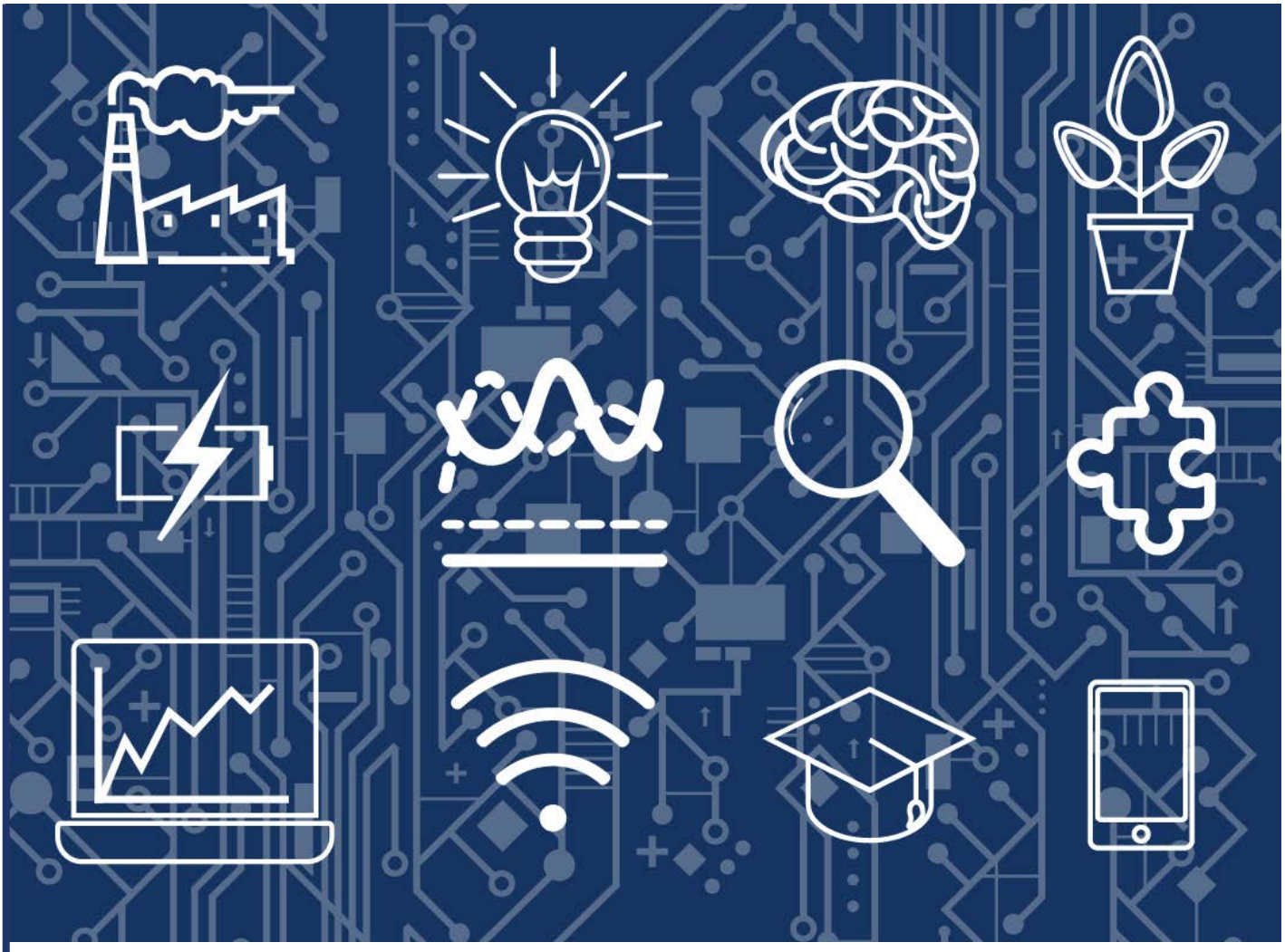
Intellectual Property Office

Carbon capture, usage and storage

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: 978-1-915090-16-4
Carbon capture, usage and storage
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.

---

[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

- **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.

