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Wind potentials for EU and neighbouring countries

Input datasets for the JRC-EU-TIMES Model

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Contents

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Abstract

Data on the potential generation of electricity from wind is crucial information for analysing the future role of this renewable energy source. In this report, a description is presented of the methodologies used for the derivation of a dataset. The dataset consists of an estimation of (1) wind speeds accounting for high-resolution effects, (2) power production accounting for a wide range of turbine types, (3) suitable areas and (4) associated cost estimates. Wind speed information is systematically derived from 30 years of meteorological data based on the MERRA reanalysis dataset, and from the high resolution geo-spatial data based on the Global Wind Atlas.

Within this project, the wind potentials and techno-economic parameters are gathered and processed into input datasets for the JRC-EU-TIMES model. This allows improved modelling of the competition and the complementarity of wind with other technologies, the key functionality of the JRC-EU-TIMES model. Moreover the datasets can also be used for the analysis of policy questions relating to the availability of wind energy.

1 Introduction

In this report, a description of the data and the underlying methodologies for the derivation and processing of wind potentials and derived cost estimates is presented. The Joint Research Centre of the European Commission develops and maintains tools and instruments for the analysis of European research and innovation policies in the field of energy and climate. One of such instruments is the JRC-EU-TIMES model.

The JRC-EU-TIMES model helps understanding the role of energy technologies and their innovation needs for meeting European policy targets related to energy and climate change. The model follows the energy system of the EU 28 and of neighbouring countries from the years 2010 to 2060. It produces projections (or scenarios) of the EU energy system under different sets of specific assumptions and constraints. In this function, the model is used for a number of research activities at DG JRC and for the Horizon 2020 project "Heat Roadmap Europe 2050" (Heat Roadmap Europe (HRE) 2017).

JRC-EU-TIMES follows the paradigm of the TIMES model generator from the ETSAP Technology Partnership of the International Energy Agency, which combines a detailed technology specification with an optimisation approach (Loulou, et al. 2016). The model solves for the cost optimum investment portfolio of technologies for the entire period under consideration[1], along the supply chains for five sectors, while fulfilling the energy-services demand. This implies simultaneously deciding on asset investments and operation, primary energy supply and energy trade.

JRC-EU-TIMES is an improved offspring of previous European energy system models developed under several EU funded projects, such as NEEDS (NEEDS project n.d.), RES2020 (RES 2020 project n.d.), REALISEGRID (REALISEGRID project n.d.), REACCESS (REACCESS project n.d.) and COMET (COMET project n.d.). JRC was partner in the NEEDS project in which the Pan European Times model was originally developed. Since then, the original project partners have developed different versions of the original model some of which are being used for EU funded research projects[2]. The JRC-EU-TIMES model has been further developed over the last years and is currently maintained by JRC unit C.7. One of the scenarios of JRC-EU-TIMES is always aligned to the latest EU reference scenario. The model can be used to assess which technological improvements are needed to make technologies competitive under various low-carbon energy scenarios.

A set of wind potentials and techno-economic parameters are gathered and processed into input datasets for the JRC-EU-TIMES model. The potentials are systematically derived from high resolution wind climate data (MERRA reanalysis data, the Global Wind Atlas) and geo-spatial data.

Since the main limitation for wind installations is the availability of suitable areas, three scenarios have been created to reflect different levels of land availability. These are based on varying degrees of stringency for the minimum allowed setback distance from settlements (onshore technologies), and for the exclusion of sensitive maritime zones (offshore technologies). The spatial analysis is combined with high-resolution mapping of wind climate, yielding a series of capacity factors within the identified available areas. Finally, costs and other techno-economic parameters are provided for several classes of wind technologies, depending on many technical and spatial characteristics, yielding a detailed representation of current and future wind energy technologies.

[1] The TIMES paradigm also allows for alternative approaches such as limited foresight, see [2].
[2] E.g. the REEEM project (http://www.reeem.org/)

2 Land availability scenarios for on-shore wind

Three wind potential scenarios are considered, that differ in the level of land available for wind installations. For onshore wind the main differentiator is the setback distance from settlements.

> **Box 1.** Regulations data collection for set-back distances
>
> A comprehensive database of current setback distances has been compiled through literature review and expert elicitation. The data was constructed based with contributions from other research organisations in 2016. The legal requirements may have been changed since the time of data collection.

2.1 Country specific setback distances

A number of documents providing information on current regulations for setback distances from settlements in the EU have been consulted (EWEA 2013), (Haugen 2011), (Vincent Onyango 2013), (Haugen n.d.), (Edwin Nieuwenhuizen 2015), (European Platform Against Windfarms 2009), (Loren D KnopperEmail 2011), (VÁZQUEZ HERNÁNDEZ C. 2016).

The current regulation for setback distance from settlements varies greatly per Member State. Often the legislation does not explicitly mention a specific setback distance. In these cases setback distances are defined as a function of the rotor diameter, hub height or acceptable noise levels. Also, setback distances are often defined on a project by project basis, as part of an Environmental Impact Assessment, taking into account legislation on maximum acceptable noise levels and the expected noise profile for each specific project or the specific turbine types to be installed. Furthermore, regulations can vary within a country at regional and municipal level. For some countries no specific information was found in the consulted literature. In these cases, assumptions on setback distances were made based on general noise pollution rules and/or similar countries in the region.

Currently all existing regulation concerning distances between wind turbines and settlements (or other infrastructure objects) is related either to the physical size of the wind turbine (stack height, rotor diameter, etc.) or to the noise levels. Both of these metrics are related to the size (power) of the wind turbine: more powerful wind turbines tend to have larger poles or rotors and emit more noise. Therefore it may be reasonable to distinguish exclusion zones for small wind turbines and large wind turbines. In this document we assume a power output of 250 kW for small turbines and 3 MW for larger turbines. Assumptions on the height and noise levels for these turbines are summarised in **Table 1**.

Member States that do not regulate wind turbines explicitly often refer to common environmental impact assessment procedures that wind power developers have to follow. There may be several metrics limiting the construction of wind turbines: height, view, shadowing, and most importantly noise pollution.

The Night Noise Guidelines for Europe by the World Health Organization (World Health Organization 2009) are accounted for in the legislation of most of the Member States. The main limiting factor for wind turbines, the long-time average noise level during the 8 hours of night (Lnight), is not very restricting. The long term average noise levels tend to be low due to relatively low capacity factors of onshore wind turbines. Countries using (Lnight) metrics tend to have lower set back distances (e.g. The Netherlands).

Noise limits are based on weighted sound pressure L_A ([3]). Most commonly used noise metrics in the legislation and/or noise control are:

- L_{Aeq}, $L_{Aeq,T}$ – weighted average sound level over specified time T. The longer the sampling interval – the less restrictive the bound is. The time range used for averaging is between minutes and hours. Lnight is a variant of this type.
- L_{A90}, $L_{A90,T}$ are defined as the weighted average noise level for 90% of the measurement period.

The main factor affecting noise levels from the wind turbine is the aerodynamic noise from the blades, therefore wind speed and size of the wind turbine will directly affect set back distances. But there also other factors that affect noise levels:

- Number of wind turbines: The rule of thumb is that adding two sound pressure levels of equal value will result in a 3 dB noise increase. In our set back distance calculation we assume a single turbine case.
- Terrain: For the setback calculations we will not take into account differences of the terrain.
- Wind direction: noise level in the direction of wind is higher. For the setback calculations we will not take into account wind direction.
- Distances sound travel is also affected by the frequency, temperature, humidity and level above the sea.

In cases where no explicit setback distance is given, we distinguish between the two turbine types:

a) small wind turbine (250 kW, 95 dB, hub height 35 m, rotor diameter 40m ([4]).)
b) larger wind turbines (3 MW, 109 dB, pole height 80 m, rotor diameter 90 meters ([5])).

The following formula is used for those cases:

$$L = L_w - 10 log(2\pi R_2) - aR + L_g,$$

L_w is the noise intensity spread by a wind turbine in the direction of its axis; R is the distance from the rotor centre to the measurement position; a is the atmospheric absorption coefficient; L_g is the noise level correction due to sound pressure pulsations reflection from the earth surface.

Taking into account low impact of the terrain to the noise levels from the wind turbines we assume L_g equal to zero. The atmospheric absorption coefficient a is calculated based on noise frequency, temperature, level above sea level and humidity. For the distance calculation we assume 1kHz, 20 degrees centigrade, at sea level with 80% of humidity (Vattenfall Wind Power Ltd 2014). The following noise levels will be used: 109 dB for large wind turbines and 95 dB for small turbines.

[3] Frequency weightings correlate objective sound measurements with the subjective human response. In the mid frequency range (500 Hz - 6 kHz) the human ear is more sensitive than in low or high range. The A-weighting covers the full audio range - 20 Hz to 20 kHz taking into account different sound perception based on frequency.

[4] Based on number of small wind turbines ranging from 30 to 50 m hub height and from 35 to 54 m. rotor diameter

[5] Based on Vestas V90. Current hi power wind turbines could have diameters above 150 m and hunb height over 160 m.

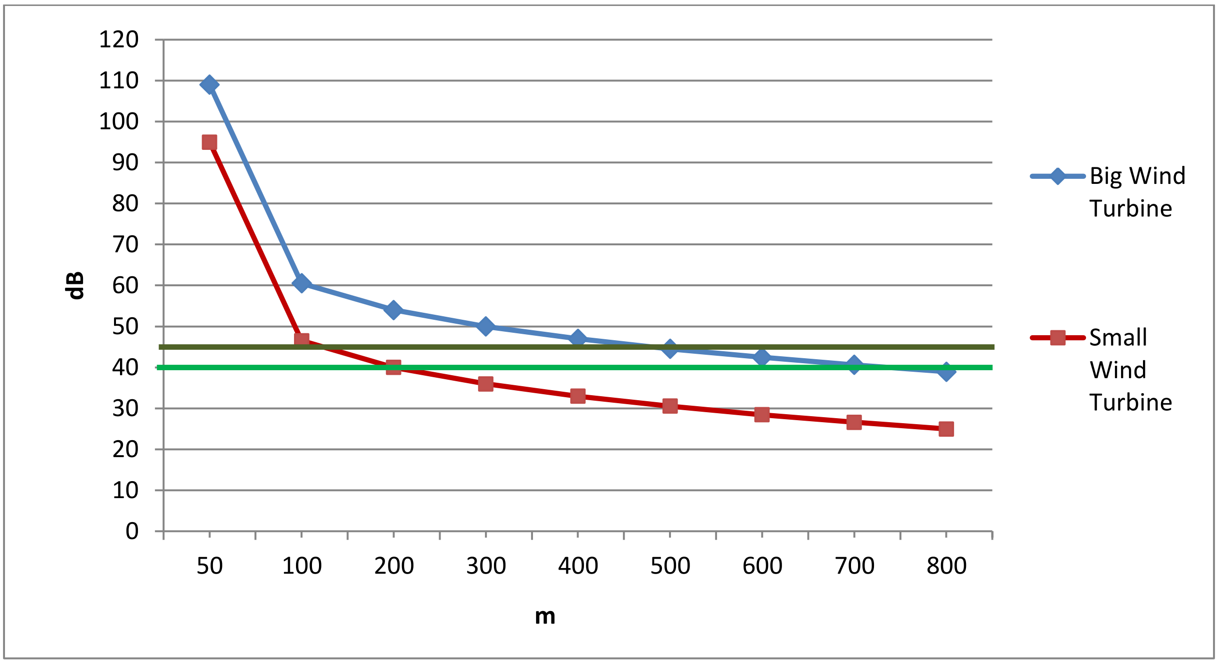


Figure 1. Noise level of wind small/large wind turbine in relation to distance

As evident from Figure 1, a threshold of 45 dB is reached at around 120 m in case of small wind turbines and at around 500 meters for large wind turbines. If the noise level is lowered to 40 dB, the setback distance from the wind turbine should be increased to 200 meters for a small wind turbine and over 700 hundred meters for a large turbine. Other studies indicate even higher distances (Chief Medical Officer of Health (CMOH) 2010), (Acoustic Ecology Institute 2012).

Table 1. Proposed minimum distances to settlement, based on different size of wind turbines and other limitations ([6]).

		Large Wind Turbines	**Small Wind Turbines**
		(m)	(m)
Noise	45 dB	500	120
	40 dB	700	200
Hub Height	1x	80	35
Tip Height	1x	125	55
Hub Height	4x	320	140
Tip Height	4x	500	220

Details about country regulations for estimating the setback distances are provided in the Annex 1. Values for setback distances are summarised in **Table 2**.

[6] These distances can increase in the case of different turbine type/design (up to 2 times in case of height limitations). Having several turbines in one site could increase sound limited placement distance considerably.

Table 2. Current setback distances

Country	Region	Small Wind Turbine	Large Wind Turbine
Albania	all	120	500
Austria	Niederösterreich	1200	1200
	Oberösterreich	800	800
	Steiermark	1000	1000
	Burgenland	1000	1000
	Vorarlberg	Not allowed	Not allowed
	Tyrol	Not allowed	Not allowed
	Salzburg	Not allowed	Not allowed
	Carinthia	Not allowed	Not allowed
	Vienna	Not allowed	Not allowed
Belgium	Flanders	600	600
	Wallonia	400	400
	Brussels	Not allowed	Not allowed
Bosnia and Herzegovina	all	120	500
Bulgaria	all	120	500
Croatia	all	500	500
Cyprus	all	850	850
Czech Republic	all	120	500
Denmark	all	600	600
Estonia	all	1000	1000
Finland	all	1000	1000
Former Yugoslav Republic of Macedonia	all	120	500
France	all	500	500
Germany	other	700	550
	Baden-Württemberg	1000	1250

Country	Region	Small Wind Turbine	Large Wind Turbine
	Bayern	1000	1000
	Brandenburg / Berlin, Hessen Niedersachsen	300	1000
	Hamburg	800	500
	Mecklenburg-Vorpommern	200	1000
	Nordrhein Westfalen	400	700
	Rheinland-Pfalz	400	1000
	Saarland	750	1000
	Sachsen	1000	1000
	Sachsen-Anhalt	400	1000
	Schleswig-Holstein	750	800
	Thüringen	700	1000
Greece	all	500	500
Hungary	all	1000	1000
Iceland	all	120	500
Ireland	all	500	500
Italy	all	200	750
Kosovo	all	120	500
Latvia	all	500	500
Lithuania	all	120	500
Luxembourg	all	120	500
Malta	all	120	500
Montenegro	all	120	500
Netherlands	all	400	400
Norway	all	120	500
Poland	all	550	1250

Country	Region	Small Wind Turbine	Large Wind Turbine
Portugal	all	120	500
Romania	all	500	500
Serbia	all	120	500
Slovakia	all	120	500
Slovenia	all	500	500
Spain	all	500	500
Sweden	all	1000	1000
Switzerland	all	120	500
United Kingdom	England	700	800
	Wales	500	500
	Northern Ireland	500	500
	Scotland	1000	2000

The setback distances are further differentiated into *small* and *large* turbines. This reflects the fact that higher noise level (larger turbines) effectively lead to less available area for onshore wind.

Three scenarios have been obtained by projecting these data to 2050:

- *Reference Scenario*: Current setback distances remain the same in future years.
- *High Wind Scenario*: Setback distances in all countries converge in 2030 to the lowest setback currently observed. Setbacks remain the same in subsequent years.
- *Low Wind Scenario*: Setback distances in all countries converge in 2030 to the highest setback currently observed. Setbacks remain the same in subsequent years.

Details are provided in the excel file *2017 09 06 - scenario assumptions.xlsx*.

