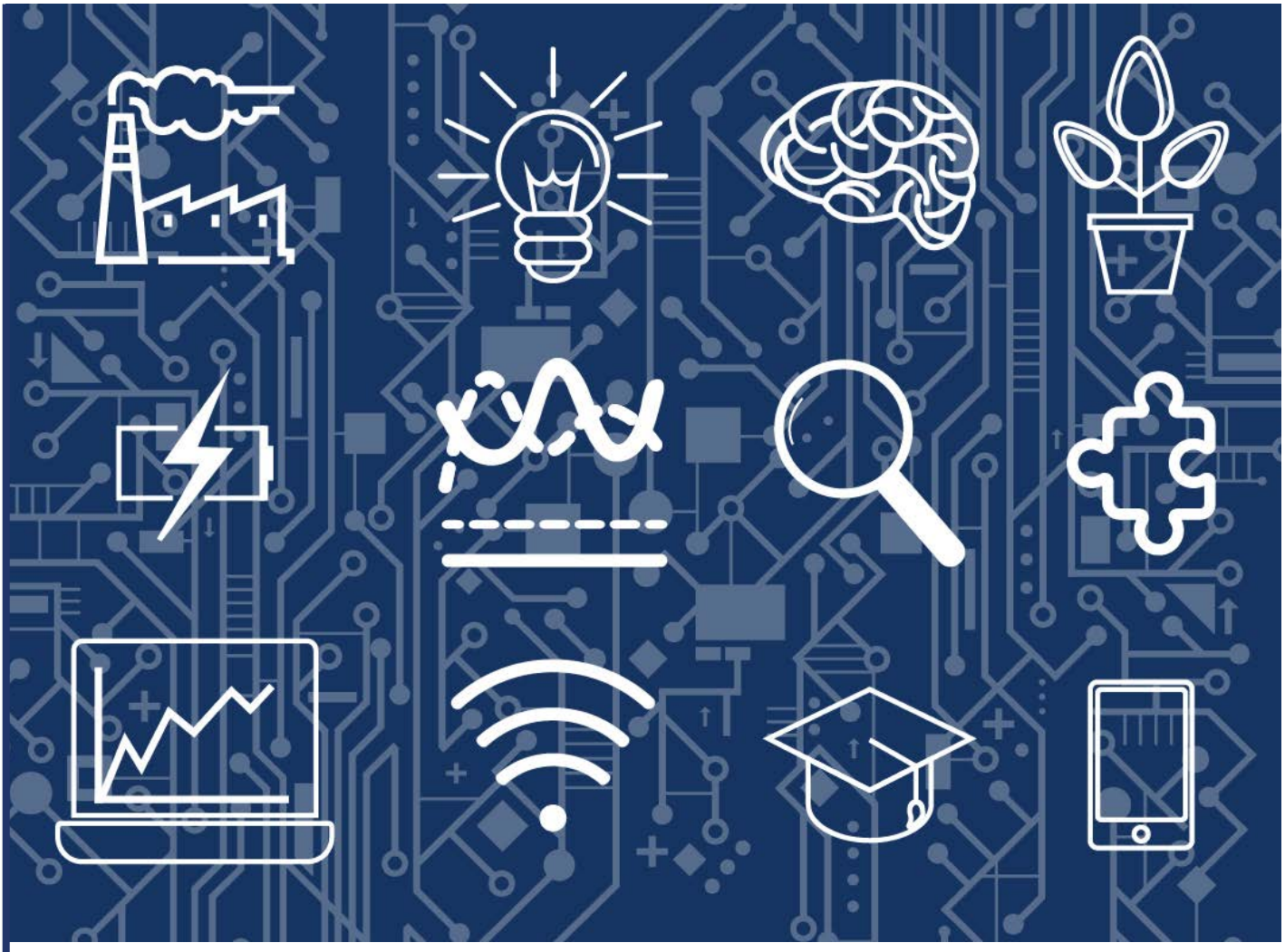
Intellectual Property Office

Offshore wind power

A worldwide overview of patenting related to the UK's ten point plan for a Green Industrial Revolution



IPO | Making life better through IP

Intellectual Property Office is an operating name of the Patent Office

ISBN: 978-1-915090-06-5
Offshore wind power
A worldwide overview of patenting related to the UK's ten point plan for a Green Industrial Revolution

Published by The Intellectual Property Office
November 2021

1 2 3 4 5 6 7 8 9 10

Any enquiries regarding this publication should be sent to:

The Intellectual Property Office
Concept House
Cardiff Road
Newport
NP10 8QQ

Tel: 0300 300 2000

e-mail:research@ipo.gov.uk

This publication is available from our website at www.gov.uk/ipo

Table of Contents

1. Introduction

1.1 Background

In June 2019, the UK became the first major economy to set a legally binding target to reach net zero greenhouse gas emissions by 2050, in recognition of the transformative change needed to tackle global climate change.[1]

The Energy White Paper (EWP)[2], published in December 2020, and the Industrial Decarbonisation Strategy[3], published in March 2021, set out complementary plans for the transformation of our energy system and industries, including actions to fully decarbonise electricity generation by 2050.

On the international stage, the UK has co-assumed[4] the presidency of COP26 (26th UN Climate Change Conference of the Parties) and is hosting the COP26 UN Climate Change Conference in Glasgow in 2021.[5,6]

In November 2020 the UK government released a ten point plan for a green industrial revolution[7], comprising:

- **Offshore wind:** produce enough offshore wind energy to power every home in the UK, producing up to 40 gigawatts by 2030.
- **Hydrogen:** reach a five-gigawatt production capacity of 'low carbon' hydrogen by 2030 – for industry, transport, power and homes – and develop the first town heated by hydrogen by the end of this decade.
- **Nuclear:** provision for a large nuclear plant, as well as for advanced small nuclear reactors.
- **Electric vehicles:** phasing out sales of new petrol and diesel-powered vehicles by 2030, so as to accelerate the transition to electric vehicles and investing in grants to help buy cars and charge point infrastructure.
- **Public transport, cycling and walking:** making cycling and walking more attractive ways to travel and investing in zero-emission public transport for the future.
- **Zero-emission air and greener maritime travel:** supporting research projects for zero-emission planes and ships.
- **Homes and public buildings:** making homes, schools and hospitals greener, warmer and more energy efficient, including a target to install 600,000 heat pumps every year by 2028.
- **Carbon capture:** developing world-leading technology to capture and store harmful emissions away from the atmosphere, with a target to remove 10 million tonnes of carbon dioxide by 2030.

---

[1] https://www.gov.uk/government/publications/department-for-business-energy-and-industrial-strategy-outcome-delivery-plan/beis-outcome-delivery-plan-2021-to-2022 - b-introduction
[2] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[3] https://www.gov.uk/government/publications/industrial-decarbonisation-strategy
[4] Together with Italy: https://www.ukcop26.org/pre-cop/
[5] The conference was originally scheduled to take place in 2020, but has been postponed to 2021 in view of the COVID-19 pandemic
[6] UN Climate Change Conference UK 2020 (Conference) https://www.ukcop26.org/the-conference
[7] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

- **Nature:** Protecting and restoring the natural environment, with plans to include planting 30,000 hectares of trees a year.
- **Innovation and finance:** Developing cutting-edge technologies and making the City of London the global centre of green finance.

Innovation has a role in helping to achieve carbon net zero[8] and innovation may be reflected in global patenting trends. Hence, this report is part of a series of studies relating to the technologies covered within the UK government's ten point plan for a green industrial revolution. This report analyses the worldwide patent landscape related to wind power, with a further specific focus on its offshore variant, and the current state of this technology in the UK. Unless otherwise specified, the wording 'wind power' should be read as meaning 'electricity generated by wind power'.

This report is based on the analysis of published patent application data rather than granted patent data. Published patent application data gives more information about technological activity than granted patent data because a number of factors determine whether an application ever proceeds to grant; these include the inherent lag in patent processing at national IP offices worldwide and the patenting strategies of applicants who may file more applications than they ever intend to pursue.

Throughout this report, patents are counted as either single published patent applications or as patent families depending on the context. A 'patent application' refers to a single patent application made in one jurisdiction and published in that jurisdiction. Patent applications are counted once regardless of the number of subsequent publications. A 'patent family' refers to a group of patent applications made and published in different jurisdictions. Each member of a patent family is considered to relate to the same invention. A patent family is counted once regardless of the number of members or publications it contains.

For this study, the LexisNexis worldwide patent database was interrogated using PatentSight.[9] The data coverage of this database is that of DOCDB, the European Patent Office's (EPO) database.[10]

Throughout this report, reference is made to 'active' patent families. A patent family in PatentSight is defined as active when at least one patent family member is either in the pending stage or 'in force' state. PatentSight updates the legal status of documents held within its database weekly.

[8] https://www.gov.uk/government/publications/promoting-innovation-and-growth-the-ipo-at-work-2020-21/innovation-and-growth-report-2020-21
[9] https://go.patentsight.com/BI2.0/bi/secure/src/resources/documentation/syntax-cheat-sheet/SyntaxCheatSheet.pdf?45be120476a49463f31ebcd79b10b19e
[10] https://www.epo.org/searching-for-patents/data/coverage/weekly.html

1.2 Wind power

Wind power is a rapidly growing renewable energy source[11]. Worldwide, wind energy generation capacity has increased by approximately 75% in the past twenty years, providing 5% of the electricity generated in 2019. In the same year, 19.8% of the UK electricity output derived from wind power

1st century CE: Heron of Alexandria invents the first known wind operated machine (a wind powered organ).[12]

7th-11th centuries CE: wind turbines are used in Asia and Europe to operate water pumps and grind cereals.[13]

1887: Scottish engineer James Blyth builds the first known wind turbine to generate electricity[14], thus powering his holiday home in Marykirk, Aberdeenshire. It has a cloth-sailed, vertical axis design (as opposed to the horizontal one mostly in use today).