- **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 may play a role in helping to achieve carbon net zero[8] and innovation may be reflected in patenting trends. Hence, this report is part of a series of studies relating to the technologies covered within the government's ten point plan for a green industrial revolution. This report analyses the worldwide patent landscape related to carbon capture and storage (CCS) and carbon capture, usage and storage (CCUS) technologies.

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 either as 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 Carbon Capture, Usage and Storage (CCUS)

Carbon capture and storage (CCS) is the process of capturing carbon dioxide before it enters the atmosphere and storing (or sequestering) it long-term. A slightly different process is the capture of carbon dioxide, and its recycling for further usage. This is termed carbon capture and utilisation/usage (CCU). Carbon capture, usage and storage (CCUS) is a combination of both of these processes, where carbon dioxide is captured, used and any unused carbon is then stored.

The UK aims to become a global leader in CCUS, and aims to deploy CCUS at scale in the 2030s.[11] To facilitate this, the government has invested over £130 million in R&D and innovation to develop CCUS in the UK.[12]

The purpose of CCUS technology is to capture carbon dioxide before it enters the atmosphere, and as a result reduce the amount of CO_2 entering the atmosphere in an attempt to slow global warming. Finding a use for the captured carbon reduces some of the challenges involved in sequestration of carbon. The recycling of this carbon can allow carbon neutrality of the production processes.

Currently there are a number of advanced of advanced CCUS proposals in the UK, spread across major industrial regions, including Scotland, Teesside, Yorkshire and Humber, the North West and South Wales. Notably, the projects in the Humber region aim to be capable of capturing over 40 million tonnes of carbon dioxide per year.[13,14]

[11] The UK Carbon Capture Usage and Storage deployment pathway: an action plan (publishing.service.gov.uk)
[12] UK carbon capture, usage and storage - GOV.UK (www.gov.uk)
[13] CCUS in Action - CCSA (ccsassociation.org)
[14] The Vision | Zero Carbon Humber

2. Carbon Capture and Storage (CCS)

2.1 Worldwide patent landscape

This section looks at the filing trends of patents relating to CCS. Firstly, this report investigates the global landscape, before investigating the UK specific landscape.

Figure 1 shows the total number of active patent families (7441) from 2001-2018. From this, we can see a significant increase in the number of active patent families filed each year, with nearly a four-fold increase from 2008 to 2018. This is indicative of a growing sector.