Land exclusions zones for onshore wind

Additionally to setback distances, certain land areas are unavailable for onshore wind in all scenarios, as summarised in **Table 3**. The area classification is taken from the LUISA database and the combined Global Land Cover and Corine databases (named GLCplus, as in the previous Work Packages).

Table 3. Onshore wind exclusion zones

		Wind high	**Wind low**	**Wind ref**
		Usable	**Usable**	**Usable**
GLCplus				
Class	Class Description			
11	Post-flooding or irrigated croplands (or aquatic)	no	no	no
14	Rainfed croplands	yes	yes	yes
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	yes	yes	yes
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	yes	yes	yes
40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	no	no	no
50	Closed (>40%) broadleaved deciduous forest (>5m)	no	no	no
60	Open (15-40%) broadleaved deciduous forest/woodland (>5m)	no	no	no
70	Closed (>40%) needleleaved evergreen forest (>5m)	no	no	no
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	no	no	no
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	no	no	no
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	yes	yes	yes
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	yes	yes	yes
130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	no	no	no
140	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	yes	yes	yes
150	Sparse (<15%) vegetation	yes	yes	yes
160	Closed to open (>15%) broadleaved forest	no	no	no

		Wind high	Wind low	Wind ref
		Usable	Usable	Usable
GLCplus				
	regularly flooded (semi-permanently or temporarily) - Fresh or brackish water			
170	Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water	no	no	no
180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water	no	no	no
190	Artificial surfaces and associated areas (Urban areas >50%)	no	no	no
191	Artificial surfaces,Urban fabric,Continuous urban fabric	no	no	no
192	Artificial surfaces,Urban fabric,Discontinuous urban fabric	no	no	no
193	Industrial, commercial and transport units	no	no	no
194	Road and rail networks and associated land	no	no	no
195	Port areas	no	no	no
196	Airports	no	no	no
197	Artificial surfaces,"Artificial, non-agricultural vegetated areas",Green urban areas	no	no	no
198	Artificial surfaces,"Artificial, non-agricultural vegetated areas",Sport and leisure facilities	no	no	no
200	Bare areas	yes	yes	yes
210	Water bodies	no	no	no
220	Permanent snow and ice	no	no	no
230	No data (burnt areas, clouds,…)	no	no	no
LUISA				
Class	Class Description			
1	Urban	no	no	no
2	Industry	no	no	no

		Wind high	Wind low	Wind ref
		Usable	**Usable**	**Usable**
GLCplus				
3	Other Arable	yes	yes	yes
4	Permanent Crops	yes	yes	yes
5	Pastures	yes	yes	yes
6	Forests	no	no	no
7	Transitional woodland-shrub	no	no	no
8	Cereals	yes	yes	yes
9	Maize	yes	yes	yes
10	Root crops	yes	yes	yes
11	Abandoned Arable Land	yes	yes	yes
12	Abandoned Permanent Crops	yes	yes	yes
13	Abandoned pastures	yes	yes	yes
14	Abandoned Urban	yes	yes	yes
15	Abandoned Industry	yes	yes	yes
16	New Energy Crops	yes	yes	yes
17	Natural land	yes	yes	yes
18	Infrastructure	no	no	no
19	Other Nature	no	no	no
20	Wetlands	no	no	no
21	Water Bodies	no	no	no
22	Urban green leisure	no	no	no
	Additional Criteria:			
	Protected Areas	no	no	no
	Geomorphology	no	no	no
	Slope <2.1°	no	no	no

		Wind high	Wind low	Wind ref
		Usable	**Usable**	**Usable**
GLCplus				
	Distance to Settlements	MS - specific values	MS - specific values	MS - specific values

2.2 Onshore wind potential - available area

The total available area in the various scenarios is reported at NUTS2 regional level. **Figure 2** and **Figure 3** present country-level summaries for onshore wind in the Reference Scenario. Note that the available area is different for small and large wind onshore turbines.

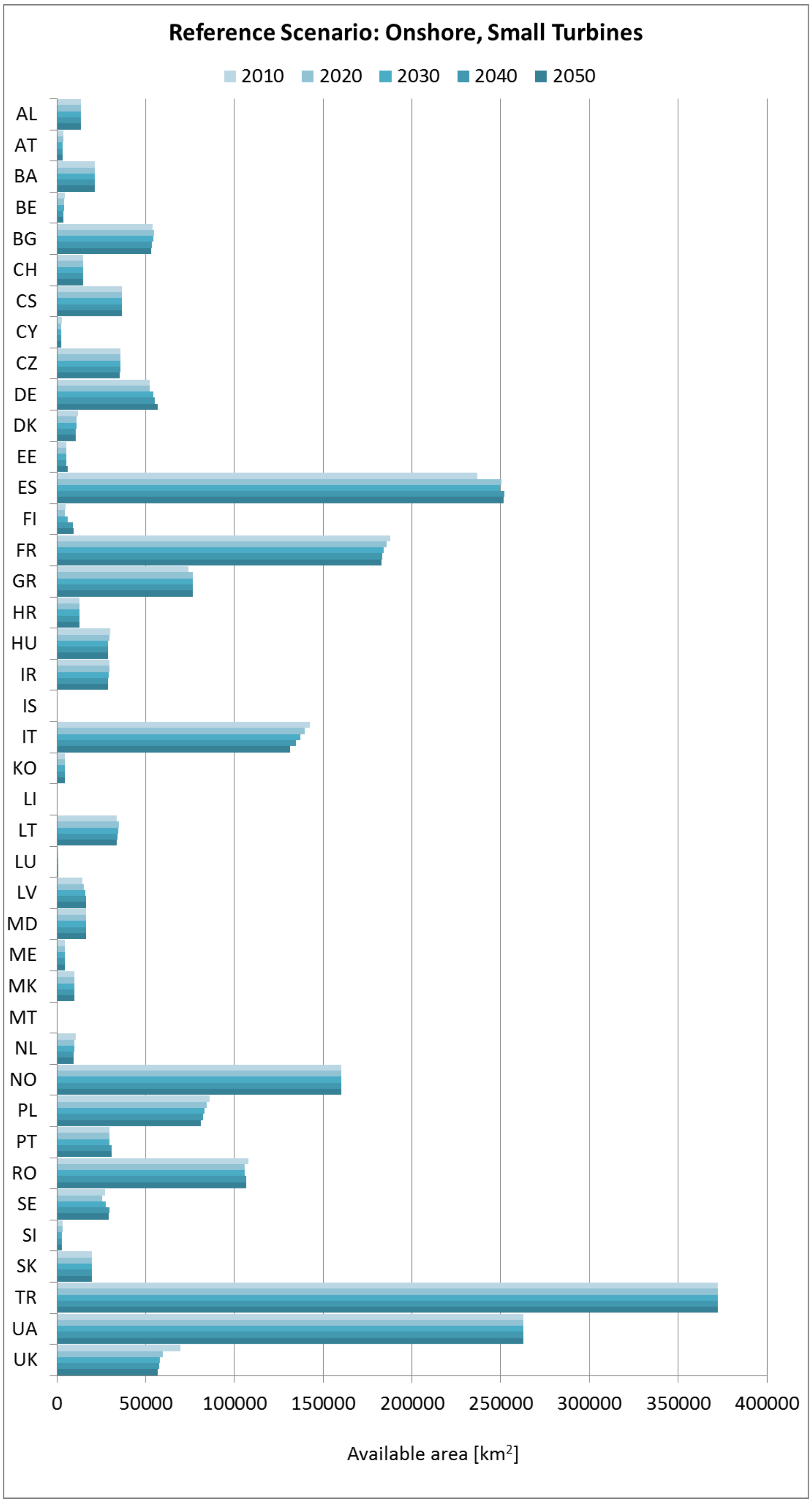


Figure 2. Available area for small onshore turbines (reference scenario)

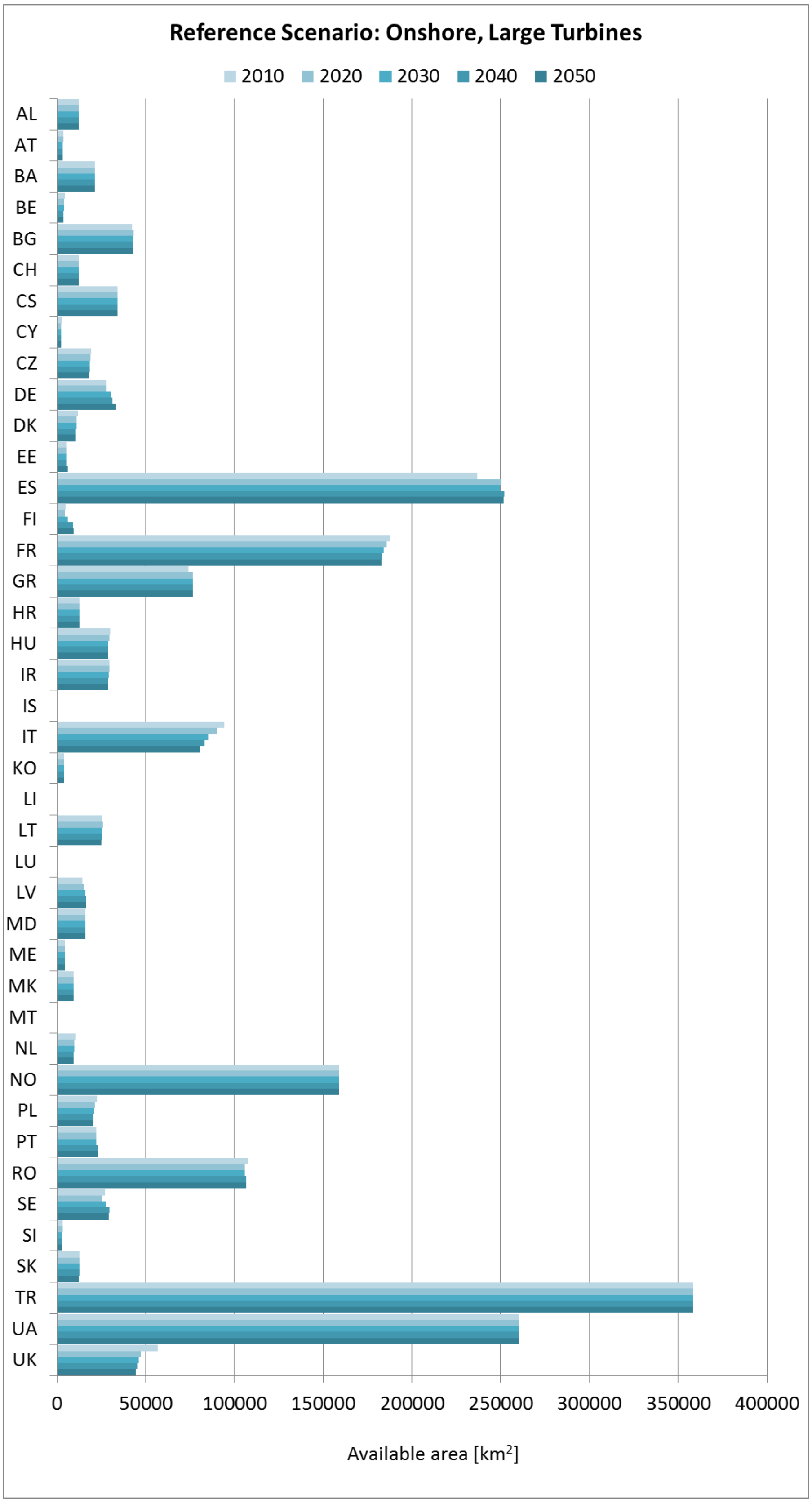


Figure 3. Available area for large onshore turbines (reference scenario)

3 Surface availability scenarios offshore Wind

3.1 Exclusions zones for offshore wind

Also for offshore wind, three scenarios have been constructed by applying different buffers around offshore exclusion zones. These scenarios (summarised in **Table 4**) are derived from the scenarios analysed in the WindSpeed project (windspeed.eu n.d.).

Table 4. Offshore wind parameters.

Parameter	Wind high	Wind low	ref	Comment
Sea depth	< 100m	< 50m	< 50m	Based on the scenarios analysed in the WindSpeed project
Shipping density (ships per year)	< 500	< 5000	< 1000	Based on the scenarios analysed in the WindSpeed project
Distance to shipping lanes	2NM	4NM	2NM	Based on the scenarios analysed in the WindSpeed project
Distance to gas & oil pipelines	2NM	4NM	2NM	Based on the scenarios analysed in the WindSpeed project
Distance to oil and gas wells	2NM	4NM	2NM	Based on the scenarios analysed in the WindSpeed project
Minumum distance to shore	12NM	12NM	12NM	While near-shore areas are typically available for wind installations, in practice these are often used for other purposes (e.g. sand extraction) or is kept free to minimise visual impact (especially in touristic regions). An exception to this rule of thumb may be Denmark where very near shore installations present and may represent a significant potential in the future.
Submarine cables	2NM	4NM	2NM	Based on the scenarios analysed in the WindSpeed project

3.2 Offshore wind potential – available surface area

The total available area in the various scenarios is reported at NUTS2 regional level. **Figure 4** presents country-level summaries for offshore wind in the Reference Scenario. For offshore technologies the turbine size does not influence the available area, hence no distinction is made (effectively only large turbines are considered for offshore installation).

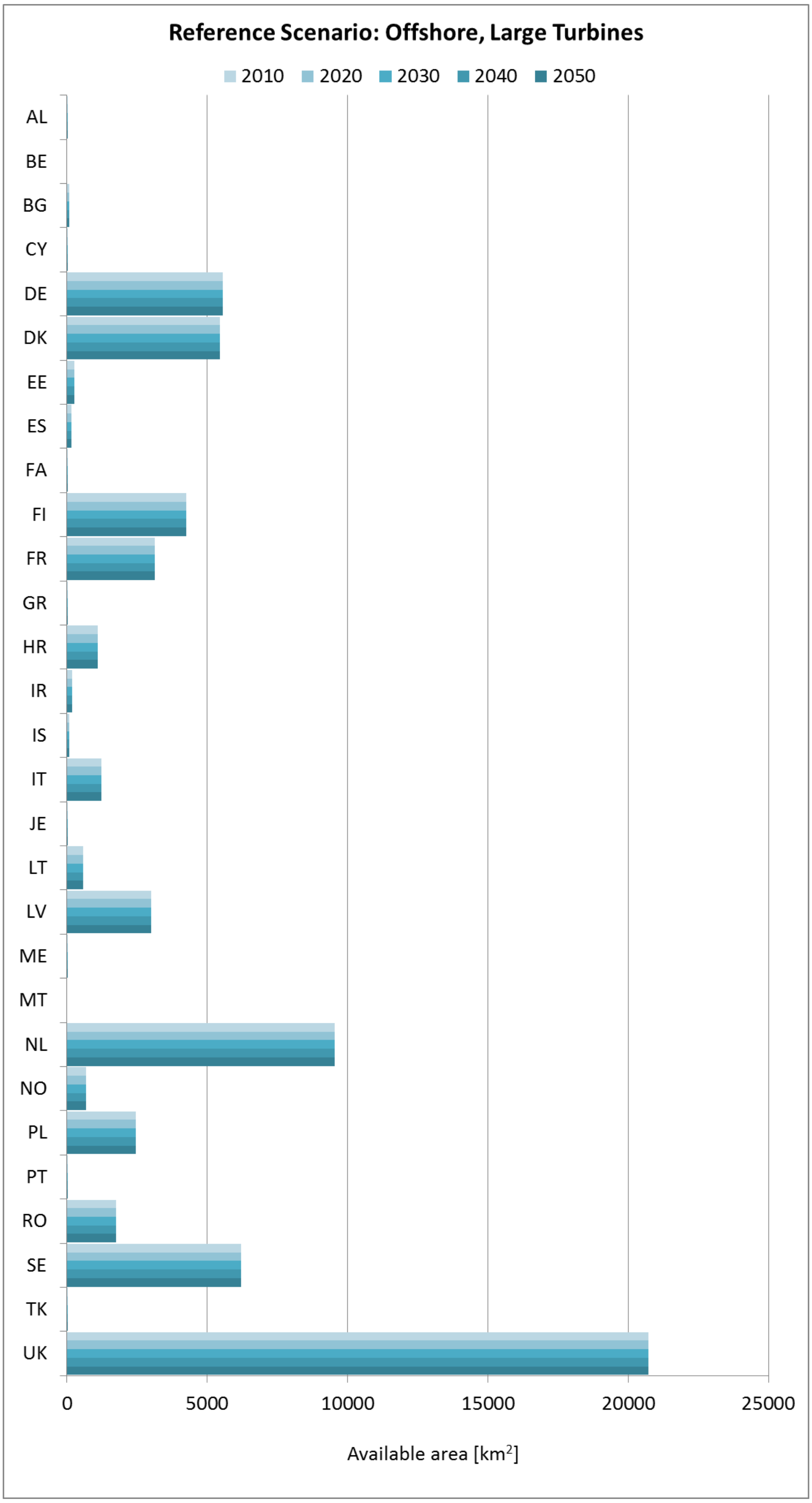


Figure 4. Available area for offshore turbines (reference scenario)

4 Wind turbine technologies

Wind technologies have been differentiated depending on technical and site characteristics, according to the scheme in

Figure 5. Details on the characterisation of the different technologies can be found in the excel file *20170801 – Area Tech Matrix and technoeconomic data.xlsx*. Below a descriptive summary is presented.