1891: Poul la Cour, a Danish scientist and inventor, builds a wind turbine that generates electricity also inventing the Kratostate[15], a regulator which ensures a constant (i.e. not fluctuating) power flow used to drive a generator.

1926: French aeronautical engineer Georges Darrieus files a patent application (granted in 1927) for an electricity-generating vertical wind turbine with aerofoil blades.[16] Modern variants of the turbine described in his patent are still in use today.

1991: the first British commercial wind farm is built at Delabole[17], in Cornwall. It originally uses turbines with conventional fixed angle blades. Newer turbines with more efficient variable pitch blades are introduced between 2009 and 2011.

2000: the first offshore (demonstration) UK wind farm is installed off the Northumberland coast.

2019: the 1.2 GW Hornsea One begins operations off the Yorkshire coast, becoming the largest offshore wind farm in the world.[18]

[11] https://www.irena.org/wind#:~:text=Today's%20new%20wind%20power%20projects,to%202%20MW%20in%202014
[12] https://interestingengineering.com/heron-the-industrial-engineer-long-before-the-industrial-age
[13] https://www.renewableenergyworld.com/2014/11/21/history-of-wind-turbines/#gref
[14] https://www.ed.ac.uk/alumni/services/notable-alumni/alumni-in-history/james-blyth
[15] https://repository.ihu.edu.gr/mwg-internal/de5fs23hu73ds/progress?id=DSyAflEjiiJxyYuLl0AWR5osxlrEqA9jhR77l7KiQBs
[16] http://www.wind-works.org/cms/index.php?id=715
[17] https://www.goodenergy.co.uk/our-energy/our-wind-farms/delabole-wind-farm/
[18] https://hornseaprojectone.co.uk/about-the-project#0

2. Wind power

2.1 Worldwide patent landscape

Figure 1 shows the number of active patent families (16,916), filed in all countries, between 2001 and 2018. Data are grouped by the earliest priority year for each patent family. Priority year refers to the year in which the first priority is claimed for a patent family, if no priority is claimed, the date when the first patent in the family has been filed is used. A clearly increasing trend can be seen. The technologies covered by these patents may be wind energy-specific (such as wind turbine blades, as in EP2358998), or may describe technologies which can also be used for wind power (for instance optimization of power grids, as in US2010/0179704).

Figure 1: Number of active wind power patent families, grouped by priority (first filing) year, 2001-2018

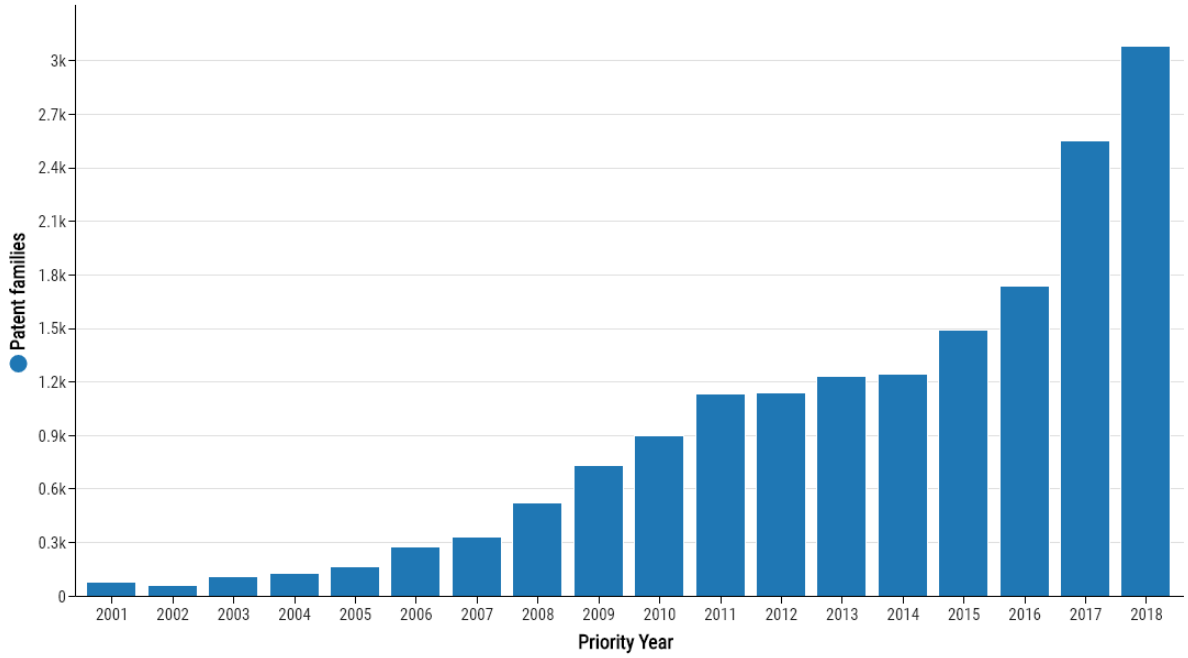
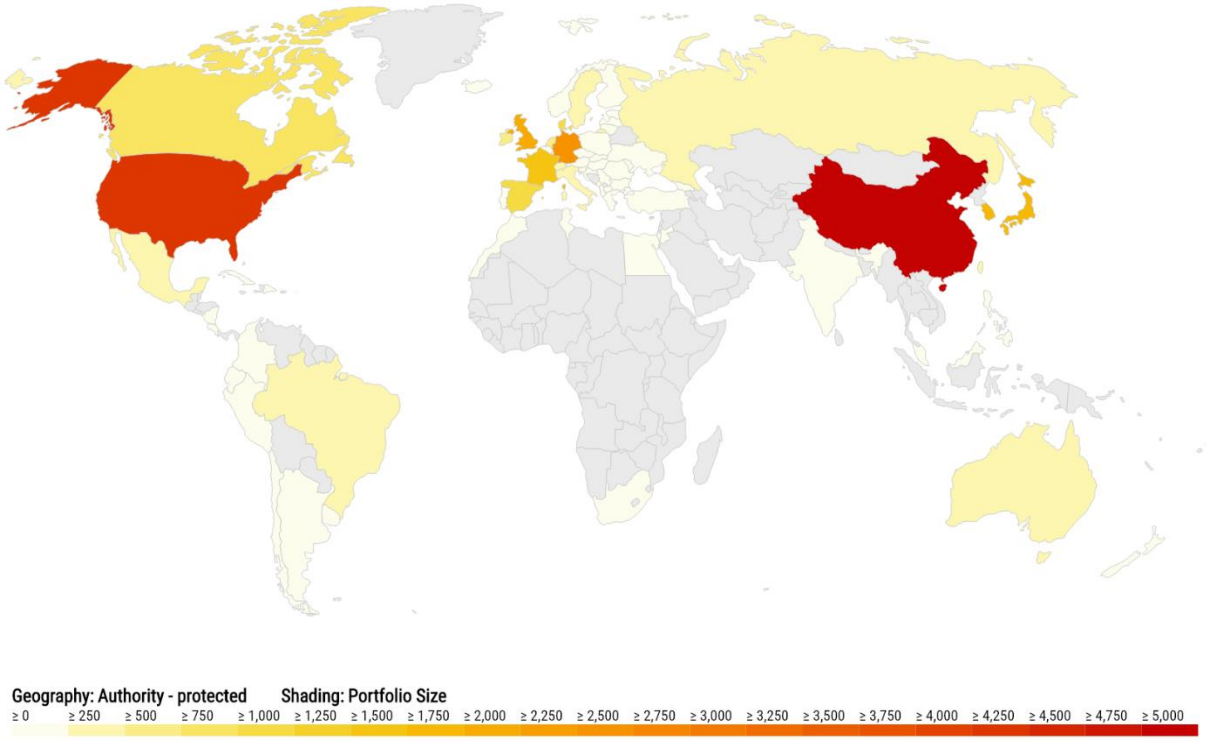


Figure 2 shows where wind power patents are being protected. From this map, we can see that China stands out clearly, followed by the US. After these countries, Japan. South Korea and European nations are the next most popular.

Figure 2: World map showing where wind power patents are being protected, 2001-2018



Using the Relative Specialisation Index (RSI) can help to account for the fact that some countries file more patent applications than others in all fields of technology. The RSI compares the fraction of a country's technology-specific patents, out of all of its patents across all fields of technology, with the corresponding fraction of technology-specific patents worldwide.

Table 1: Relative Specialisation Index (RSI) of top 10 patenting countries for wind power patents, 2001-2018

Country	Relative Specialisation Index
India	0.319
China	0.153
United Kingdom	**0.128**
Australia	0.119
France	0.078
Canada	0.059
South Korea	-0.016
Germany	-0.010
USA	-0.176
Japan	-0.451

Table 1 looks at where patent applications originate from. It shows the Relative Specialisation Index (RSI)[19] of the top 10 patenting countries for wind power. The UK here shows a value higher than zero, suggesting that UK-based inventors are producing more wind power patents than you would expect given the absolute levels of patenting within the UK. India has the highest RSI value, suggesting that they are also producing more wind power patents than you would expect given the absolute levels of patenting within India.

