuel cycle. Thus, in developing their energy law and policy for offshore wind facilities on the high seas, flag States should develop energy laws and policy with the environment in mind based on the natural fuel cycle (Heffron et al., 2018).

5.8 Issue of cables and onshore grid connection

If the power generated from the high seas is meant to be consumed onshore, there is a need to connect the power from the offshore wind farms with the onshore grid. For issues relating to grid connection, the international legal regime of cables and pipelines under UNCLOS is well-established and will come into play.

Cables that are laid on the high seas and the continental shelf are governed under the legal regime of the high seas. Therefore, all States have a right to lay cables and pipelines in these maritime areas (Arts. 79, 112, UNCLOS). No State needs to ask the permission of any other State before cables can be laid on these areas. The national laws of the operator who owns or is laying the cables will apply. In laying cables, States must exercise due regard to cables and pipelines already in position (Art. 79.5 UNCLOS). In practice, in laying and maintaining cables, cable operators and owners comply with the recommendations and rules on cable routes and cable crossing criteria adopted by the International Cable Protection Committee (UNEP and ICPC, 2009).

However, the cables which are laid in the territorial sea which are connected from the continental shelf or the high seas, will need to obtain the permission of the coastal State. Further, such cables shall be laid in accordance with the conditions and requirements set by the coastal State (Art. 79.4 UNCLOS).

5.9 Challenges concerning decommissioning

There will also be uncertainties with respect to the duty to decommission disused offshore wind parks on the high seas. Under UNCLOS, the duty to remove disused or abandoned installations or structures exist for coastal States with respect to installations and structures on the EEZ and the continental shelf. However, this duty is not explicitly stated for disused or abandoned installations and structures on the high seas. The IMO has issued guidelines for the removal of installations and structures on the continental shelf and the EEZ but not for the high seas (IMO, 1989). There is therefore no existing regulatory framework relating to the decommissioning of offshore wind parks on the high seas.

Decommissioning offshore wind energy structures at the end of their life is part of the concept of “sustainable energy” which must establish a legal and regulatory framework that takes into account all issues of the "natural fuel cycle." Any potential operator and flag State planning to undertake offshore wind park energy development on the high seas should take a pro-active approach to decommissioning and should learn from the lessons of the offshore oil and gas industry. Decommissioning oil and gas offshore platforms is a current problem for the industry as many platforms that have come to the end of their economic life did not factor in such costs prior to commencing operations (Hamzah, 2003). Germany, Denmark and the UK – three States which are currently leading in offshore wind park development in the EEZ - all require an EIA and decommissioning plans as conditions for approval of offshore wind parks. In addition, these States also require the operators to deposit a financial guarantee to cover the cost of decommissioning at the end of life (BSH, 2018; Wagner-Cardenal, Kersten, Treibmann, Beate, Kahle, 2011).

6. Discussion

The results of our geo-spatial model have demonstrated that a number of marine areas on the high seas have very good to excellent technical wind energy potential and could be developed with technologies that are currently available on an operational level. In both the *shallow water* and the *deep water* case, the Mascarene Plateau in the Indian Ocean and the Grand Banks/Flemish Cap region off Canada offer attractive technical offshore wind resource potential.

It needs to be recognised that the geospatial model results need to be treated as indicative only, as the currently available bathymetry data has only a relatively coarse resolution of 30 arc-seconds. With higher resolved data on water depth, more accurate delineation would be possible. Currently efforts such as *GEBCO Seabed 2030 Project* are geared towards the complete and consistent mapping of the world ocean in much higher resolution (Mayer et al., 2018) are therefore to be welcomed and highly anticipated.

Better bathymetry data will also aid the planning and modelling of cable routes, as high seas offshore wind projects would most likely require extensive cable laying activities to either connect them directly into national power grids or to link them into a wider regional or even global grid network (Chatzivasileiadis et al., 2014).

The challenge of connecting potential high seas offshore wind projects to terrestrial demand centres will be an important criterion when evaluating the respective attractiveness of the resource areas that were identified by our model. The tablemounts in the Southern Ocean and also the Mascarene Plateau are at very remote locations and more than 1000 nm away from meaningful urban centers. In contrast to this, the Hatton Ridge/Rockall Bank and Grand Banks/Flemish Cap areas are in relative vicinity to European and Canadian territory, respectively. A cable link might be more realistically feasible in these cases.

An alternative scenario to cable-based grid connections could be approaches where electricity generated by offshore wind power is converted to "green hydrogen" that could then be used to decarbonise the transport sector and industrial production (Jepma and van Schot, 2017; Philibert, 2017). Initial modelling seems to suggest that at locations where renewable energy sources would supply capacity factors of more than 60%, such an approach might be economically competitive (Philibert, 2018). Our analysis shows that such load factors are realistic for the identified tablemount areas.

The analysis of the legal aspects for developing offshore wind parks on the high seas has demonstrated that such projects would be subject to a very different regulatory environment, compared to territorial waters and EEZ. For the offshore wind park on the high seas, the legal framework established under UNCLOS is the starting point, along with international conventions which prescribe standards in respect to maritime safety and environmental protection.

The UNCLOS legal framework incorporates some of the core principles that make up sustainable energy law. But UNCLOS is only a framework treaty and many areas of the natural fuel cycle of offshore wind parks can only be addressed from the flag State legal system. The flag State, as has been shown in this paper, is the key actor in the legal framework applicable in the offshore wind park on the high seas.