Turbine characteristics

3 types of turbine:	Turbine A	Low specific power	Turbine type determines power curves	Technical characteristics determine costs	Area - Technology matrix together with GIS analysis determines capacity factors
	Turbine B	Medium specific power			
	Turbine C	High specific power			
Hub height & foundation:	Onshore:	3 different hub heights (50, 100, 200 m)			
	Offshore:	1 hub height (100 m) 3 foundation types (monopile, jacket, floating)			
Site characteristics	Onshore	/			
	Offshore	distance from shore (short, medium, long) water depth (<30, 30-60, >60 m)			
Wind characteristics	High, medium and low - the average of the top 10%, the middle 40% and the bottom 50% Capacity Factors				

Figure 5. Wind technologies scheme

4.1 Turbine types

The performance of a turbine in a given wind regime is characterised by its power-velocity curve. For this Work Package we consider three different turbines, whose power-velocity curves are modelled after the V136, V112 and V90 Vestas turbines. These are referred to as Turbine A, B and C, respectively. The three power curves are presented in **Figure 6**. The specific power (or specific capacity) of Turbine A, B and C is respectively 0.20, 0.30 and 0.47 kW/m2. Turbine C is associated with the *small turbines* of the area analysis, while turbines A and B are associated with *large turbines*.

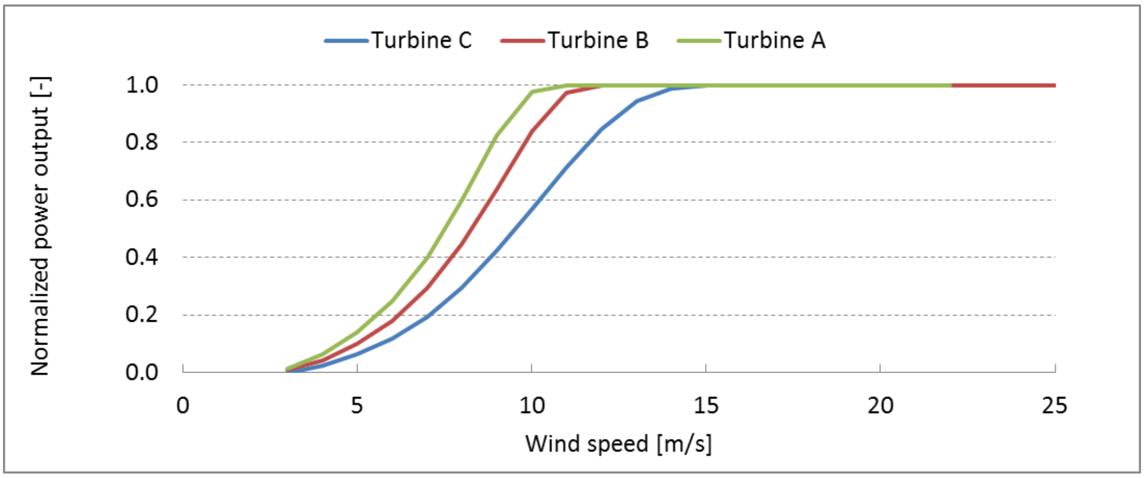


Figure 6. Power-velocity curves

4.2 Technology Matrix

For onshore wind, each of the three turbines can be deployed at three different hub heights of 50, 100 and 200 m.

Offshore wind climate does not vary significantly with height, in comparison with the onshore case. Therefore offshore technologies are all assumed at 100 m hub height. A differentiation is made with respect to water depth and distance from shore. Water depth is linked to indicative foundation concepts according to **Table 5**; this classification is useful to simplify the naming convention in the TIMES model input, as explained in Chapter 4. Distance from shore is qualitatively classified as short, medium and long. Water depth and distance from shore mainly influence technology costs.

Table 5. Water depth classification

Water depth	Indicative foundation type
Water depth <30m	Monopole (MP)
Water depth 30-60	Jacket (JK)
Water depth >60m	Floating (FL)

Additionally, all onshore and offshore technology combinations can be deployed on high, medium and low wind resource areas (the classification of wind resource areas is presented in Chapter 3). All possible technology combinations are summarised in the technology matrix of **Figure 7**.

	Site characteristics			Turbine characteristics		
Onshore	low wind resource areas	low hub height		turbine A	turbine B	turbine C
		medium hub height		turbine A	turbine B	turbine C
		high hub height		turbine A	turbine B	turbine C
	medium wind resource areas	low hub height		turbine A	turbine B	turbine C
		medium hub height		turbine A	turbine B	turbine C
		high hub height		turbine A	turbine B	turbine C
	high wind resource areas	low hub height		turbine A	turbine B	turbine C
		medium hub height		turbine A	turbine B	turbine C
		high hub height		turbine A	turbine B	turbine C
Offshore	low wind resource areas	short distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
		medium distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
		long distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
	medium wind resource areas	short distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
		medium distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
		long distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
	high wind resource areas	short distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
		medium distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating
		long distance to shore	Water depth <30m	turbine A monopile	turbine B monopile	turbine C monopile
			Water depth 30-60	turbine A jacket	turbine B jacket	turbine C jacket
			Water depth >60m	turbine A floating	turbine B floating	turbine C floating

Figure 7. Technology matrix

5 Wind resource analysis

The wind resource analysis is carried out in two steps: First the capacity factors per technology, and time slice are calculated on a high resolution grid; then the resulting geotiff files are re-projected onto the land-availability maps (Chapter 2), and aggregated at NUTS2 (regional) and NUTS0 (country) level.

5.1 Calculation of High Resolution Capacity Factors

In the following the method to calculate capacity factors (CF) in time slices and turbine technologies on a high resolution grid is described.

From the MERRA reanalysis data (1981/01/01 to 2009/12/31) we calculate (I) the Weibull A (A_{ts}) and k (k_{ts}) parameters as a function of height, sector, season, and day time (**Table 6**), where the day time is season dependent (**Table 7**) and (II) the Weibull A (A_{ren}) and k (k_{ren}) parameters as a function of height and sector only. Furthermore, the normalised wind direction frequencies (FWD_{ts}) are calculated for every height, season, and day time. All intermediate results from the reanalysis data are stored in netcdf files.

Table 6. List of dependencies in the processing

Height:	(1) 50 m, (2) 100 m, and (3) 200m
Sector:	12 x 30° sectors
Season:	(1) Spring(15/03 - 31/05) (2) Summer(01/06 - 30/08) (3) Autumn(31/08 - 15/11) (4) Winter(16/11 - 14/03)
Day time:	(1) day (D), (2) night (N), and (3) peak (P)
Turbine technology:	(1) Vestas V90, (2) Vestas V112, and (3) Vestas V136

Global Wind Atlas (GWA) Weibull A (A_{gwa}) and k (k_{gwa}) parameters are sector wise available on 50 m, 100 m, and 200 m heights with a 250 m spatial resolution. Now, for every height, time slice (day time and season) and sector, we step through the wind speed distribution with a resolution of dws (set to 1m/s). For every bin, we correct the lower boundary of the bin with:

$$U_{c1} = A_{gwa}\left(\frac{U_{b1}}{A_{ren}}\right)^{\frac{k_{ren}}{k_{gwa}}}$$

and upper boundary of the bin with:

$$U_{c2} = A_{gwa}\left(\frac{U_{b2}}{A_{ren}}\right)^{\frac{k_{ren}}{k_{gwa}}}.$$

Here U_c and U_b are the corrected and original bin boundaries. From the corrected lower and upper bin boundaries the corrected average wind speed (U_{av}) is calculated. Then, we loop over the turbine technologies and if U_{av} is between the cut-in (U_{in}) and cut-out (U_{out}) wind speed of the specific turbine, the wind direction (FWD_{ts}) and wind speed (FWS_{ts}) weighted capacity factor is calculated:

$$CF(i,j,k,l,m) = \sum_{q=1}^{12} \sum_{p=(U_{in}+1)}^{U_{out}} FWD_{ts}(i,j,k,l,q) \cdot FWS_{ts} \cdot \left[\frac{\big(P(p,m) - P(p-1,m)\big)\big(U_{av} - U(p-1)\big)}{U(p) - U(p-1)} + P(p-1,m)\right],$$

where i is the longitude, j the latitude, k the season. l day time, m the turbine technology, and P the normalised turbine power production. The wind direction weights is normalised such that:

$$\sum_{q=1}^{12} FWD_{ts}(i,j,k,l,q) = 1 \quad \forall\, i,j,k,l.$$

The wind speed weights (FWS_{ts}) are obtained from difference of the season and day time dependent weibull cumulative distribution functions of the upper:

$$P_2 = 1 - exp\left(-\left(\frac{U_{c2}}{A_{ts}}\right)^{k_{ts}}\right)$$

and lower:

$$P_1 = 1 - exp\left(-\left(\frac{U_{c1}}{A_{ts}}\right)^{k_{ts}}\right)$$

corrected wind speed bin. The final results are stored in geotiff tiles.

Table 7. Day time D (day), N (night), P (peak) as a function of the season

Hour of day	Spring	Summer	Fall	Winter
1	N	N	N	N
2	N	N	N	N
3	N	N	N	N
4	N	N	N	N
5	N	N	N	N
6	N	N	N	N
7	N	N	N	N
8	N	N	N	N
9	D	D	D	D
10	D	D	D	D
11	D	D	D	D
12	D	P	D	D
13	D	D	D	D
14	D	D	D	D

Hour of day	Spring	Summer	Fall	Winter
15	D	D	D	D
16	D	D	D	D
17	D	D	D	D
18	D	D	D	D
19	D	D	D	D
20	P	D	P	P
21	N	N	N	N
22	N	N	N	N
23	N	N	N	N
24	N	N	N	N

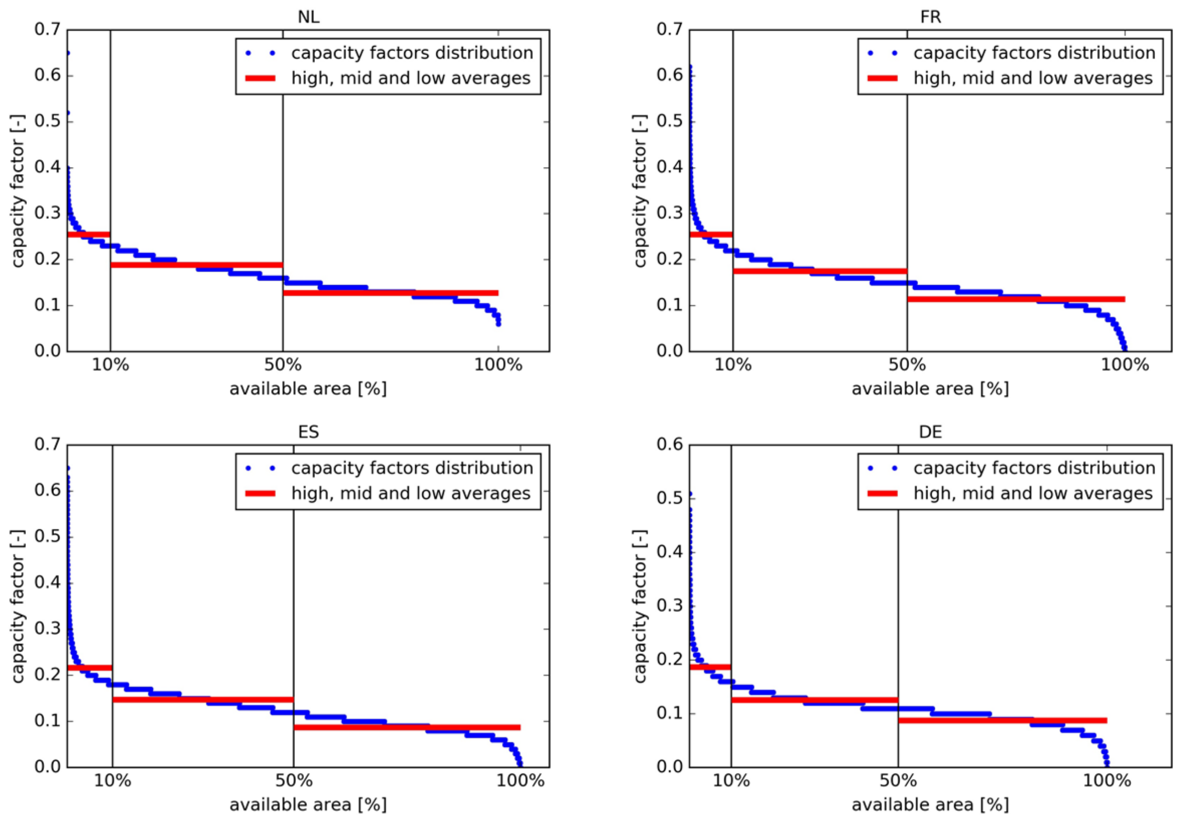


Figure 8. Onshore capacity factor distributions for the Netherlands (top left), France (top right), Spain (bottom left) and Germany (bottom right). Note the difference in y-axis scale in the 'DE' panel.

5.2 Resource Area Classification

The geotiff files from the previous step are reprojected onto the land-availability maps (Chapter 1) for the different scenarios, and aggregated at NUTS2 (regional) and NUTS0 (country) level. The results of this operation entail several hundred GBs of data. By way of example, **Figure 8** presents the distribution of onshore Capacity Factors (CF) for four countries. The blue dots represent the CF of each available raster cell in the country. The three red lines represent the average of, respectively, the top 10% of the CFs (classified as high resource areas), the middle 40% (medium resource areas), and the lowest 50% (low resource areas). In this way the available area is subdivided into three separate classes in each country (see technology matrix), depending on the wind resource level. The three levels of capacity factors per country are then used in the model input files. These country-level summary data can be found in the excel file *capacityfactors_[SCEN].xlsx*, where*SCEN* can be *REF, LOW* or *HIGH*.