Figure 3: Top 20 owners of active wind power patent families, 2001-2018

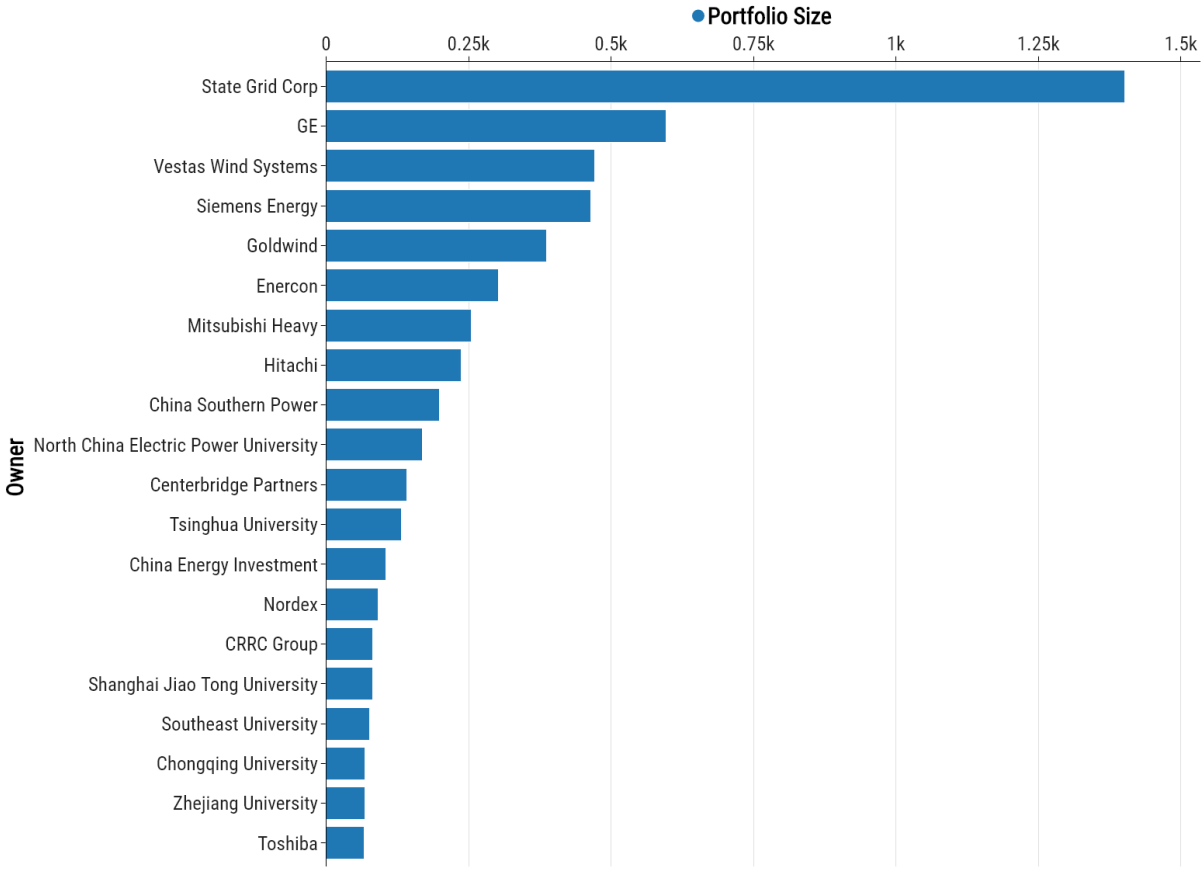


Figure 3 shows State Grid Corporation (China) has by far the largest patent portfolio in this field, followed by General Electric (US) and Vestas (Denmark). There also appear to be a number of Chinese Universities that appear to have active patent families in this field. 34% of patents relating to wind power are owned by these 20 owners.

[19] See Appendix C for details of how the Relative Specialisation Index (RSI) is calculated

Figure 4: Bubble chart showing number of active wind power patent families per year, grouped per owner, 2001-2018

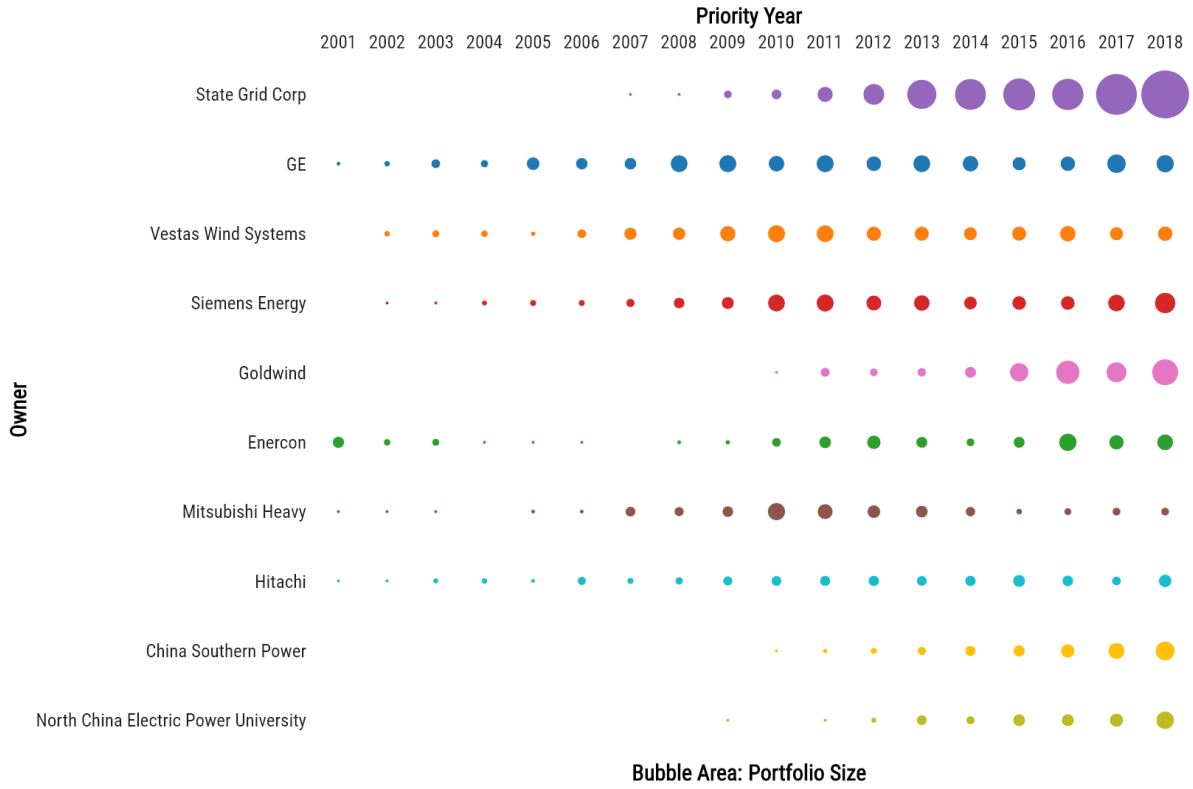
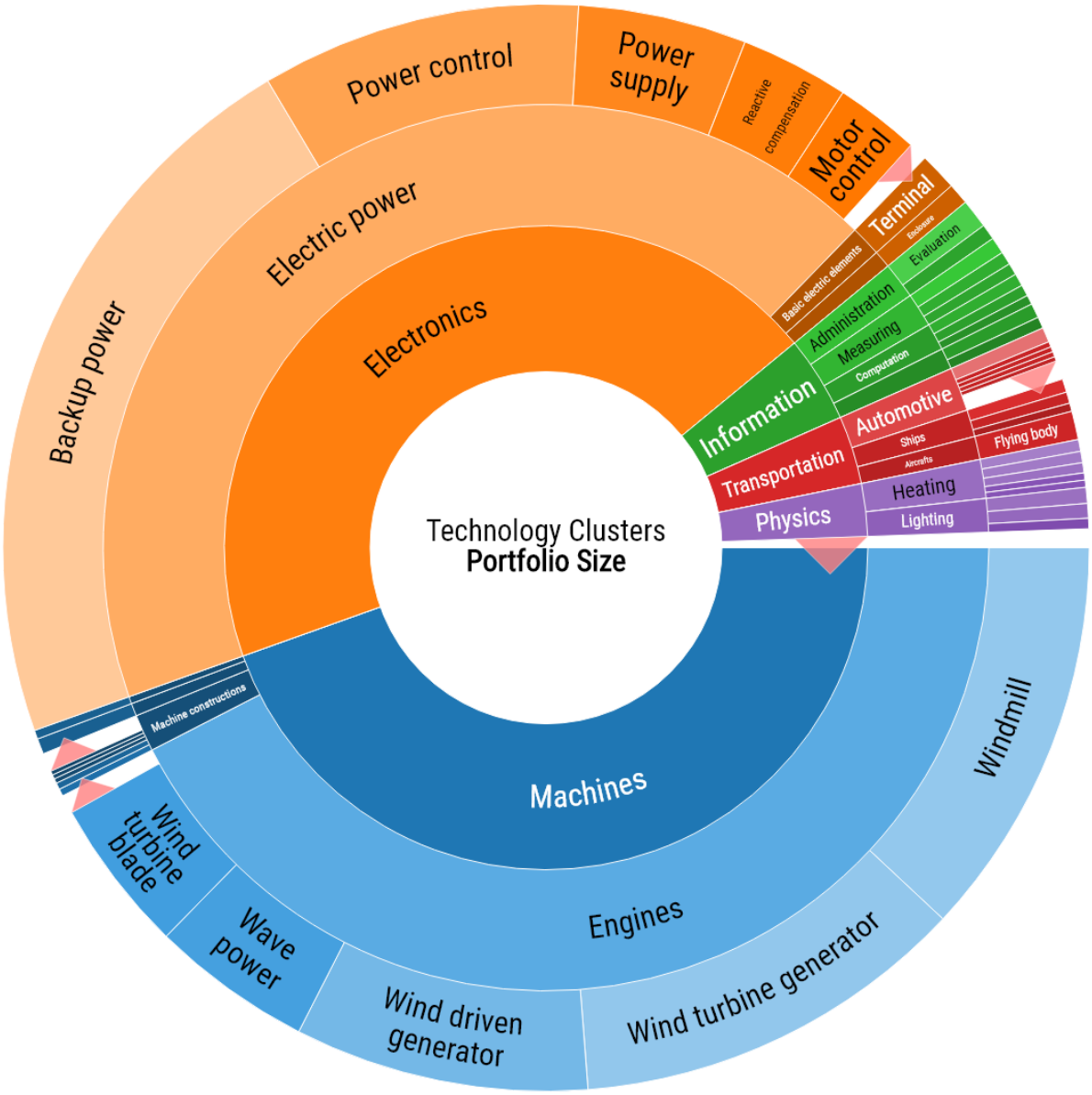