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

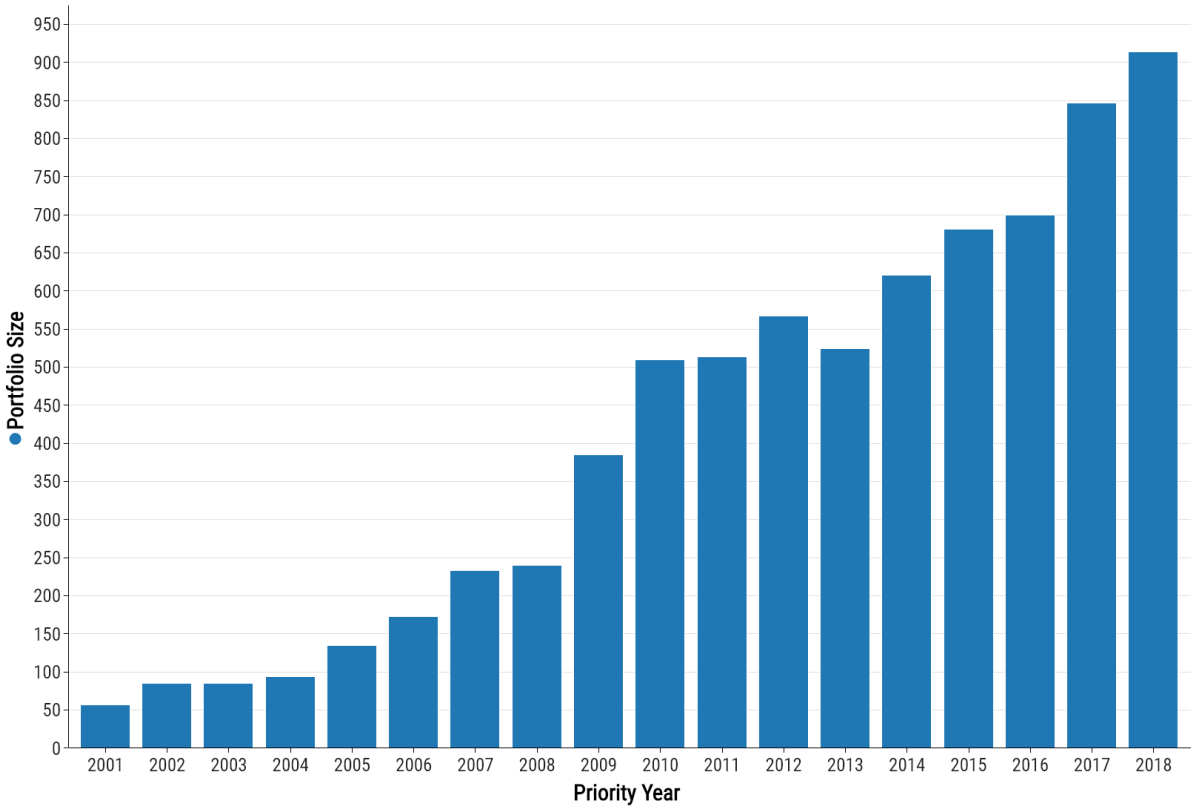


Figure 2 shows where CCS patent families are being protected. China and the US feature heavily here, with notable activity in Europe, Australia and Canada, as well as in South Korea and Japan.

Figure 2: World map showing where active CCS patent families are being protected, 2001-2018