5.3 Data processing

The resource area analysis delivers the capacity factors grouped in the following percentiles:

- P10: average of top 10% CFs
- P20: average of top 20% CFs
- P30: average of top 30% CFs
- P40: average of top 40% CFs
- P50: average of top 50% CFs
- P100: average of all the CFs

From these we need to calculate the three red lines in Figure 9:

- HI – the average of the top 10% CFs
- ME – the average of the middle 40% CFs
- LO – the average of the bottom 50% CFs

This is done using the following formulas:

- $\mathrm{HI} = \mathrm{P10}$,
- $\mathrm{ME} = (5 \times P50 - P10)/4$,
- $\mathrm{LO} = 2 \times \mathrm{P100} - \mathrm{P50}$.

A short derivation of these formula is presented below.

- HI is just P10 by definition
- ME is derived as follows:

If we label all CFs as CF_i, with i = 1 … N, ME is defined as $\mathrm{ME} = \sum_{i=1+N/10}^{N/2} \mathrm{CF}_i \ / \ 0.4\mathrm{N}$. Considering that $\mathrm{P10} = \sum_{i=1}^{N/10} \mathrm{CF}_i \ / \ 0.1\mathrm{N}$, and $\mathrm{P50} = \sum_{i=1}^{N/2} \mathrm{CF}_i \ / \ 0.5\mathrm{N}$, we can rewrite ME as $\mathrm{ME} = (0.5 \times \mathrm{P50} - 0.1 \times P10)/0.4 \ = (5 \times P50 - P10)/4$, where in the last equality we multiplied numerator and denominator by 10.

- LO is derived analogously:

By definition $\mathrm{LO} = \sum_{i=N/2+1}^{N} \mathrm{CF}_i \ / \ 0.5\mathrm{N}$. Given that $\mathrm{P100} = \sum_{i=1}^{N} \mathrm{CF}_i \ / \ \mathrm{N}$ and $\mathrm{P50} = \sum_{i=1}^{N/2} \mathrm{CF}_i \ / \ 0.5\mathrm{N}$, we can write LO as $\mathrm{LO} = (\mathrm{P100} - 0.5 \times P50)/0.5 \ = 2 \times P100 - P50$, where in the last equality we divided numerator and denominator by 0.5.

6 JRC-EU-TIMES model Input Files

Excel files containing model input data in VEDA-FE format are provided for each scenario. The files contain a set of sheets that are common to all scenarios:

- *Comm*: New commodities
- *Processes*: New processes
- *SubRES*: New technology characteristics, containing parameters that are common to all scenarios.

Additionally a set of scenario-specific sheets are provided:

- *Area_Scen_xxx*: Upper bound on available area
- *NCAP_AF_Scen_xxx*: Capacity factors, specified per technology, resource area, time slice and year. As of 9 September 2017, parameter NCAP_AF is only available for Turbine C, 50 m hub height, year 2010, for all time slices except for WN and WP. For the latter time slices and other years, a default capacity factor of 15% is temporarily provided, for model testing purposes.
- *UC_Area_Scen_xxx*: User constraint ensuring that available area for large turbines is not exceeded. User constraint ensuring that the offshore area available for each sea depth / distance from shore combination is not exceeded.

6.1 Processes

All technologies in the matrix of Figure 6 have been included in the model input files. The naming convention for onshore and offshore technologies is presented in **Table 8** and **Table 9**, respectively. Furthermore, six additional mining processes have been added that "create" the available area for wind technologies. The corresponding naming convention is presented in **Table 10**. The complete list of new processes and their description is presented in Annex 2.

Table 8. Onshore wind processes naming convention (27 combinations)

Onshore			
Root	**Turbine**	**Height**	**Resource**
EUWINDON	A	050	HI
	B	100	ME
	C	200	LO

Table 9. Offshore wind processes naming convention (81 combinations)

Offshore naming convention				
Root	**Turbine**	**Foundation type (water depth)**	**Distance from shore**	**Resource**
EUWINDOFF	A	MP	LD	HI
	B	JK	MD	ME
	C	FT	SD	LO

Table 10. Mining processes for available wind area naming convention (9 combinations)

MINING		
Root	**Type**	**Resource**
MINWIND	ON	HI
	OFF	ME
	C	LO

The MIN* processes provide the potentials by "creating" available area for wind installations. This area is converted into electricity based on an average density of installed turbines of 5 MW/km^2. In order to assign a suitable value to this parameter several literature sources have been consulted (see (Paul Denholm, Land-Use Requirements of Modern Wind Power Plants in the United States 2009) (Jonathan Bosch 2017) (IPCC 2012), and references therein). From the literature review it was concluded that 5 MW/km^2 is a representative value that fits well the chosen technologies, and ensures that wake effects are kept to a minimum.

6.2 Wind Potentials

Wind potentials are expressed via the available area created by the MIN* processes. In input-sheet *AREA_Scen_xxx* an activity bound is set for the MIN* processes so that the total area made available by these processes does not exceed the total available area for small turbines from Chapter 1. Linking back to the resource classification of section 3.2, MIN*HI processes have a 10% share of the total available area, while MIN*ME and MIN*HI processes have shares of 40% and 50%, respectively.

Finally a user constraint (UC) is defined in sheet UC_area_Scen_xxx, to ensure that the area taken by turbines A and B does not exceed the total available area for large turbines from Chapter 1. In the same table another UC is defined to limit the available area for each sea depth / distance from shore combination.

7 Cost curves

Given the many possible combinations technologies, capacity factors and countries, it is useful to come up with a simple criterion to have an idea which combinations are less likely to be deployed by the JRC EU-TIMES model. This can be done for example by ranking various technology / CF combinations by their expected levelised cost of electricity (LCOE). The combinations displaying the highest LCOEs are unlikely to be deployed, unless there are very stringent constraints on the available areas where the levelised costs are cheaper (i.e. areas with higher CF).

In order to estimate the LCOEs, first a yearly capacity factor for each technology, height, area type (HI, ME or LO) and country combination is obtained by averaging the values in file *capacity_factors_REF.xslx* over the time slices. The yearly capacity factor (hereafter referred to simply as CF) is then used in the following formula to calculate the LCOE:

$$LCOE = \frac{CAPEX + \sum_{i=1}^{LT} \frac{OPEX_i}{(1+r)^i}}{8760 \times CF \times \sum_{i=1}^{LT} \frac{1}{(1+r)^i}},$$

where the CAPEX and OPEX are those presented in chapter 2, LT is the technology lifetime.

8 Results

A number of results were produced to illustrate possible uses of this dataset. Most of the results are given for 3 types of new wind turbines as described in chapter 4. Wind turbines with a specific power less than 300 W/m^2 are less economic today, despite the higher capacity factor. For the calculation of the average capacity factor, losses are assumed to be 15% (icing, down time, transformer losses and park effects). This chapter gives one table with an overview of EU28 results and a series of visualisations.

Table 11. Overview of EU28 results, data based on turbine type B (300 W/m^2), hub height 100 m., losses included

	Scenario	Onshore	Offshore
Average CF for CF > 0.2	All	27.5%	39.5%
Surface use, as share of the surfaces for CF > 0.2	Restrictions - High	9.4%	0.4%
	Reference	15.7%	1.6%
	Restrictions - Low	21.9%	18.0%
Capacity (GW) for CF > 0.2	Restrictions - High	2050	80
	Reference	3400	350
	Restrictions - Low	4750	3800
Power production (TWh) for CF > 0.2	Restrictions - High	4950	350
	Reference	8400	1300
	Restrictions - Low	11700	14250
Ratio Power Production by 2016 power consumption	Restrictions - High	1.8	0.1
	Reference	3	0.5
	Restrictions - Low	4.2	5.1

8.1 Land and surface availability

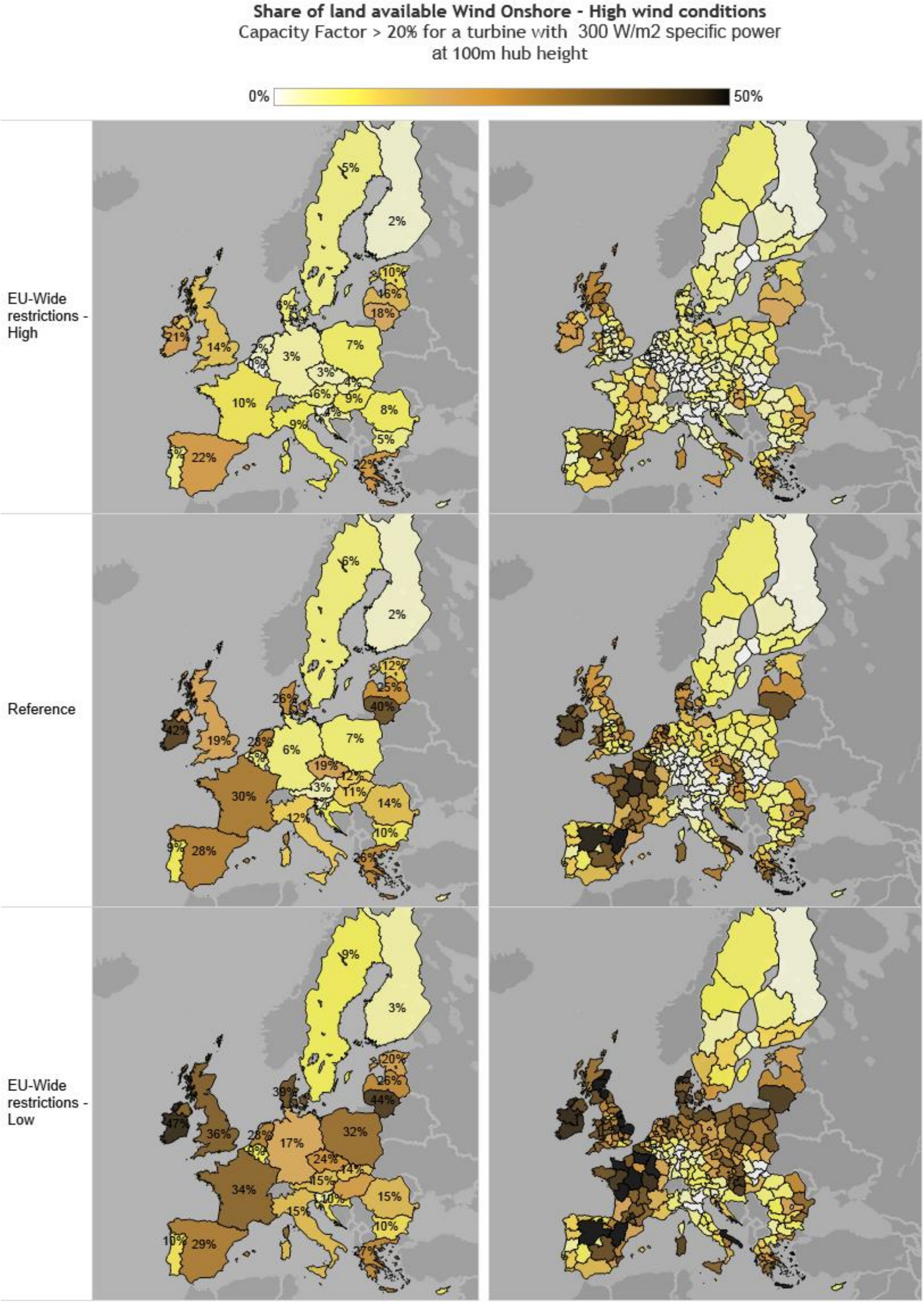


Figure 9. Share of land available Onshore Wind with a capacity factor higher than 20%

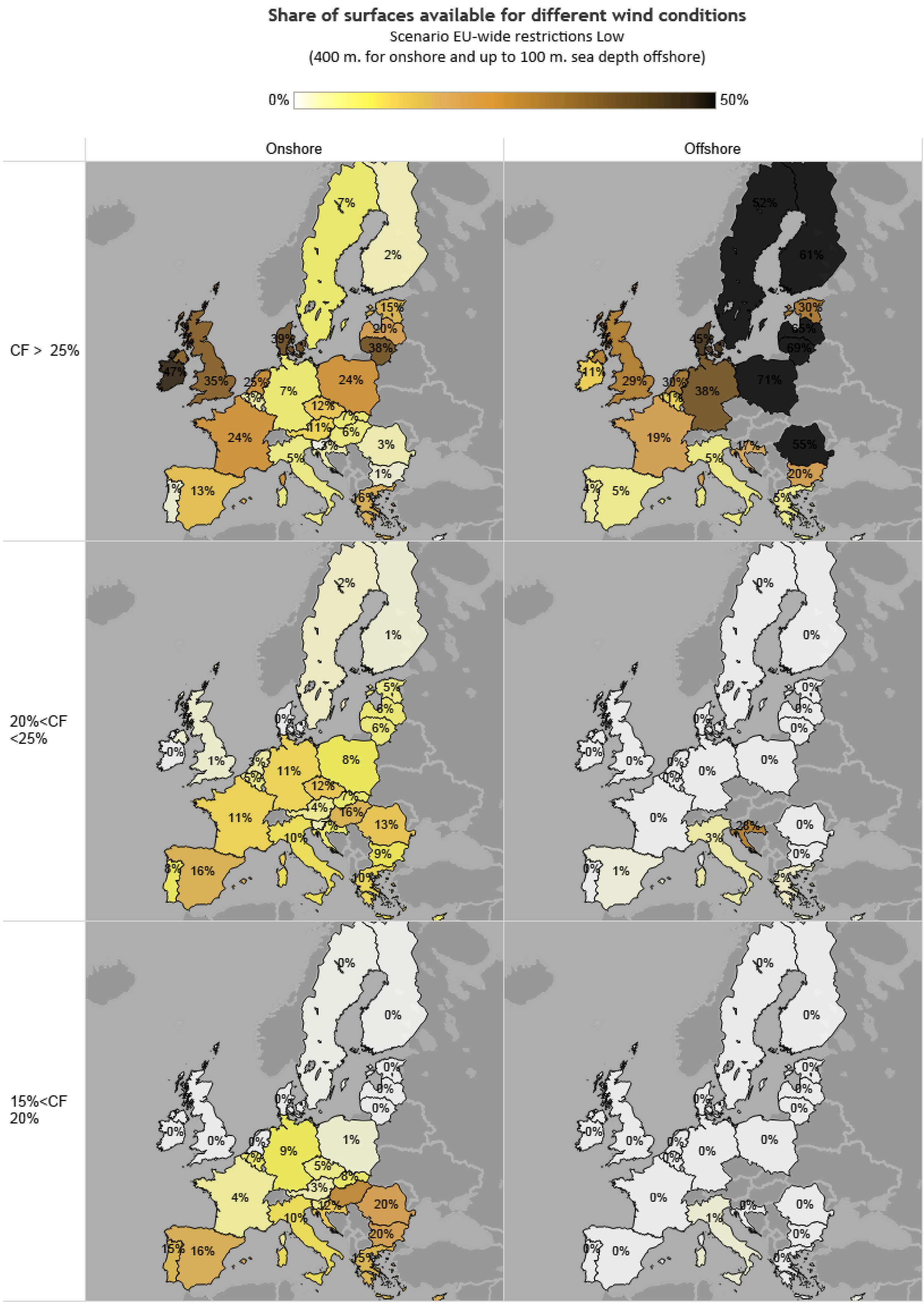


Figure 10. Share of surfaces available for different wind conditions – Scenario low restrictions