Figure 4 shows how the patent portfolios of the top 10 owners has changed from 2001-2018. From this we can see notable increases for State Grid Corporation and Goldwind, another Chinese company.

Figure 5: Sunburst chart showing technology clusters of wind power patents, 2001-2018

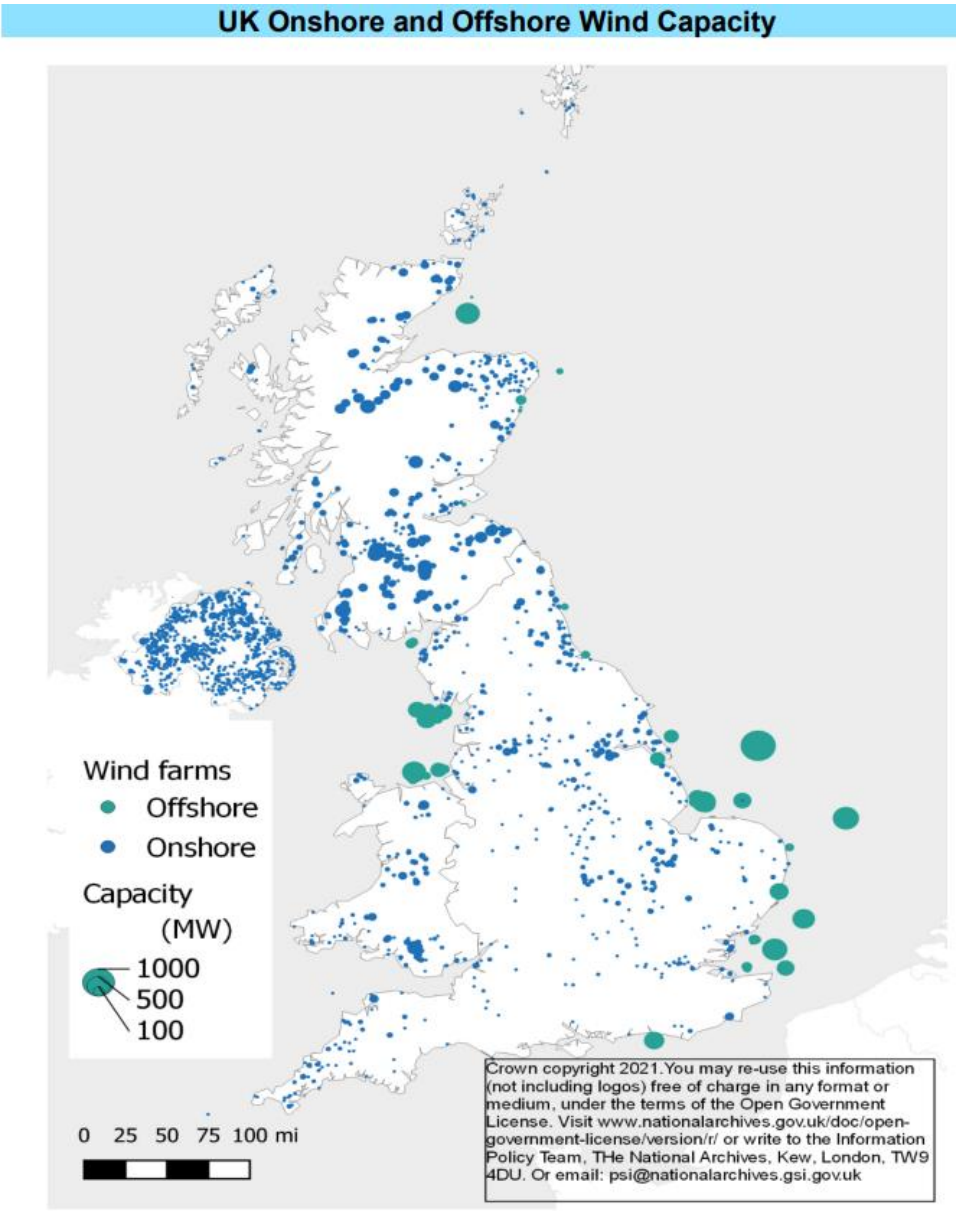


Sunburst charts provide a quick and intuitive understanding of a technology area, including the categories of inventions that are protected and in what proportions. Figure 5 shows an equal split between machines and electronics as high-level technology breakdowns. Backup power appears to make up a substantial portion of patents, with 15.4% of patents related to this.

2.2 UK patent landscape

In 2018, the UK had 38 operational wind farms.[20] In 2019, the overall electricity generated by the UK was 332.9 TWh[21]. Of this, 32.2 TWh was produced by onshore wind power, and 32.1 TWh generated by offshore wind power.

Figure 6: UK map showing distribution of wind farms within the UK, taken from BEIS 'UK Energy in Brief, 2021' 22



[20] https://www.nsenergybusiness.com/features/offshore-wind-power-europe-uk/
[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904503/UK_Energy_in_Brief_2020.pdf
[22] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1016822/UK_Energy_in_Brief_2021.pdf#:~:text=UK%20Energy%20in%20Brief%20aims%20to%20provide%20a,in%20which%20energy%20use%20influences%20greenhouse%20gas%20emissions.

Figure 7: Number of wind power patents which are active in the UK, grouped by priority (first filing) year, 2001-2018