The legislation and implementation of the rules and regulations rest on individual flag States. This opens up the possibility that developers might adopt flag States with rather lenient standards, similar to the 'flags of convenience' phenomenon that has become common practise in the merchant shipping industry and fishing industry.

This might lead to a scenario where offshore wind parks within the EEZ of e.g. the UK or Canada would have to comply to strict national regulations. Neighbouring high seas projects, on the other hand, could operate under more relaxed regulatory conditions because they are registered to a flag State of convenience. However, this might be balanced by the need to get consent from the respective coastal States to whose grid they want to connect to. Such 'grid States' could therefore use their consent privilege to indirectly enforce certain environmental and safety standards on the high seas wind park and by this counterbalance the competitive effect of choosing a flag of convenience.

7. Conclusions and Policy Implications

Our geospatial analysis has demonstrated that there are indeed large resource areas on the high seas that have substantial technical offshore wind potential. Particularly the deep water scenario identifies excellent development opportunities just outside the EEZs of Canada, the UK and New Zealand.

Given the rapid transition of offshore wind to a mature and cost-competitive energy industry, it seems not unrealistic that some of these areas could be of interest to energy investors in the mid-term. A central attraction for project initiators could be that they would not have to undergo lengthy licensing and consent procedures with coastal states, as is the case for projects within the EEZ.

Energy law which is considered to inhibit an inherent complexity can often only be addressed in the context of other disciplines (Heffron and Talus, 2016). Indeed, interdisciplinary scholarship is a central characteristic of energy law (Heffron et al., 2018). Our paper is making a point in case, as the legal framework for high seas energy projects is intricate.

The overall central legal basis for offshore wind energy projects on the high seas is the UNCLOS. Under the high seas legal regime, flag states will play a central regulatory role for high seas wind energy. This paper has shown that the high seas legal regime, as it is currently practiced, has particular flaws and is open to abuses. There is the danger that flags of convenience might evolve and unduly undercut environmental and safety standards that are in place for wind energy projects on the territorial sea or EEZ and by this gain a financial advantage. Such abuse of high seas freedom could compromise the UNCLOS principle of 'due regard' for the rights of other states and actors on the high seas and the EEZ.

The current concept of the high seas legal regime is based on uses or freedoms that do not lead to an appropriation of the high seas. Long-term operation of huge off-shore wind parks on the high seas will however be semi-permanent and therefore could be considered a de-facto appropriation of high seas areas.

There are two promising ways forward to address the shortcomings of the high seas legal regime in the context of wind energy generation on the high seas. The first path is to integrate the principle of energy justice into the legal regime of high seas, especially for a high seas freedom that is akin to a semi-permanent appropriation of a large chunk of the high seas such as wind energy projects. The discourse on energy justice within the energy law framework is evolving (Heffron and McCauley, 2017; Sovacool et al., 2016). There is compelling reason to integrate the concept of energy justice, usually discussed for on-shore energy projects, onto wind energy projects on the high seas. Three forms of energy justice discussed in literature are particularly cogent: distributional justice, procedural justice and cosmopolitan justice (McCauley et al., 2019).

In the context of onshore energy projects, distributional justice is traditionally concerned with location of energy technology and the ability to access their output, e.g. the electric grid. In the high seas context, it is not only the wind resources on the high seas that are a common good, but the physical space were the wind parks are located do not and cannot be appropriated by any State or entity. The very essence of wind energy project may be said to embody distributive justice. However, from the procedural justice point of view, the current high seas regime does not ensure energy justice. Procedural justice underscores the right to a fair and inclusive process in energy developments. While the high seas legal regime means that any operator from any State could undertake wind energy development, such "open" system does not necessarily lead to a fair and inclusive process. Offshore wind energy is a highly specialized technological endeavor with substantial financing requirements. This in effect means that only very few actors from a select group of industrialized countries will be capable to access wind resources on the high seas and economically benefit from their output. Both types of energy justice are reinforced by the concept of cosmopolitan justice which emphasizes the universal applicability of procedural and distributional justice to all nations of the world.

Another path, which does not exclude but rather complements the first path, is to add the discussion of wind energy projects on the high seas to the on-going negotiations for a legally binding agreement on areas beyond national jurisdiction. This addresses the shortcomings of the high seas legal regime in the context of modern offshore economic activities, in particular in reference to marine biological diversity on the high seas. The lack of institutional and procedural arrangements for development activities in areas beyond national jurisdictions have been on the agenda of the international community for some years now. In 2015, the UN General Assembly decided to initiate an intergovernmental conference which will develop an international legally binding instrument under the UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (UNGA Resolution 69/292 of 19 June 2015). The discussions in the first session in 2018 included area-based management tools, including the establishment of marine protected areas and environmental impact assessment requirements for development activities (U.N., 2018).

Such instruments would be helpful to address potential negative impacts of wind projects on living resources of the high seas. However, they will do little to address potential misappropriation on the high seas and manage and resolve conflicts of freedoms between and among States. It is therefore desirable to extend the common heritage of mankind principle to all economic developments in areas beyond national jurisdictions. By this, wind energy projects would benefit the international community and humankind in general and not only a small group of actors from industrialised States.

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