8.2 Average Capacity Factor

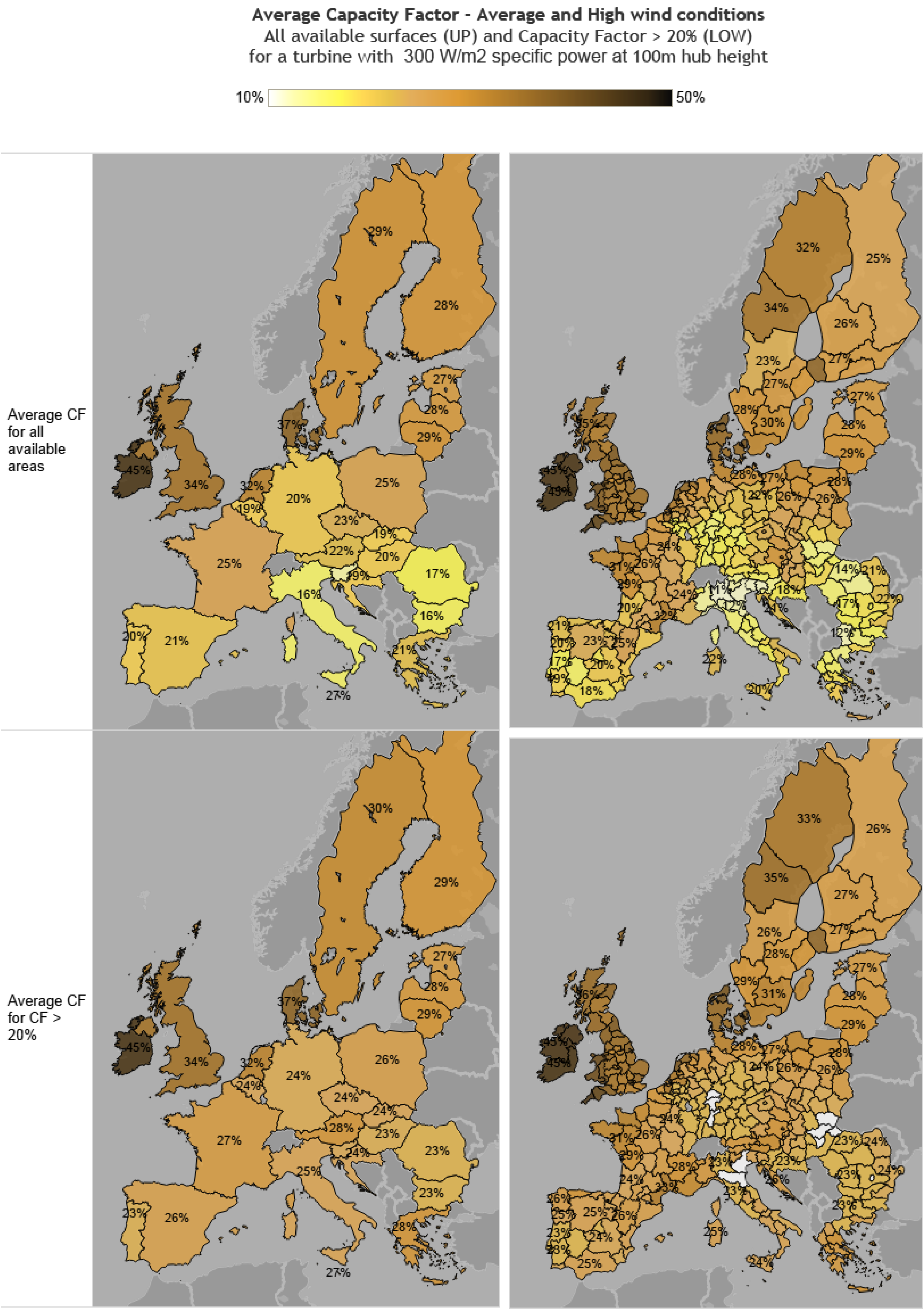
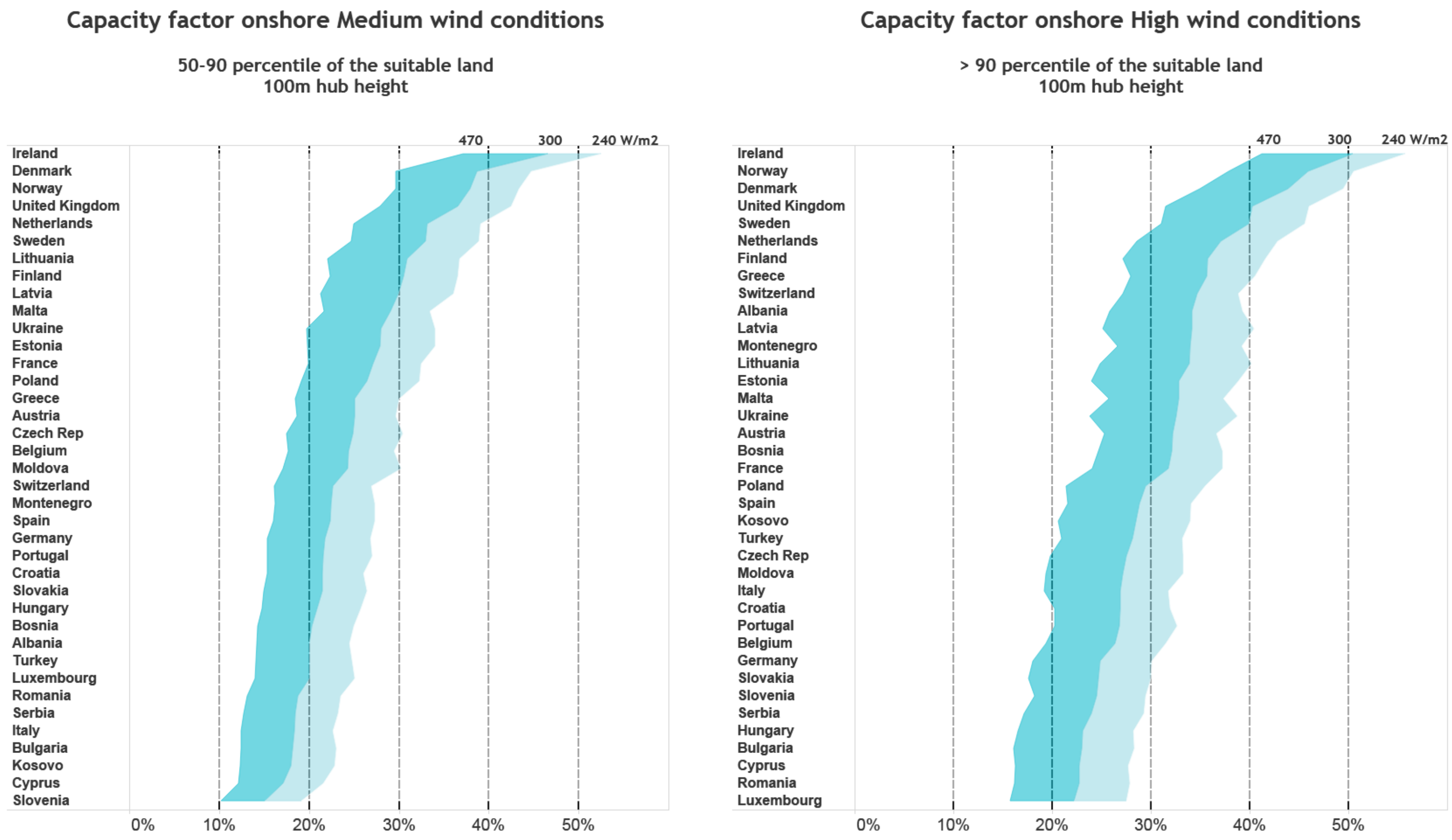


Figure 11. Average CF for wind onshore All areas (UP) and where CF is higher than 20% (LOW)



Data is given for 3 types of new wind turbines. From left to right, the specific power is 470 W/m2, 300 W/m2 and 240 W/m2. The specific power is the wind turbine's power per square meter of rotor swept area. There is a cost optimal level and in most cases with medium to high wind conditions, this level is higher than 300 W/m2 (dark shaded zone). Wind turbines with a specific power less than 300 W/m2 (light shaded) are less economic today, despite the higher capacity factor.
Losses are assumed to be 15% (icing, down time, transformer losses and park effects)