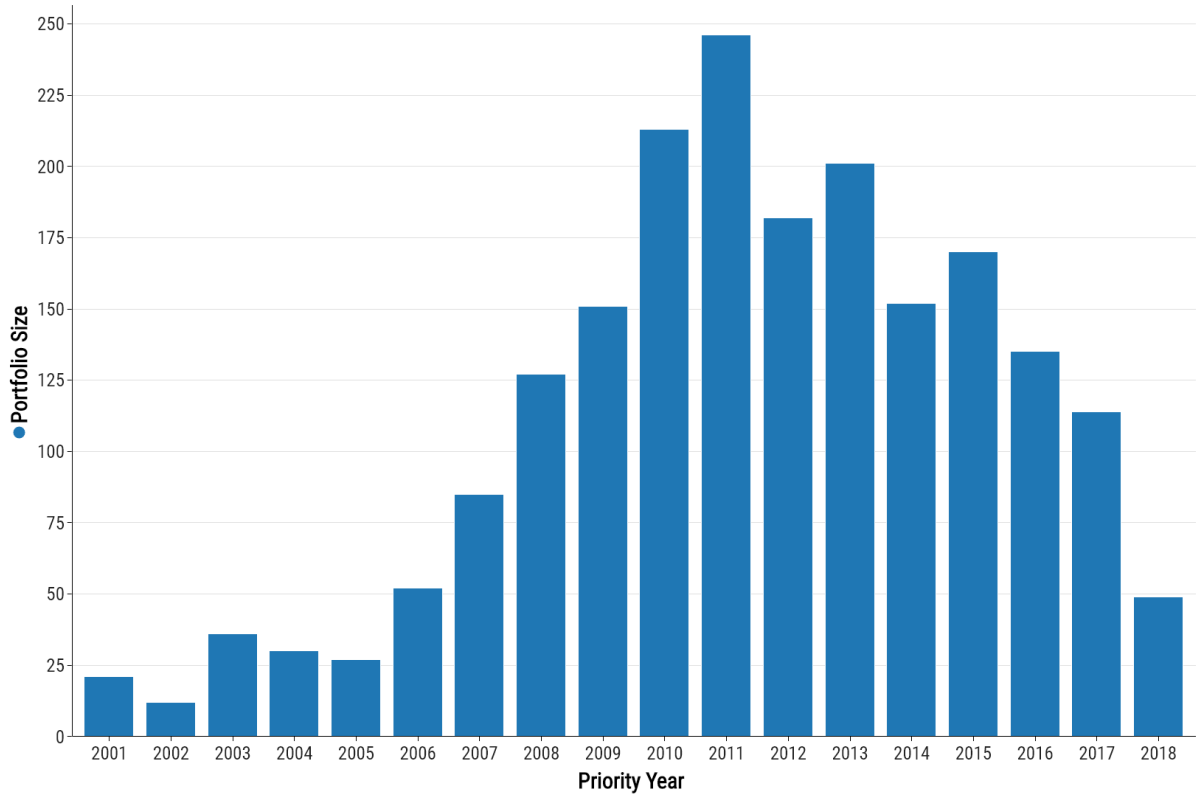
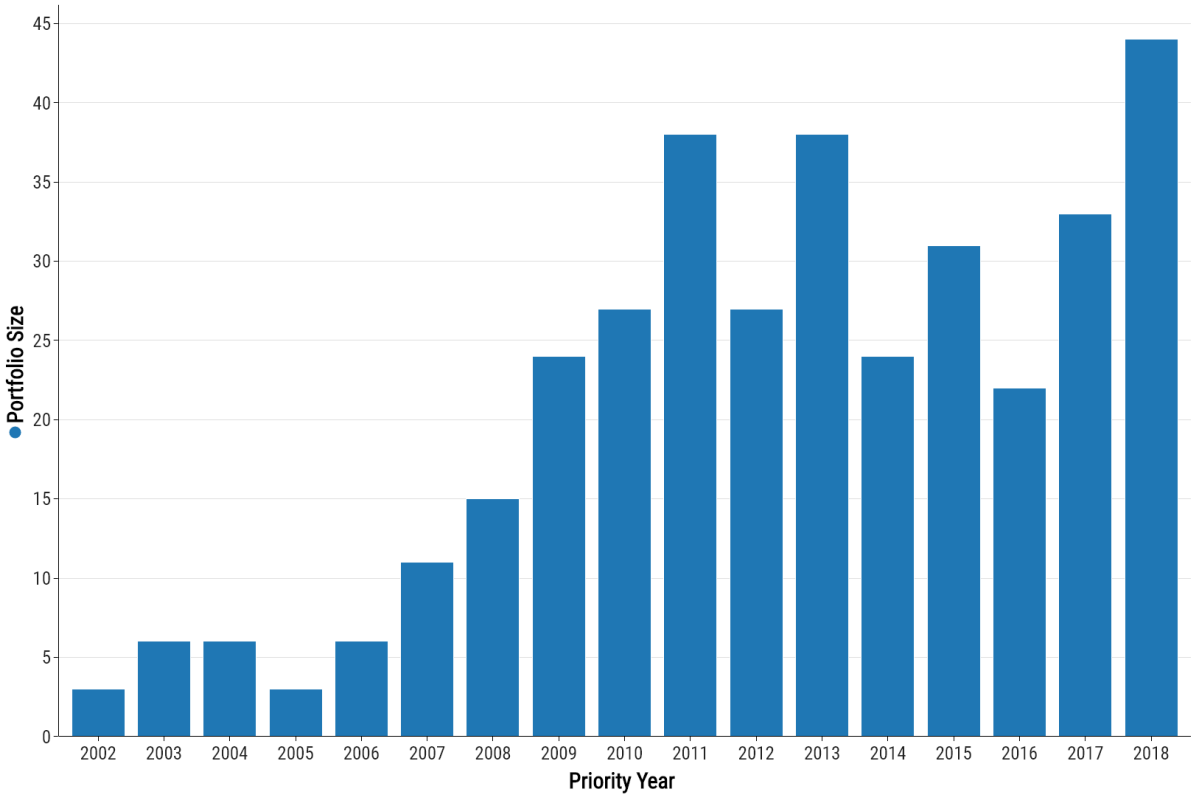


Figure 7 shows the number of wind power patents active in the UK (2,045). The number of active patent families filed each year appears to have increased significantly up to 2011, after which there seems to have been a decline.

Figure 8: Number of wind power patents which were invented in the UK, grouped by priority year, 2001-2018



In Figure 8, above, active patent families (358 patent families) per priority year are depicted, but this time filtered by having at least one inventor in the UK. There was an increase in the number of active patent families filed each year from 2005-2011. The growth in the number of active patent families with at least one UK inventor has remained relatively steady from this point onwards, and there is no decrease in this chart in contrast to Figure 7.

Figure 9: Top 10 owners of wind power patents active in the UK, 2001-2018

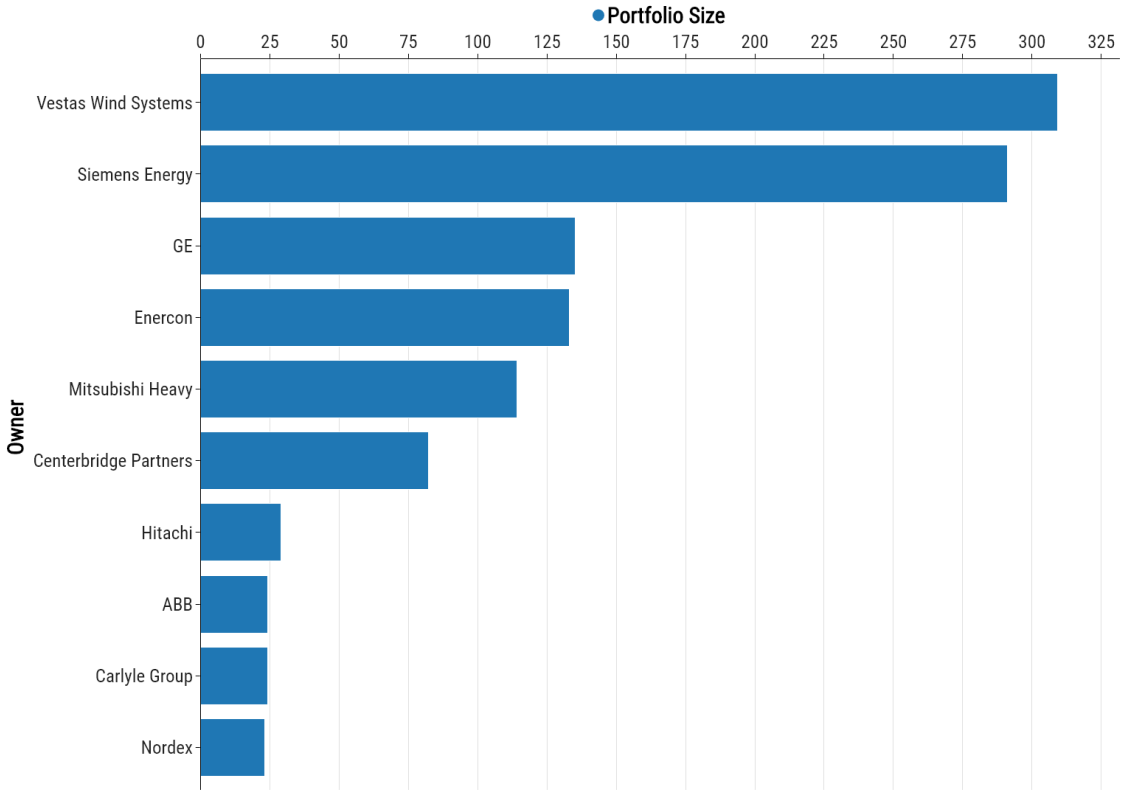


Figure 9 above shows who the top 10 owners of patents active in the UK which have a priority year from 2001-2018. Between them, these top 10 owners own 58% of the patents active in the UK in this area. It is clear that Vestas and Siemens have around double the number of patents active in the UK compared to other owners.

3. Offshore wind power

This section focuses specifically on offshore wind power, as opposed to wind power in general.

3.1 Worldwide patent landscape

Figure 10: Number of active offshore wind power patent families worldwide, grouped by priority (first filing) year 2001-2018