Figure 12. Capacity factor onshore wind for medium and high wind conditions

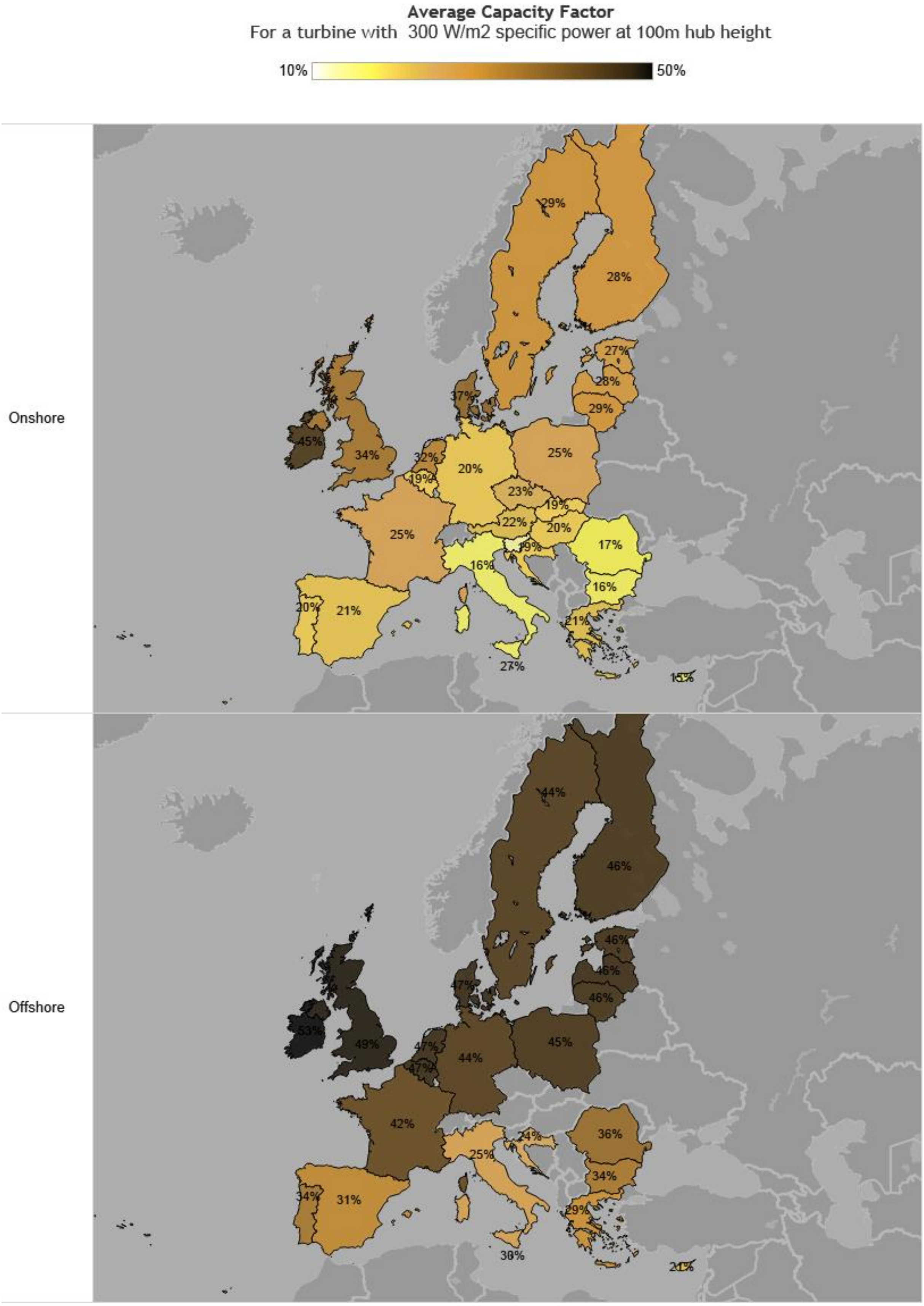


Figure 13. Average capacity factor all areas for both onshore and offshore

8.3 Potential Wind Capacity

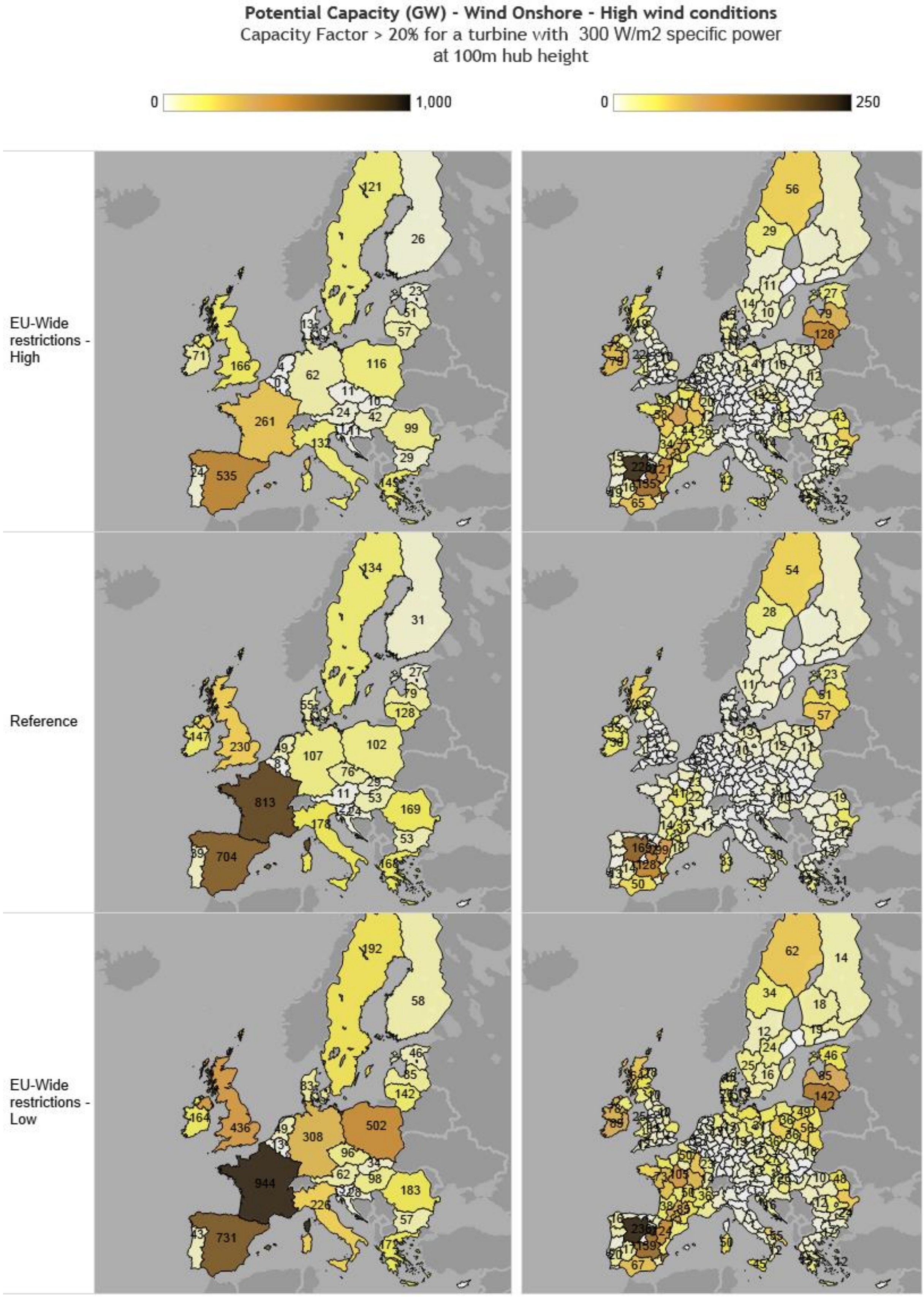


Figure 14. Potential capacity for wind onshore

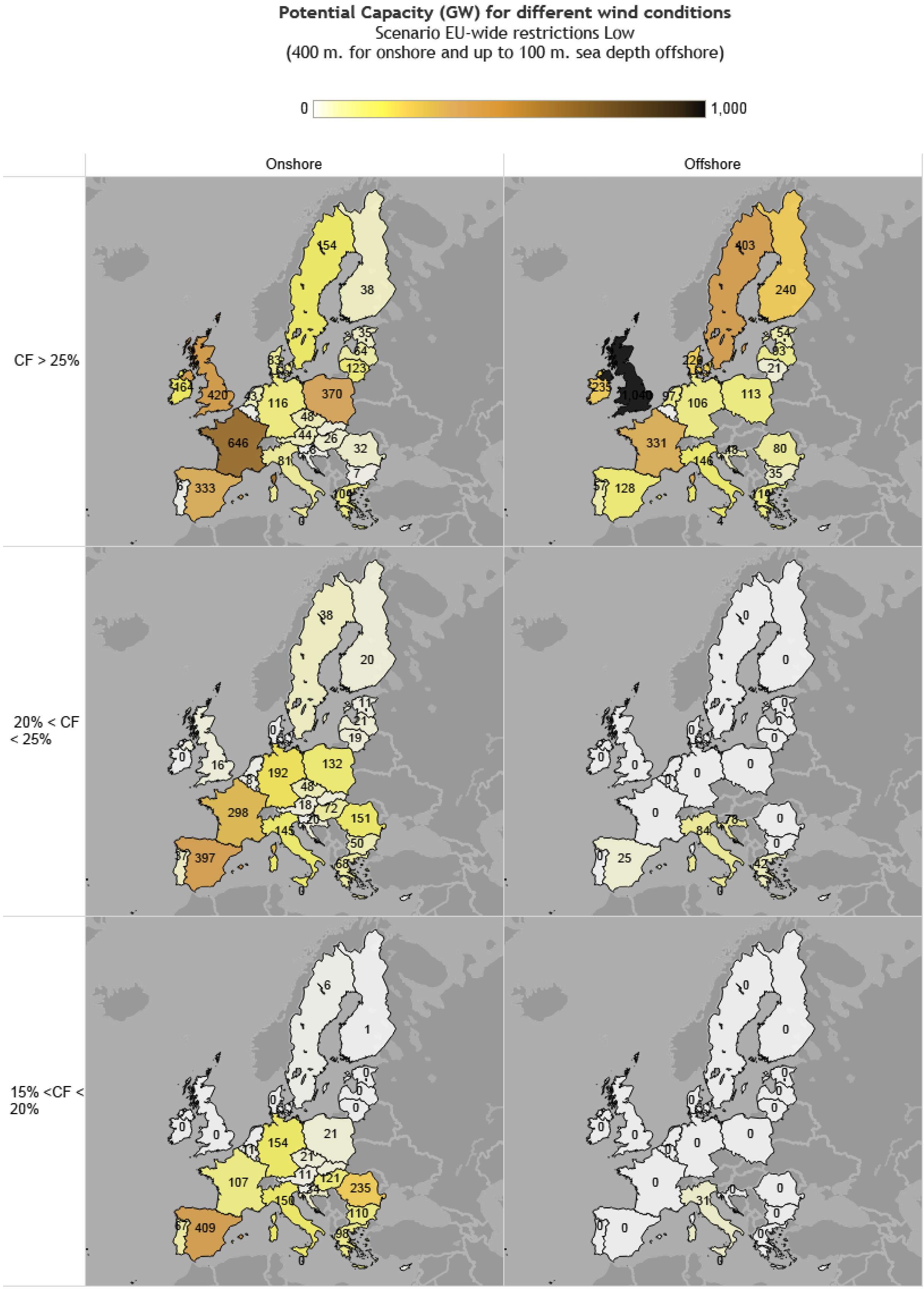


Figure 15. Potential capacity of wind for different wind conditions – Scenario low restrictions

8.4 Potential Power Production from Wind

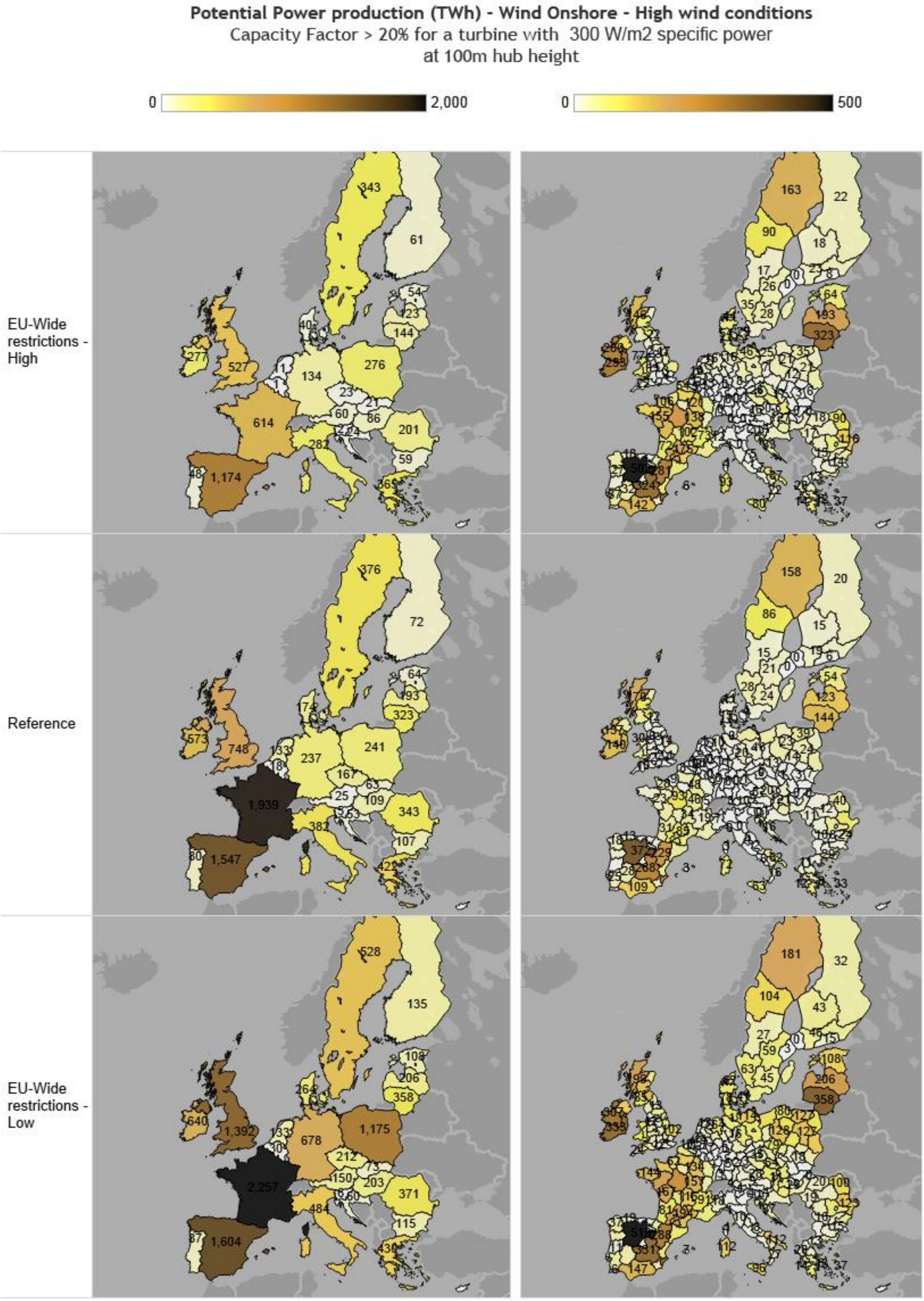


Figure 16. Potential power production from wind onshore

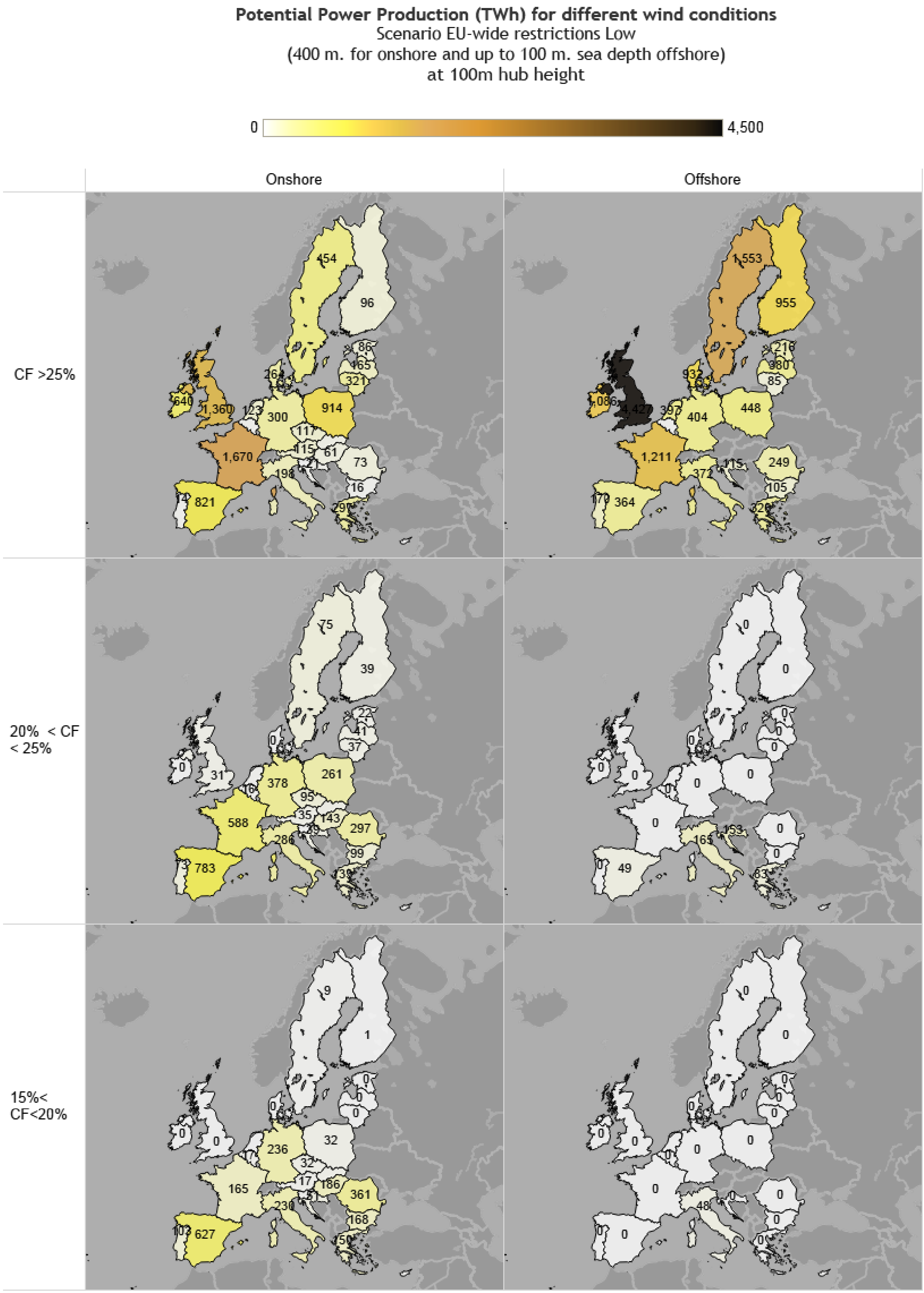


Figure 17. Potential production of electricity from wind for different wind conditions
Scenario low restrictions

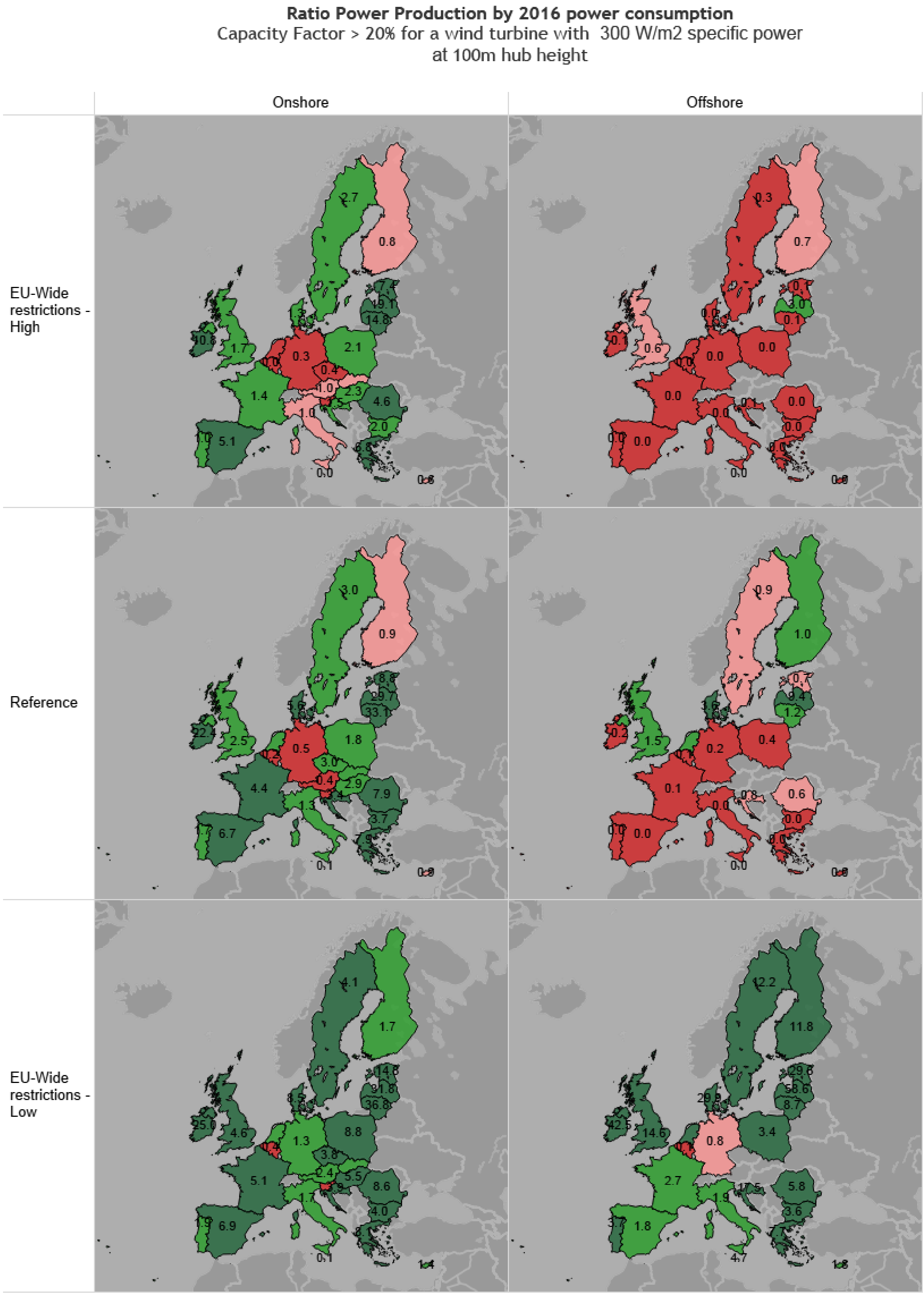


Figure 18. Ratio power production by 2016 power consumption

9 Conclusions

In this report, a description is presented of the methodologies used for the derivation of a wind resource dataset. The dataset consists of an estimation of:

(1) wind speeds accounting for high-resolution effects,

(2) power production accounting for a wide range of turbine types,

(3) suitable areas and

(4) associated cost estimates.

A consistent methodology was used for each of these elements and for each NUTS2 (regional) and NUTS0 (country) level, ensuring increased transparency in the input data.

Wind speed information is systematically derived from 30 years of meteorological data based on the MERRA reanalysis dataset, and from the high resolution geo-spatial data based on the EUDP Global Wind Atlas. The project is one of the first concrete examples of the EUDP Global Wind Atlas data being comprehensively used in an energy system model. High resolution terrain is required because low resolution wind datasets can have very serious shortcomings, in that the wind energy resource is underestimated in most of the cases, as small scale variability of winds is missing. Crucially it is the windiest sites that suffer the largest wind resource errors; in simple terrain the windiest sites may be underestimated by 25% for complex terrain the underestimate can be 100%. In order to produce the specified time slice datasets required by JRC-EU-TIMES, the MERRA reanalysis dataset was used. These hourly time series data allowed determining how the wind potential is distributed in time.

A **technology matrix** is created with 9 technology combinations for both onshore and offshore wind turbines. This level of detail allows analysing the impact of specific power and hub height in the case of onshore wind and the impact of specific power and foundation type in the case of offshore wind. Low specific power wind turbines are able to generate electricity with increased capacity factors. In regions where low wind speeds prevail, these wind turbines can be economic due to their large rotor diameter. The new dataset allows analysing the role of all types of wind turbines, including the ones with low specific power. In more windy areas low specific power turbines produce less electricity per turbine and have for that reason a higher levelised cost of electricity. The electricity generation can be further increased (and levelised costs of electricity can be reduced) by increasing the generator size. However, low specific power turbines have a higher capacity factor (more MWh of electricity generated per MW installed) which could become more and more important in future energy systems. From the technology matrix, together with site characteristics and wind characteristics, capacity factors are determined.

Three scenarios have been created for the **suitable areas** that can be used to better understand the impact of choices with respect to land restrictions. A comprehensive database of current setback distances has been compiled through literature review and expert elicitation. The data was constructed based with contributions from other research organisations in 2016. Additionally to setback distances, certain land areas are unavailable for onshore wind in all scenarios. The area classification is taken from the LUISA database and the combined Global Land Cover and Corine databases.

For all NUTS2 regions and for each country, the resource area analysis delivers the **capacity factors** grouped in percentiles. All suitable areas are split in three wind zones: high, medium and low with respectively the average of the top 10%, the middle 40% and the bottom 50% of the capacity factors. As a consequence, we introduce 27 combinations for onshore (9 technology and 3 wind zones) and 243 for offshore (9 technology, 9 site characteristics and 3 wind zones).

Associated costs are estimated based on all combinations of technology, site characteristics and wind zone. The combinations are ranked by their expected levelised cost of electricity (LCOE). The output of this can be used to identify which combinations are less likely to be deployed by the JRC EU-TIMES model and can be used to generate quick country summaries in the form of cost curves.

Within this project, the wind potentials and techno-economic parameters are gathered and processed into input datasets for the JRC-EU-TIMES model. This allows improved modelling of the competition and the complementarity of wind with other technologies, the key functionality of the JRC-EU-TIMES model. Moreover the datasets can also be used for the analysis of policy questions relating to the availability of wind energy.

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Annex 1 Country regulations for estimating onshore setback distances

Albania

No information was found in literature. The value for Albania has been adopted, on the basis of neighbouring countries. The distance was set to 500 m for the large wind turbines and 120 m for small wind turbines.

Austria

Minimum distances are set by regions (Länder), ranging between 800-1200 m:

a) Niederösterreich 1200 m,

b) Oberösterreich 800 m ,

c) Steiermark 1000 m,

d) Burgenland 1000 m (to be increased to 1200 m).

The values apply to all land dedicated for construction, not to the structures themselves. Priority zones for the development of wind energy have been designated. These are smaller than the theoretical zones resulting from the application of minimum distances.

We adopt 1000m as a minimum distance and exclude development in the states of Vorarlberg, Tyrol, Salzburg, Carinthia and Vienna.

References: (University of Natural Resources and Life Sciences Vienna (BOKU) 2015), (EWEA 2013).

Belgium

Thus far only noise regulations are in place, delegated to regional governments.

For Flanders, the noise limitation during night hours is 39dB (translating to roughly 600 m). One of the rules is that when the background noise is higher than the noise norm itself, the background noise becomes the limit. Also in that specific case, there is an additional criterion that the distance has to be at least 3 times the rotor diameter.

In the case of Wallonia, the minimum distance is 400m, or 4 times the total height of the wind turbine.

No wind development is expected for the Brussels region.

As a minimum distance we adopted 600 m for Flanders, 400 m for Wallonia and excluded the Brussels region.

References: (EWEA 2013), (Edwin Nieuwenhuizen 2015), (Departement Leefmilieu, Natuur en Energie van de Vlaamse overheid n.d.), (Infrax, Eandis, Elia 2012)

Bosnia and Herzegovina

No information found in literature. The value for Bosnia and Herzegovina has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Bulgaria

No information found in literature. The value for Bulgaria has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Croatia

Legislation suggests 45db noise limit, minimum of existing installations 350m (Noise Act, national legislation)

As a minimum distance we recommend using 500 m.

References: (Pozar 2016)

Cyprus

Placement of the wind farms in Cyprus is governed by the number of laws, setting minimum distances from coast line, borders, forest, archaeological sites, power lines, road, etc. Nevertheless major limitation is related to buildings:

a) more than 850 m from already defined Development Boundary and more than 350 m from legally existing construction outside the Development Boundary
b) more than 300 m from the Coast and Conservation Area Boundary, Protected
c) Two wind farms with a total of more than 15 wind turbines will not be allowed within a distance of less than 2 km between them. For wind farms with smaller number of wind turbines the Town Planning Authority can accept up to 1.5 km between them.

Noise level limitations also effect placement of the wind farms. Noise limit varies between 35 and 70 dBA depending on the area and time of day.

As a minimum distance we recommend using 850 m.

References: (2009)

Czech Republic

According to Government Regulation No. 272/2011 Coll., on health protection from adverse effects of noise and vibrations, there must be a fulfilment of hygienic limits of noise i.e. 50 dB in day-time, 40 dB in night-time.

The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

References: (Government Regulation No. 272/2011 on protection of health from adverse effects of noise and vibrations. 2011), (Republic 2016)

Denmark

Guidelines state 4 times tip height. We choose an average tip height of 150 m, based on the technologies considered in this project.

As a minimum distance we recommend using 600 m.

References: (EWEA 2013), (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (Edwin Nieuwenhuizen 2015), (European Platform Against Windfarms 2009), (Loren D KnopperEmail 2011)

Estonia

Noise level legislation is the main criterion setting the minimum distance between houses and wind turbines. Currently not more than 45 dB at night is allowed.

This distance can be increased by local (counties level) legislation. There are 4 counties in the western Estonia (which covers all western Estonia and is the best wind energy production area) that have set the minimum distances by their county plans, mostly 1000 m but in some places also 2000 m.

As a minimum distance we recommend using 1000 m.

References: (Association 2016)

Finland

No specific rules set for distances in Finland, even if some municipalities are considering 2 km. The distances are set by noise limits. Based on noise, the 3 MW and plus turbines usually require about 1 km distance.

As a minimum distance we recommend using 1000 m.

References: (VTT 2016)

Former Yugoslav Republic of Macedonia

No information found in literature. The value for Former Yugoslav Republic of Macedonia has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

France

The law of 2011 requires that wind turbines are located at least 500 meters from all residential areas and 300 m from all nuclear installations.

As a minimum distance we recommend using 500 m.

References: (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (European Platform Against Windfarms 2009), (Loren D KnopperEmail 2011), (MINISTÈRE DE L'ÉCOLOGIE, DU DÉVELOPPEMENT DURABLE, DES TRANSPORTS ET DU LOGEMENT 2011)

Germany

The German states and local governments are responsible for creating guidelines or requirements determining wind turbine siting and setbacks. However, according to German planning and building laws, state policies cannot be overly restrictive and must allow 20% of areas favourable to wind energy to remain open for wind facility development. Many German state governments recommend a 1000 m wind turbine setback from residences, but minimum setbacks may be as small as 300 m or less. Therefore a large spread is observed in practice. The value of 500 m has been chosen as representative average. Numbers in brackets are referring to single houses.

- Baden-Württemberg 700
- Bayern 10 times the turbine height
- Brandenburg / Berlin, Hessen and Niedersachsen 1000
- Hamburg 500 (300)
- Mecklenburg-Vorpommern 1000 (800)
- Nordrhein Westfalen – related to noise
- Rheinland-Pfalz 1000 (400);
- Saarland- case by case
- Sachsen 750-1000 or 10 x hub height (300-500);
- Sachsen-Anhalt 1000m or 10 x total height (1000);
- Schleswig-Holstein 800 (400); Thüringen 750-1000

As a minimum distance we recommend using 500 m.

References: (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (Edwin Nieuwenhuizen 2015), (Überblick zu den landesplanerischen Abstandsempfehlungen für die Regionalplanung zur Ausweisung von Windenergiegebieten 2012), (State of Bavaria 2016)

Greece

Apart from the distances (500 – 1500m from rural areas which are verified) and restricted areas there is a per region max density quota. Additional wind power plants density criteria are defined: wind turbines cannot cover more than 8% of the municipality area. Other restrictions based on type of the land exist.

As a minimum distance we recommend using 500 m.

References: (EWEA 2013), (Regulation authority for energy n.d.), (Η ΕΠΙΤΡΟΠΗ ΣΥΝΤΟΝΙΣΜΟΥ ΤΗΣ ΚΥΒΕΡΝΗΤΙΚΗΣ ΠΟΛΙΤΙΚΗΣ ΣΤΟΝ ΤΟΜΕΑ ΤΟΥ ΧΩΡΟΤΑΞΙΚΟΥ ΣΧΕΔΙΑΣΜΟΥ ΚΑΙ ΤΗΣ ΑΕΙΦΟΡΟΥ ΑΝΑΠΤΥΞΗΣ 2008), (Ο ΥΠΟΥΡΓΟΣ ΑΝΑΠΤΥΞΗΣ 2007)

Hungary

Defined by Hungarian National Land Use Plan: "The county's land use plan - to protect the local area - the downtown boundary of at least 1,000 m, but up to 2000 m distance protection may determine in which wind farms cannot be established"

As a minimum distance we recommend using 1000 m.

References: (legistlation 2017)

Iceland

No information found in literature. The value for Iceland has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Ireland

General wind development guidelines are based on the acceptable noise levels (45 dB or 5 dB above the background noise level). IN the guidelines these noise levels are converted into 500 m. It should help to avoid noise and shadow flicker. In 2013 revisions to existing legislation was proposed lowering recommended noise levels (in the noise sensitive areas) to the 40 dB and stating 500 m. as the minimum distance from the commercial scale wind turbine to the nearest point of property.

As a minimum distance we recommend using 500 m.

References: (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (The Department of the Environment, Heritage and Local (Ireland) 2006), (Enviroment, Comunity and Local Goverment 2013)

Italy

Regulations state 200 m from the single dwelling or 6 times tip height from towns. In practice there is substantial variety depending on region.

In addition, there are noise level emissions limits (during night) depending on the area category (35dB for protected areas, 40dB for residential, 45dB mixed, 50dB for areas with intense human activity, 55dB mostly industrial, 65dB exclusively industrial)

The distance of 750 m. for the big wind turbines and 200 m. from small will be adopted.

References: (EWEA 2013), (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (European Platform Against Windfarms 2009), (Loren D KnopperEmail 2011), (Prezidente Del Consiglio Dei Ministri 1997)

Kosovo

No information found in literature. The value for Kosovo has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Latvia

There no strict restriction in Latvia for the placement of wind turbines. Only limiting factor set by legislation is noise levels (40-45 dB during the night, L_{night}). Existing recommendation for the placement of wind turbines suggest at least 500 m. distance from the buildings.

As a minimum distance we recommend using 500 m.

References: (Latvija Ministru kabineta 2010), (Ministry of Environmental protection and Regional development of the Republic of Latvia 2011)

Lithuania

The main limiting factor for building wind turbines in is noise levels. According to the current legislation, sound pressure during the night should be less than 45 dB, shadow coverage should be less than 30h/year.

Distance from the overhead power lines should be at least 100 meters or 1.5 times of the wind turbine blades. If turbine is higher than 100 meters, owners should get permission from the aviation authority. Building of wind turbines in nature reserves is not allowed. Environmental impact assessment is necessary in 10 km. radius

The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

References: (Lietuvos Respublikos sveikatos apsaugos ministerija 2011), (Lietuvos Respublikos aplinkos apsaugos ministerija 2010)

Luxembourg

No information found in literature. The value for Luxembourg has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Malta

No information found in literature. The value for Malta has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Montenegro

No information found in literature. The value for Montenegro has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Netherlands

Regulations state 4 times hub height. We choose an average hub height of 100 m based on the technologies considered in this project. There also noise, radar exclusion zones and other regulations limiting expansion of wind turbines.

As a minimum distance we recommend using 400 m.

References: (EWEA 2013), (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (Edwin Nieuwenhuizen 2015), (European Platform Against Windfarms 2009), (Over Rijksdienst voor Ondernemend Nederland n.d.)

Norway

No information found in literature. The value for Norway has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Poland

National legislation: "Ustawa o inwestycjach w zakresie elektrowni wiatrowych", article 4 requires 10 times total height of the wind turbine including blades.

The distance of 1250 m. for the big wind turbines and 550 m. from small will be adopted.

References: (Polish legistlation 2016)

Portugal

There is no specific regulation imposing a minimum distance from houses, but during the Environmental Impact Assessment, it must be shown that the layout of the wind farm complies with the limits set out in Noise regulation (Decree-Law 9/2007 of January 17th). Wind farms have to respect limits according to day-evening-night level indicators and night level indicators that differ according to type of area: residential areas/ dwellings, mix areas or areas not classified. Typical the noise limits imposed correspond to a distance of 500 m, changeable with the orography of the area of implementation.

The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted

References: (EWEA 2013), (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (Association) 2016), (MINISTÉRIO DO AMBIENTE, DO ORDENAMENTODO TERRITÓRIO E DO DESENVOLVIMENTO REGIONAL 2001)

Romania

Distances specified in a technical norm on areas of protection and safety for energy generation plants. Minimum distance to isolated buildings is 300m, for more than 5 buildings, the distance increases to at least 500 m.

As a minimum distance we recommend using 500 m.

References: (Romanian legistlation 2007)

Serbia

No information found in literature. The value for Serbia has been adopted, on the grounds of similar geographical location, culture and economy. The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Slovakia

No information found. The same value as Czech Republic has been chosen, due to geographical proximity and similar economy.

The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

Slovenia

No special legislation in place and almost no wind energy development to this date. The same value is assumed as for Croatia.

As a minimum distance we recommend using 500 m.

References: (Pozar 2016)

Spain

Setback distances in urban areas usually install the wind farms at a minimum distance of 1km. However in the case of isolated dwelling, they usually consider 500m (the most common value in regional regulations in Spain and the value you are considering for scenarios). This value also depends on the geographic situation of the wind farm. If the wind farm is close to a forest or on a slope, the distance may be shortened.

As a minimum distance we recommend using 500 m.

References: (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.)

Sweden

1000 m to urban areas and 500 m to isolated houses. There is no general guideline regarding distance between wind power parks and houses in Sweden. Sweden only has guidelines for noise which is 40 dB.

As a minimum distance we recommend using 1000 m.

References: (Shahid Hussain Siyal 2015), (Institute 2016), (Boverket 2012)

Switzerland

There no regulation specifying required wind turbines exclusion zones in Switzerland and can differ on canton by canton basis. Recommendation for the planning of wind turbine requires take into account protected zones, existing planning documents, scenery, and noise. Wind turbine developers are obliged to prepare Environmental Impact assessment.