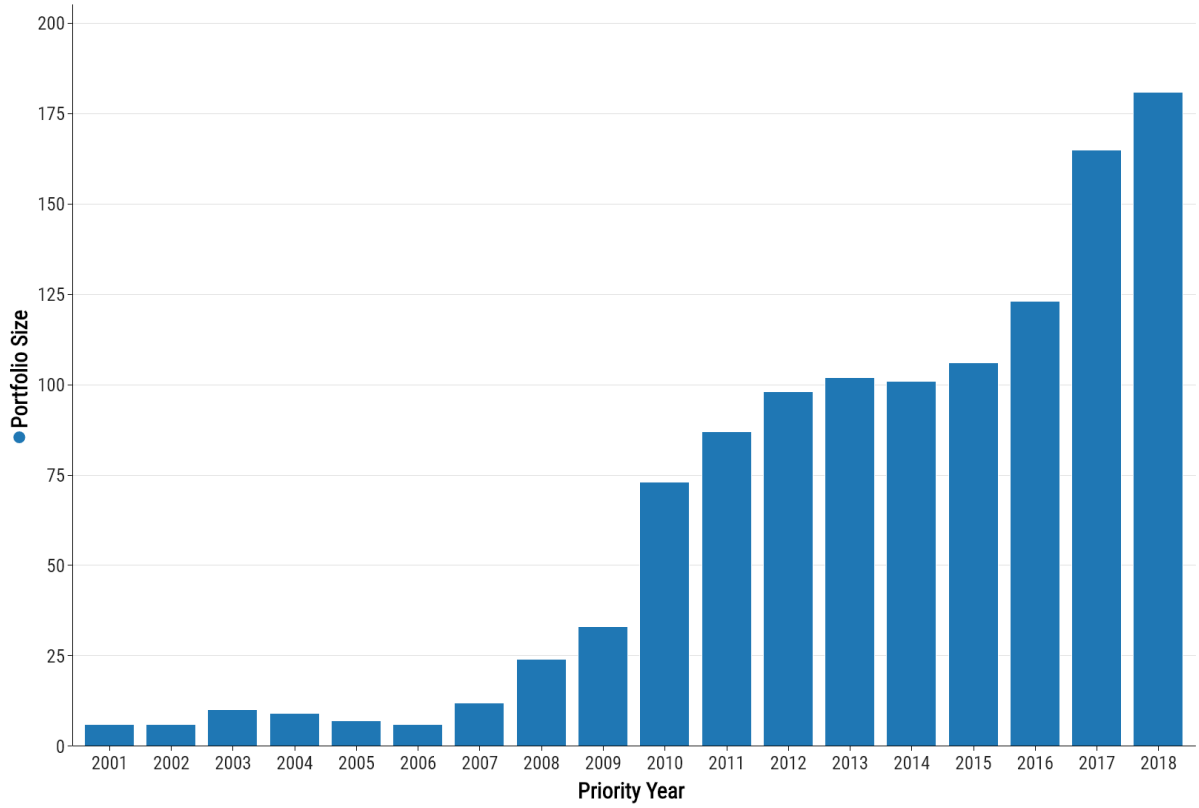


Figure 10 shows how the number of active patent families being filed each year (1149 in total) relating to offshore wind power increased from 2007-2010, before plateauing for some years. In more recent years (2016-2018), the number of active patent families being filed per year appears to have greatly increased once more. There was a 70% increase in the number of patent families being filed each year in 2018 compared to 2015. The timing of this increase is interesting, since it may be indicative of an increase in patenting activity that could have resulted following the Paris Agreement.[23]

[23] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Figure 11: World map showing where offshore wind power patents are being protected, 2001-2018

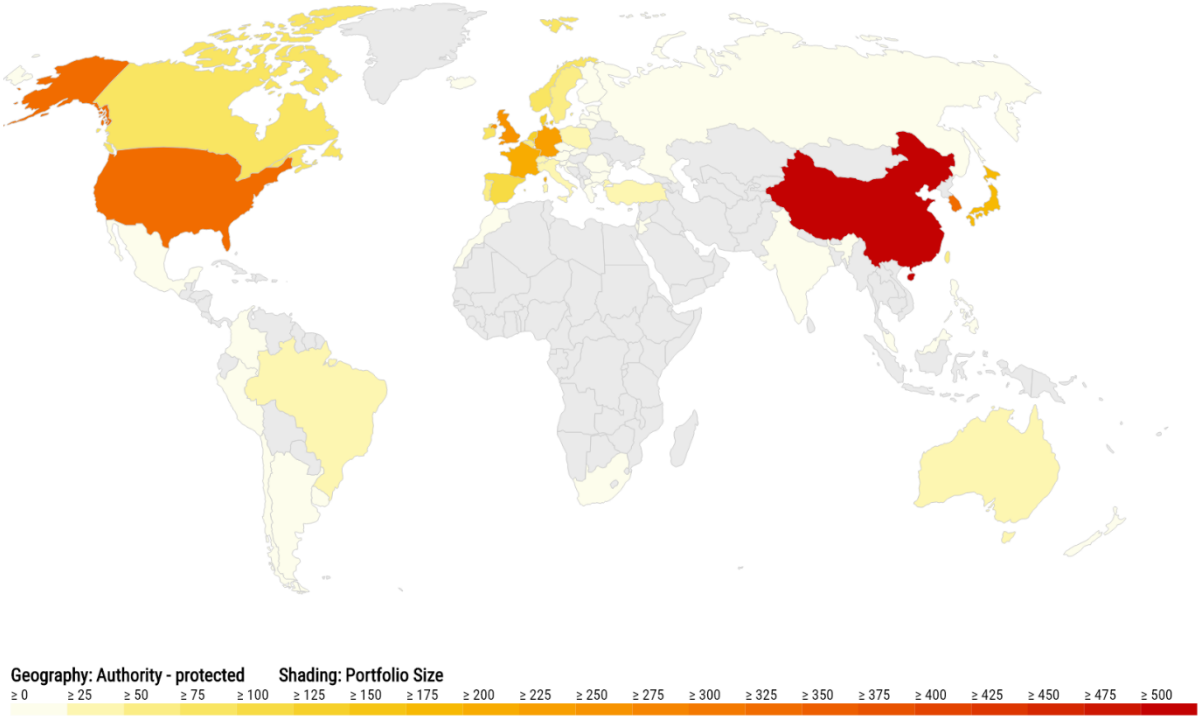


Figure 11 shows that there are more active patents in China compared to other countries. The US also appears to have more active patent families compared to other countries. This map is broadly reflective of wind power patents in general.

Table 2: Relative Specialisation Index of top 10 patenting countries for offshore wind power patents, 2001-2018

Country	Relative Specialisation Index
United Kingdom	**0.553**
France	0.445
South Korea	0.363
India	0.286
Australia	0.159
China	-0.009
Germany	-0.160
USA	-0.240
Canada	-0.357
Japan	-0.430

Table 2 shows the RSI values for the top 10 patenting countries, relating to offshore wind power. This table shows the UK has the highest RSI out of these countries, indicating it is showing the UK produces more patents in this field compared to what would be expected due to absolute patenting levels in this country.

Figure 12: Top 20 owners of offshore wind power patents, 2001-2018

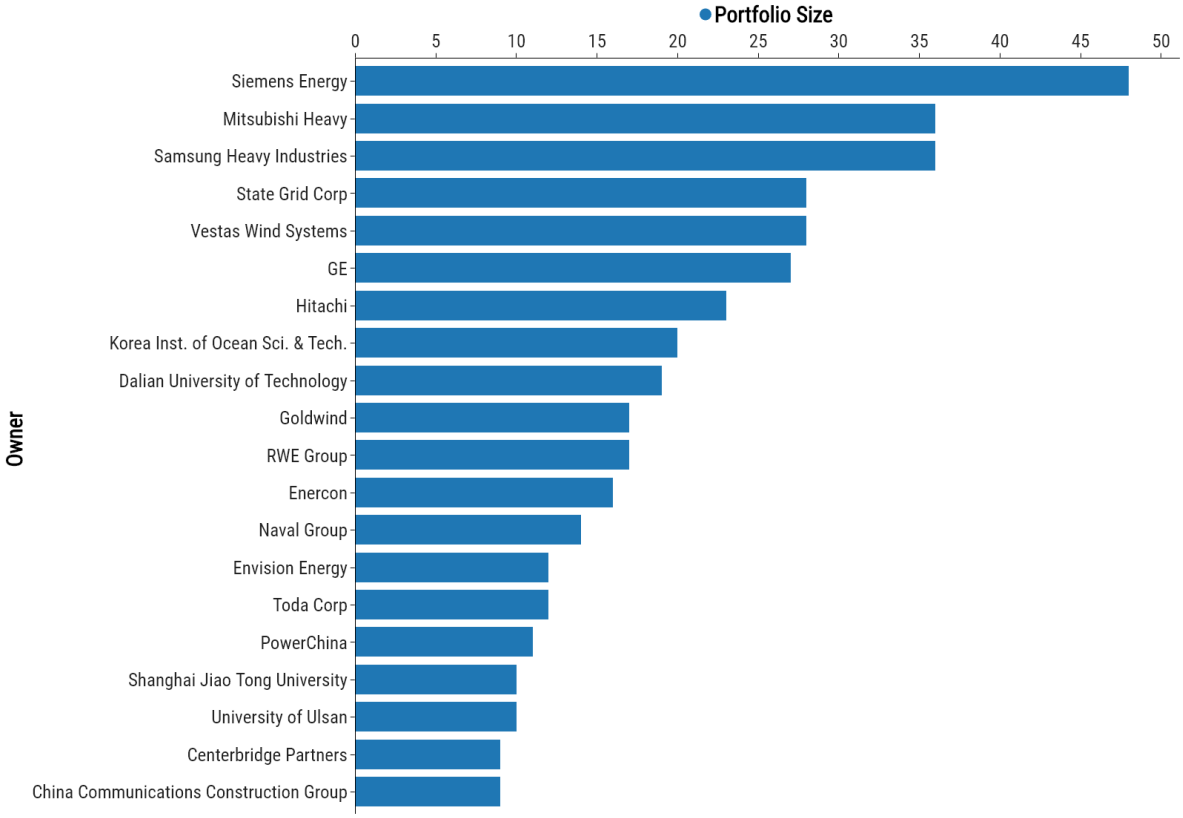


Figure 12 shows how the total number of active patent families relating to offshore wind power appears to be more evenly distributed compared to wind power in general, without a single owner having a portfolio larger than 50 patents in this field. 35% of patents relating to offshore wind power are owned by the top 20 owners.

Figure 13: Number of active offshore wind power patent families per owner, grouped by priority (first filing) year, 2001-2018

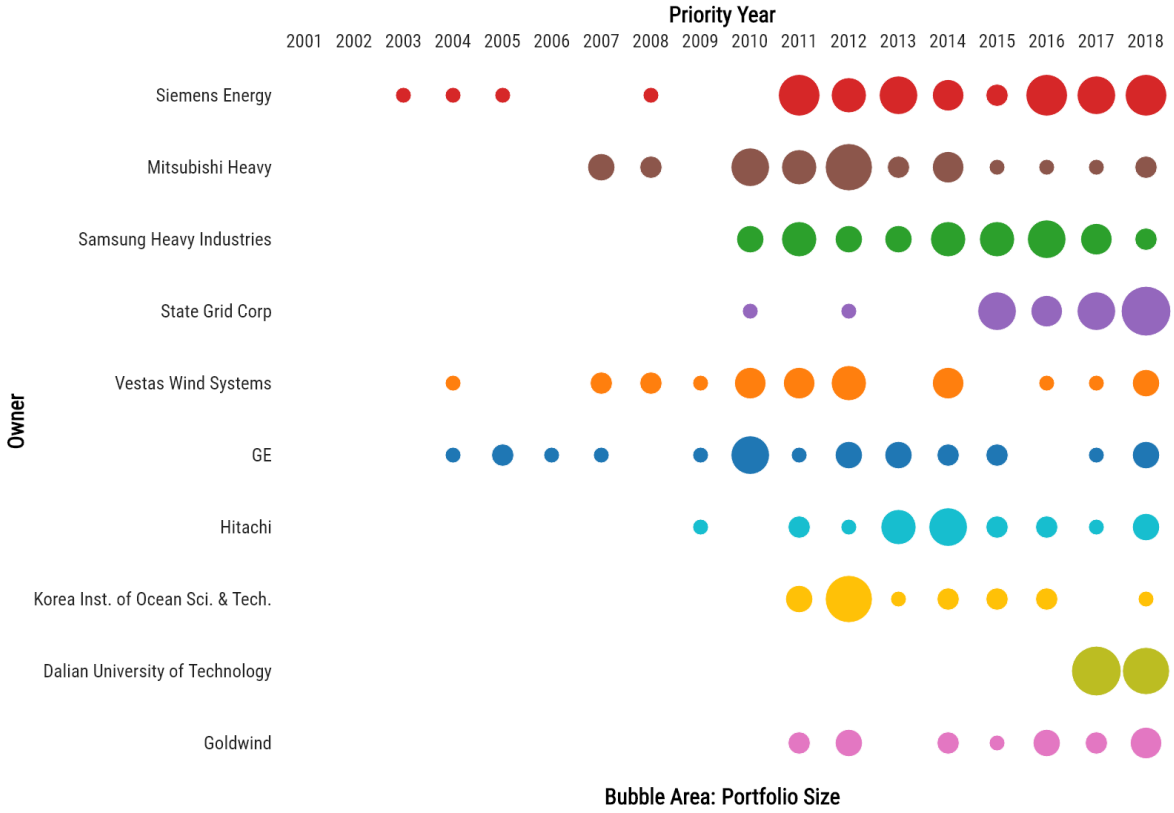
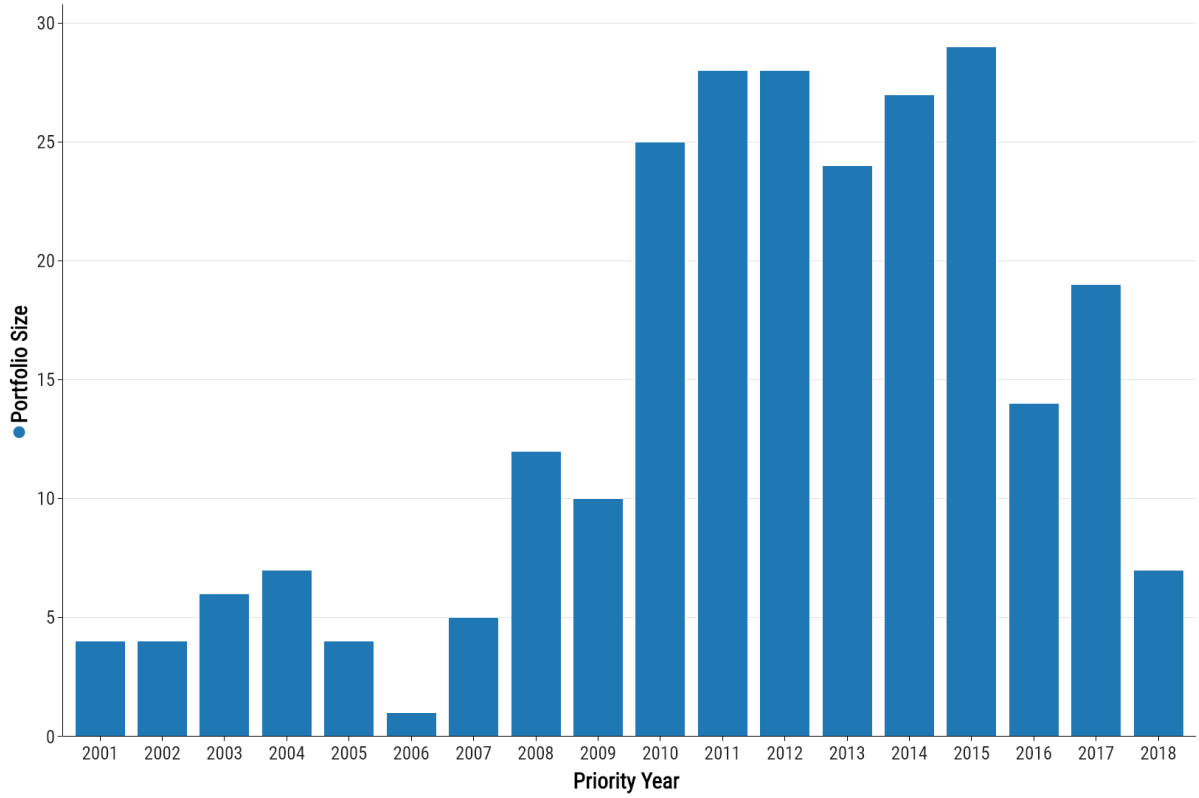


Figure 13 shows how the number of active patent families has varied with different owners from 2001-2018. It is clear that a number of owners had no active patent families in this area in earlier years. Activity on the whole appears to have increased from 2010 onwards, whereas GE and Vestas both had some patents relating to offshore wind power in 2004.

3.2 UK patent landscape

The UK is reported to be the global leader in offshore wind, with more capacity installed than any other country.[24] As of 2020, UK's offshore wind capacity is estimated to be in the region of 10.4GW,[25] and offshore wind power accounted for 13% of the UK's total electricity generation in 2020.[26]

Figure 14: Number of offshore wind patent families active in the UK, grouped by priority (first filing) year, 2001-2018



Looking at Figure 14, the number of active patent families filed each year (254 in total) significantly increased from 2009-2010. The number of patents active in the UK is relatively small, making changes appear more pronounced on this chart. There appears to have been a decrease in the number of active patent families being filed from 2016 onwards, broadly reflecting the reduced growth rate seen in wind power patents in general.

[24] https://www.ge.com/renewableenergy/en/uk/offshore-wind
[25] https://gwec.net/global-wind-report-2021/
[26] https://www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021

Figure 15: Number of offshore wind power patents invented in the UK, 2002-2018

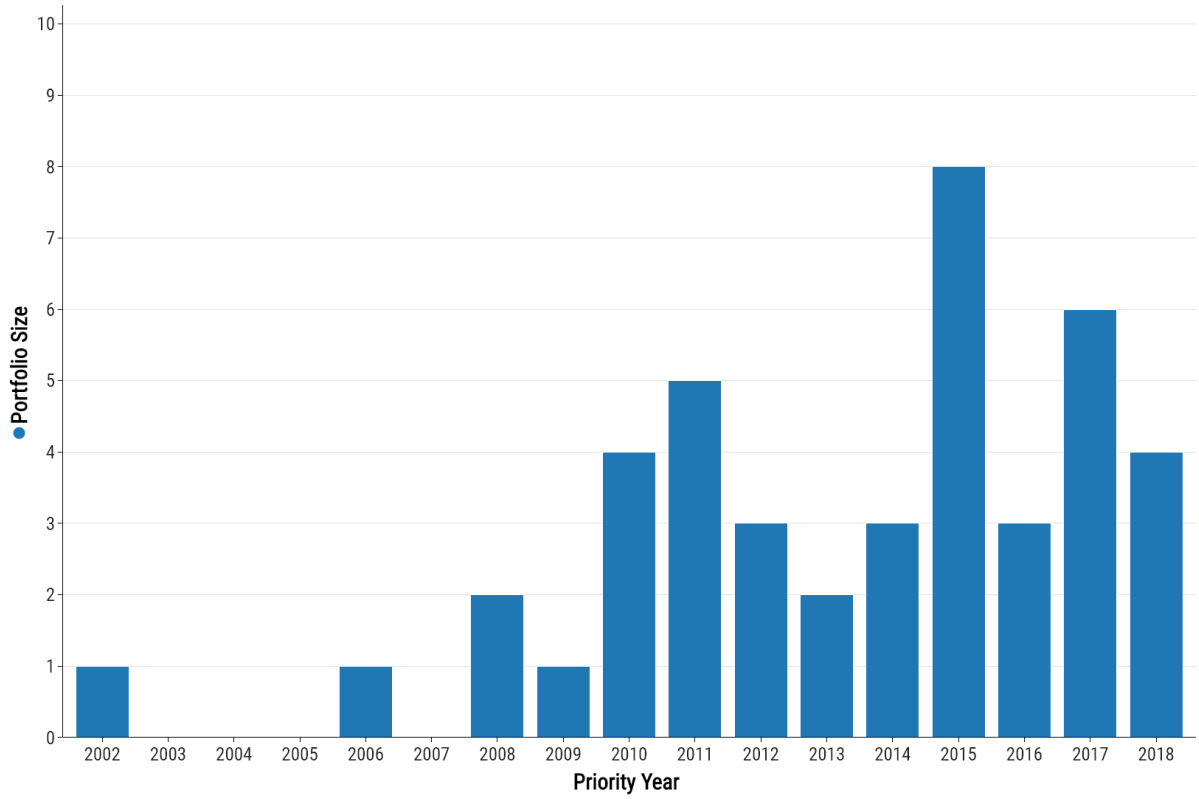


Figure 15 shows the number of offshore wind power patents invented in the UK (43), grouped by priority year. The relative number of active patents is relatively low per year compared to wind power in general. This creates a challenge in determining a pattern when considering patents invented in the UK, however, there seems to have been a peak in patenting activity in 2015. These patents were invented by a range of different companies, including Offshore Renewable Energy Catapult Ltd, Wind Farm Analytics Ltd and First Subsea Ltd.