Several cantons have dedicated zones recommended for placement of wind turbines.

The distance of 500 m. for the big wind turbines and 120 m. from small will be adopted.

References: (European Platform Against Windfarms 2009), (Sartoris 2010), (EMPA 2010)

United Kingdom

The situations differ between England, Wales, Scotland and Northern Ireland.

In **England** there are no national minimum separation distances set between wind turbines and housing. There have been several legislative attempts to introduce an England-wide separation distance, none of which have passed through all of the stages in Parliament to become law. The Government Companion Guide to Planning Policy Statement 22 gives examples of noise suggesting a practical separation distance of 350 metres.

In a written ministerial statement (WMS) on 18 June 2015 the Government announced new considerations to be applied to proposed wind energy development so that "local people have the final say on wind farm applications.

In some specific circumstances, it has been possible for a local planning authority to set its own separation distance in its own local area.

Local minimum distances range between 700m to 10 times the turbine height and even 2 km.

Wales Planning Policy recommends 500m as the typical separation distance between a wind turbine and residential property to avoid unacceptable noise impacts.

In a statement on the content of the proposals in April 2013, the Scottish Parliament informed that Scottish Ministers intend to extend the separation distance between wind farms and cities, towns and villages.

In **Northern Ireland**, there is no statutory separation distances stipulated in legislation. Recommendations or suggestions for separation are made through planning policy and guidance. The Department of the Environment's best practice guidance recommends to generally applying a separation distance of 10 times rotor diameter to occupied property (with a minimum distance of not less than 500m).

There exist some local recommendations of 2000 m. distance from the dwellings in **Scotland**.

In practice a large variety is observed. The lowest value in the available recommendation data has been chosen as representative.

As a minimum distance we recommend using 500 m.

References: (EWEA 2013), (Haugen, International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns 2011), (Haugen, Summary of Wind Policies and Recommendations by Country n.d.), (Vincent Onyango 2013), (European Platform Against Windfarms 2009), (Loren D KnopperEmail 2011), (Allerdale Borough Council 2014), (Smith 2016), (Cave 2013), (Departament of Enviroment 2009)

Annex 2 New processes and descriptions in JRC-EU-TIMES

Technology name	Description
EUWINDONA100HI	Wind onshore: Turbine A, 100 m - High wind resource areas
EUWINDONA200HI	Wind onshore: Turbine A, 200 m - High wind resource areas
EUWINDONA050HI	Wind onshore: Turbine A, 50 m - High wind resource areas
EUWINDONB100HI	Wind onshore: Turbine B, 100 m - High wind resource areas
EUWINDONB200HI	Wind onshore: Turbine B, 200 m - High wind resource areas
EUWINDONB050HI	Wind onshore: Turbine B, 50 m - High wind resource areas
EUWINDONC100HI	Wind onshore: Turbine C, 100 m - High wind resource areas
EUWINDONC200HI	Wind onshore: Turbine C, 200 m - High wind resource areas
EUWINDONC050HI	Wind onshore: Turbine C, 50 m - High wind resource areas
EUWINDOFFAMPLDHI	Wind offshore: Turbine A , Water depth <30m, long distance from shore - High wind resource areas
EUWINDOFFAMPMDHI	Wind offshore: Turbine A , Water depth <30m, medium distance from shore - High wind resource areas
EUWINDOFFAMPSDHI	Wind offshore: Turbine A , Water depth <30m, short distance from shore - High wind resource areas
EUWINDOFFAFTLDHI	Wind offshore: Turbine A , Water depth >60m, long distance from shore - High wind resource areas
EUWINDOFFAFTMDHI	Wind offshore: Turbine A , Water depth >60m, medium distance from shore - High wind resource areas
EUWINDOFFAFTSDHI	Wind offshore: Turbine A , Water depth >60m, short distance from shore - High wind resource areas
EUWINDOFFAJKLDHI	Wind offshore: Turbine A , Water depth 30-60, long distance from shore - High wind resource areas
EUWINDOFFAJKMDHI	Wind offshore: Turbine A , Water depth 30-60, medium distance from shore - High wind resource areas
EUWINDOFFAJKSDHI	Wind offshore: Turbine A , Water depth 30-60, short distance from shore - High wind resource areas
EUWINDOFFBMPLDHI	Wind offshore: Turbine B , Water depth <30m, long distance from shore - High wind resource areas
EUWINDOFFBMPMDHI	Wind offshore: Turbine B , Water depth <30m, medium distance from shore - High wind resource areas

Technology name	Description
EUWINDOFFBMPSDHI	Wind offshore: Turbine B , Water depth <30m, short distance from shore - High wind resource areas
EUWINDOFFBFTLDHI	Wind offshore: Turbine B , Water depth >60m, long distance from shore - High wind resource areas
EUWINDOFFBFTMDHI	Wind offshore: Turbine B , Water depth >60m, medium distance from shore - High wind resource areas
EUWINDOFFBFTSDHI	Wind offshore: Turbine B , Water depth >60m, short distance from shore - High wind resource areas
EUWINDOFFBJKLDHI	Wind offshore: Turbine B , Water depth 30-60, long distance from shore - High wind resource areas
EUWINDOFFBJKMDHI	Wind offshore: Turbine B , Water depth 30-60, medium distance from shore - High wind resource areas
EUWINDOFFBJKSDHI	Wind offshore: Turbine B , Water depth 30-60, short distance from shore - High wind resource areas
EUWINDOFFCMPLDHI	Wind offshore: Turbine C , Water depth <30m, long distance from shore - High wind resource areas
EUWINDOFFCMPMDHI	Wind offshore: Turbine C , Water depth <30m, medium distance from shore - High wind resource areas
EUWINDOFFCMPSDHI	Wind offshore: Turbine C , Water depth <30m, short distance from shore - High wind resource areas
EUWINDOFFCFTLDHI	Wind offshore: Turbine C , Water depth >60m, long distance from shore - High wind resource areas
EUWINDOFFCFTMDHI	Wind offshore: Turbine C , Water depth >60m, medium distance from shore - High wind resource areas
EUWINDOFFCFTSDHI	Wind offshore: Turbine C , Water depth >60m, short distance from shore - High wind resource areas
EUWINDOFFCJKLDHI	Wind offshore: Turbine C , Water depth 30-60, long distance from shore - High wind resource areas
EUWINDOFFCJKMDHI	Wind offshore: Turbine C , Water depth 30-60, medium distance from shore - High wind resource areas
EUWINDOFFCJKSDHI	Wind offshore: Turbine C , Water depth 30-60, short distance from shore - High wind resource areas
EUWINDONA100ME	Wind onshore: Turbine A, 100 m - Medium wind resource areas
EUWINDONA200ME	Wind onshore: Turbine A, 200 m - Medium wind resource areas

Technology name	Description
EUWINDONA050ME	Wind onshore: Turbine A, 50 m - Medium wind resource areas
EUWINDONB100ME	Wind onshore: Turbine B, 100 m - Medium wind resource areas
EUWINDONB200ME	Wind onshore: Turbine B, 200 m - Medium wind resource areas
EUWINDONB050ME	Wind onshore: Turbine B, 50 m - Medium wind resource areas
EUWINDONC100ME	Wind onshore: Turbine C, 100 m - Medium wind resource areas
EUWINDONC200ME	Wind onshore: Turbine C, 200 m - Medium wind resource areas
EUWINDONC050ME	Wind onshore: Turbine C, 50 m - Medium wind resource areas
EUWINDOFFAMPLDME	Wind offshore: Turbine A , Water depth <30m, long distance from shore - Medium wind resource areas
EUWINDOFFAMPMDME	Wind offshore: Turbine A , Water depth <30m, medium distance from shore - Medium wind resource areas
EUWINDOFFAMPSDME	Wind offshore: Turbine A , Water depth <30m, short distance from shore - Medium wind resource areas
EUWINDOFFAFTLDME	Wind offshore: Turbine A , Water depth >60m, long distance from shore - Medium wind resource areas
EUWINDOFFAFTMDME	Wind offshore: Turbine A , Water depth >60m, medium distance from shore - Medium wind resource areas
EUWINDOFFAFTSDME	Wind offshore: Turbine A , Water depth >60m, short distance from shore - Medium wind resource areas
EUWINDOFFAJKLDME	Wind offshore: Turbine A , Water depth 30-60, long distance from shore - Medium wind resource areas
EUWINDOFFAJKMDME	Wind offshore: Turbine A , Water depth 30-60, medium distance from shore - Medium wind resource areas
EUWINDOFFAJKSDME	Wind offshore: Turbine A , Water depth 30-60, short distance from shore - Medium wind resource areas
EUWINDOFFBMPLDME	Wind offshore: Turbine B , Water depth <30m, long distance from shore - Medium wind resource areas
EUWINDOFFBMPMDME	Wind offshore: Turbine B , Water depth <30m, medium distance from shore - Medium wind resource areas
EUWINDOFFBMPSDME	Wind offshore: Turbine B , Water depth <30m, short distance from shore - Medium wind resource areas

Technology name	Description
EUWINDOFFBFTLDME	Wind offshore: Turbine B , Water depth >60m, long distance from shore - Medium wind resource areas
EUWINDOFFBFTMDME	Wind offshore: Turbine B , Water depth >60m, medium distance from shore - Medium wind resource areas
EUWINDOFFBFTSDME	Wind offshore: Turbine B , Water depth >60m, short distance from shore - Medium wind resource areas
EUWINDOFFBJKLDME	Wind offshore: Turbine B , Water depth 30-60, long distance from shore - Medium wind resource areas
EUWINDOFFBJKMDME	Wind offshore: Turbine B , Water depth 30-60, medium distance from shore - Medium wind resource areas
EUWINDOFFBJKSDME	Wind offshore: Turbine B , Water depth 30-60, short distance from shore - Medium wind resource areas
EUWINDOFFCMPLDME	Wind offshore: Turbine C , Water depth <30m, long distance from shore - Medium wind resource areas
EUWINDOFFCMPMDME	Wind offshore: Turbine C , Water depth <30m, medium distance from shore - Medium wind resource areas
EUWINDOFFCMPSDME	Wind offshore: Turbine C , Water depth <30m, short distance from shore - Medium wind resource areas
EUWINDOFFCFTLDME	Wind offshore: Turbine C , Water depth >60m, long distance from shore - Medium wind resource areas
EUWINDOFFCFTMDME	Wind offshore: Turbine C , Water depth >60m, medium distance from shore - Medium wind resource areas
EUWINDOFFCFTSDME	Wind offshore: Turbine C , Water depth >60m, short distance from shore - Medium wind resource areas
EUWINDOFFCJKLDME	Wind offshore: Turbine C , Water depth 30-60, long distance from shore - Medium wind resource areas
EUWINDOFFCJKMDME	Wind offshore: Turbine C , Water depth 30-60, medium distance from shore - Medium wind resource areas
EUWINDOFFCJKSDME	Wind offshore: Turbine C , Water depth 30-60, short distance from shore - Medium wind resource areas
EUWINDONA100LO	Wind onshore: Turbine A, 100 m - Low wind resource areas
EUWINDONA200LO	Wind onshore: Turbine A, 200 m - Low wind resource areas
EUWINDONA050LO	Wind onshore: Turbine A, 50 m - Low wind resource areas
EUWINDONB100LO	Wind onshore: Turbine B, 100 m - Low wind resource areas

Technology name	**Description**
EUWINDONB200LO	Wind onshore: Turbine B, 200 m - Low wind resource areas
EUWINDONB050LO	Wind onshore: Turbine B, 50 m - Low wind resource areas
EUWINDONC100LO	Wind onshore: Turbine C, 100 m - Low wind resource areas
EUWINDONC200LO	Wind onshore: Turbine C, 200 m - Low wind resource areas
EUWINDONC050LO	Wind onshore: Turbine C, 50 m - Low wind resource areas
EUWINDOFFAMPLDLO	Wind offshore: Turbine A , Water depth <30m, long distance from shore - Low wind resource areas
EUWINDOFFAMPMDLO	Wind offshore: Turbine A , Water depth <30m, medium distance from shore - Low wind resource areas
EUWINDOFFAMPSDLO	Wind offshore: Turbine A , Water depth <30m, short distance from shore - Low wind resource areas
EUWINDOFFAFTLDLO	Wind offshore: Turbine A , Water depth >60m, long distance from shore - Low wind resource areas
EUWINDOFFAFTMDLO	Wind offshore: Turbine A , Water depth >60m, medium distance from shore - Low wind resource areas
EUWINDOFFAFTSDLO	Wind offshore: Turbine A , Water depth >60m, short distance from shore - Low wind resource areas
EUWINDOFFAJKLDLO	Wind offshore: Turbine A , Water depth 30-60, long distance from shore - Low wind resource areas
EUWINDOFFAJKMDLO	Wind offshore: Turbine A , Water depth 30-60, medium distance from shore - Low wind resource areas
EUWINDOFFAJKSDLO	Wind offshore: Turbine A , Water depth 30-60, short distance from shore - Low wind resource areas
EUWINDOFFBMPLDLO	Wind offshore: Turbine B , Water depth <30m, long distance from shore - Low wind resource areas
EUWINDOFFBMPMDLO	Wind offshore: Turbine B , Water depth <30m, medium distance from shore - Low wind resource areas
EUWINDOFFBMPSDLO	Wind offshore: Turbine B , Water depth <30m, short distance from shore - Low wind resource areas
EUWINDOFFBFTLDLO	Wind offshore: Turbine B , Water depth >60m, long distance from shore - Low wind resource areas
EUWINDOFFBFTMDLO	Wind offshore: Turbine B , Water depth >60m, medium distance from shore - Low wind resource areas

Technology name	Description
EUWINDOFFBFTSDLO	Wind offshore: Turbine B , Water depth >60m, short distance from shore - Low wind resource areas
EUWINDOFFBJKLDLO	Wind offshore: Turbine B , Water depth 30-60, long distance from shore - Low wind resource areas
EUWINDOFFBJKMDLO	Wind offshore: Turbine B , Water depth 30-60, medium distance from shore - Low wind resource areas
EUWINDOFFBJKSDLO	Wind offshore: Turbine B , Water depth 30-60, short distance from shore - Low wind resource areas
EUWINDOFFCMPLDLO	Wind offshore: Turbine C , Water depth <30m, long distance from shore - Low wind resource areas
EUWINDOFFCMPMDLO	Wind offshore: Turbine C , Water depth <30m, medium distance from shore - Low wind resource areas
EUWINDOFFCMPSDLO	Wind offshore: Turbine C , Water depth <30m, short distance from shore - Low wind resource areas
EUWINDOFFCFTLDLO	Wind offshore: Turbine C , Water depth >60m, long distance from shore - Low wind resource areas
EUWINDOFFCFTMDLO	Wind offshore: Turbine C , Water depth >60m, medium distance from shore - Low wind resource areas
EUWINDOFFCFTSDLO	Wind offshore: Turbine C , Water depth >60m, short distance from shore - Low wind resource areas
EUWINDOFFCJKLDLO	Wind offshore: Turbine C , Water depth 30-60, long distance from shore - Low wind resource areas
EUWINDOFFCJKMDLO	Wind offshore: Turbine C , Water depth 30-60, medium distance from shore - Low wind resource areas
EUWINDOFFCJKSDLO	Wind offshore: Turbine C , Water depth 30-60, short distance from shore - Low wind resource areas
MINWINDONHI	Surface potential wind onshore - High CF
MINWINDONME	Surface potential wind onshore - Medium CF
MINWINDONLO	Surface potential wind onshore - Low CF
MINWINDOFFHI	Surface potential wind offshore - High CF
MINWINDOFFME	Surface potential wind offshore - Medium CF
MINWINDOFFLO	Surface potential wind offshore - Low CF

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