Figure 16: Top 10 owners of offshore wind power patents active in the UK, 2001-2018

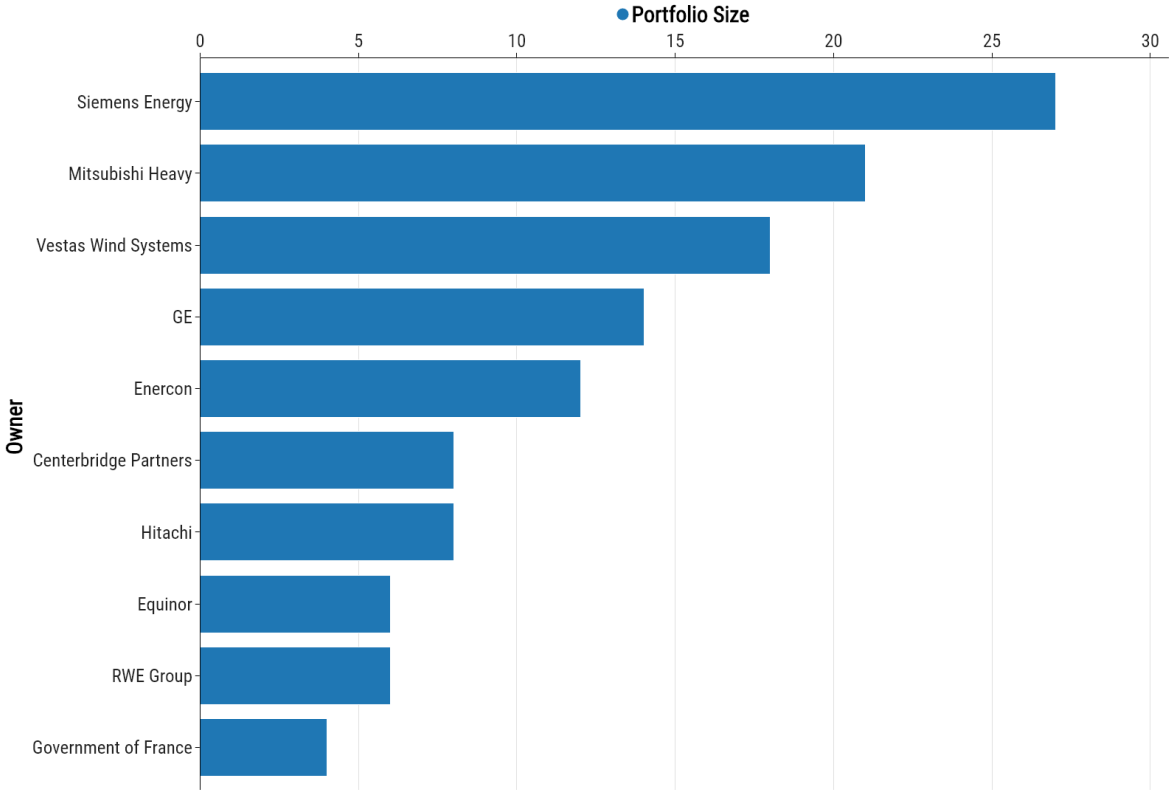


Figure 16 shows how the top owners of offshore wind patents which are active in the UK broadly reflect worldwide trends, where patents appear to be owned by a range of various companies. Siemens Energy has the most patents in this field which are active in the UK, whilst the French government also appear to have a stake in some patents active in the UK. 48% of offshore wind patents active in the UK are owed by these top 10 owners.

4. Case study: Vestas

Vestas is a Danish transnational company, specialising in wind turbines.[27] MHI Vestas Offshore Wind was founded as a joint venture with Mitsubishi Heavy Industries. From a UK perspective, there is a wind turbines and blades technology research unit at Newport (Isle of Wight). From a technological standpoint, in addition to wind turbine components, Vestas also holds patents which relate to the control of wind power plants such as EP3400384. A technically interesting innovation is disclosed in patent application GB2526795, describing wind turbine blades incorporating radar-absorbing material. The technical problem to overcome is the fact that moving rotor blades can exhibit a radar signature similar to moving aircraft, which can be problematic for air traffic control.

[27] https://www.vestas.com/

5. Conclusions

Wind power has seen an increase in worldwide patenting activity between 2001 and 2018. This trend does not appear to be reflected in the UK. The most prolific patent filers worldwide are the State Grid Corporation (China) - by far the largest operator - followed by General Electric (US) and Vestas (Denmark).

The Relative Specialisation Index (RSI) values for wind power show that the UK is slightly more specialised in this field compared to other European nations. Vestas and Siemens Energy are the most prolific owners of patent families active in the UK. There also appears to be a fairly steady number of patents invented in the UK in recent years.

Focusing on offshore wind power, the observed trends are similar to the ones observed for overall wind power, with an increase in worldwide patenting trends. On a global stage, Vestas and Siemens Energy dominate, closely followed by General Electric. In the UK, Siemens Energy, Vestas and Mitsubishi Heavy dominate the landscape, closely followed by General Electric. The UK also appears to be more highly specialised in offshore wind power related patents compared to wind power patents in general. Of the top 10 patenting countries, the UK also has the highest RSI in relation to offshore wind power.

The UK government plans to quadruple the country's offshore wind capacity by 2030 and aims to be producing 40GW of power from this. As part of this plan, the government hopes to develop floating offshore wind capabilities. The patent family of EP3797068A1, owned by UK company Floating Energy Systems[28] relates to this area, and more activity relating to floating offshore technology may be seen in future.

[28] http://floatingenergysystems.com

Appendices

Appendix A – Search strategy

For this study, the LexisNexis worldwide patent database was interrogated using PatentSight[29].

A.1 Wind power

(CPC=(F03D, H02J, H02P, Y02E 10/70) OR IPC=(F03D, H02J, H02P)) AND TitleAbstractClaims=((*eolic* OR wind) AND *electric*) AND PriorityDate=(2001-01-01 TO 2018-12-31)

A.2 Offshore wind power

(CPC=(F03D, H02J, H02P, Y02E 10/70) OR IPC=(F03D, H02J, H02P)) AND TitleAbstractClaimsDescription=((*eolic* OR wind) AND *electric*) AND PriorityDate=(2001-01-01 TO 2018-12-31) AND TitleAbstractClaims=(off_shore)

Appendix B – Classification Definitions

F03D	Wind motors
H02J	Circuit arrangements or systems for supplying or distributing electric power; systems for storing electric energy.
H02P	Control or regulation of electric motors, electric generators or dynamo-electric converters; controlling transformers, reactors or choke coils.
Y02E10/70	Wind energy

[29] https://go.patentsight.com/BI2.0/bi/secure/src/resources/documentation/syntax-cheat-sheet/SyntaxCheatSheet.pdf?45be120476a49463f31ebcd79b10b19e

Appendix C – Relative Specialisation Index

Relative Specialisation Index (RSI) was calculated to account for the fact that some countries file more patent applications than others in all fields of technology. In particular US, Chinese and Japanese applicants and inventors are prolific patentees.

The RSI compares the fraction of a country's technology-specific patents, out of all of its patents across all fields of technology, with the corresponding fraction of technology-specific patents worldwide.

A logarithm is applied to scale the fractions more suitably; an RSI of zero then represents a country that is no more or less specialised than the worldwide average.

The Relative Specialisation Index (RSI) for country c in technology t is defined as:

$$RSI_{c,\,t} = \ln\left(\frac{n_{c,t}/n_t}{N_c/N}\right)$$

where:

$n_{c,t}$ = number of patents for country c in technology t
n_t = sum of patents in all countries in technology t
N_c = number of patents for country c
N = sum of patents for all countries.

A value above positive indicates that a country has a higher specialisation in this field than would be expected, whilst a negative value indicates a lower specialisation than expected for that country.

Concept House
Cardiff Road
Newport
NP10 8QQ

Tel: 0300 300 2000
Email: information@ipo.gov.uk
Web: www.gov.uk/ipo

Facebook: TheIPO.UK
Twitter: @The_IPO
YouTube: ipogovuk
LinkedIn: uk-ipo

For copies in alternative formats please contact our Information Centre.

When you no longer need this booklet, please recycle it.

Published: March 2021