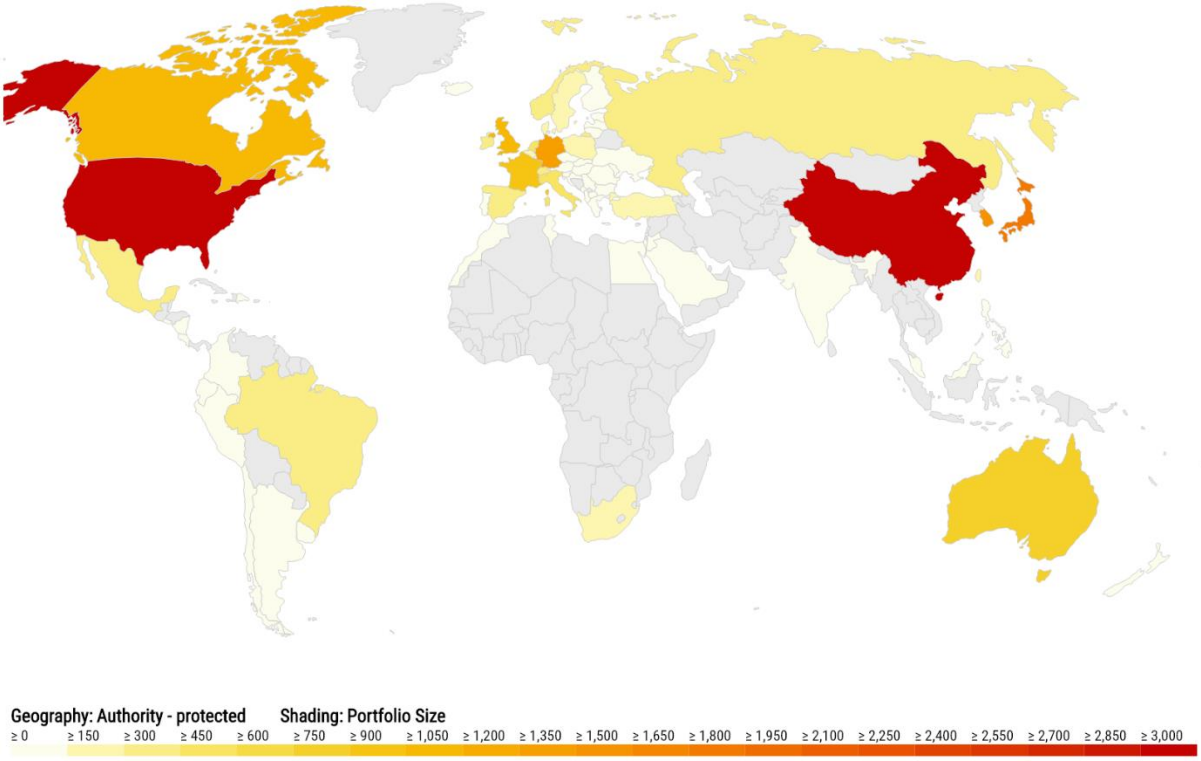


Figure 3: World map showing where CCS patents are being invented, 2001-2018

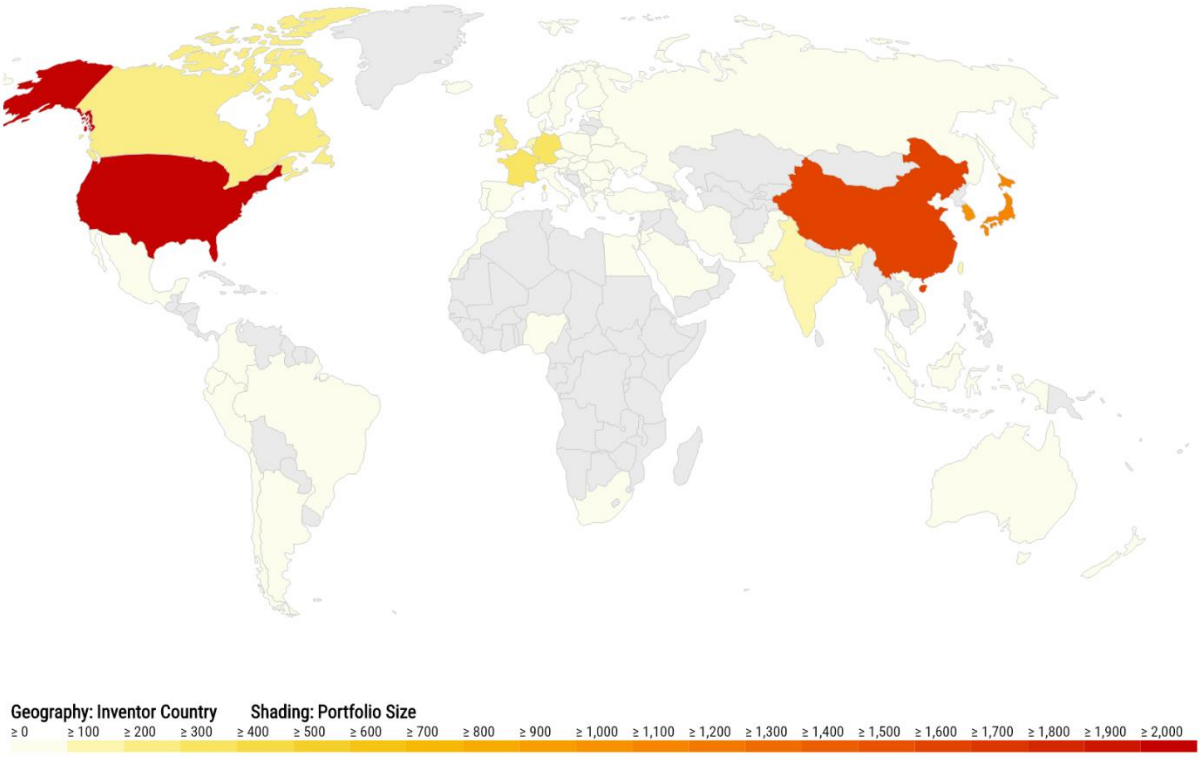


Figure 3 looks at where CCS patents are being invented, and is dominated by the US and China.

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 selected nations for CCS patents, 2001-2018

Country	Relative Specialisation Index
Australia	0.782
Canada	0.633
United Kingdom	**0.238**
France	0.215
India	0.166
USA	0.124
South Korea	0.059
China	-0.184
Germany	-0.221
Japan	-0.247

Table 1 shows the Relative Specialisation Index (RSI)[15] of the top 10 patenting countries for CCS. It shows that Australia is the most specialised country for CCS related technologies. A value of above zero for the UK indicates that the UK is more specialised in this filed since it is producing more patents compared to what would be expected given the absolute levels of patenting within the UK.

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

Figure 4: Top 20 owners of CCS patents, 2001-2018

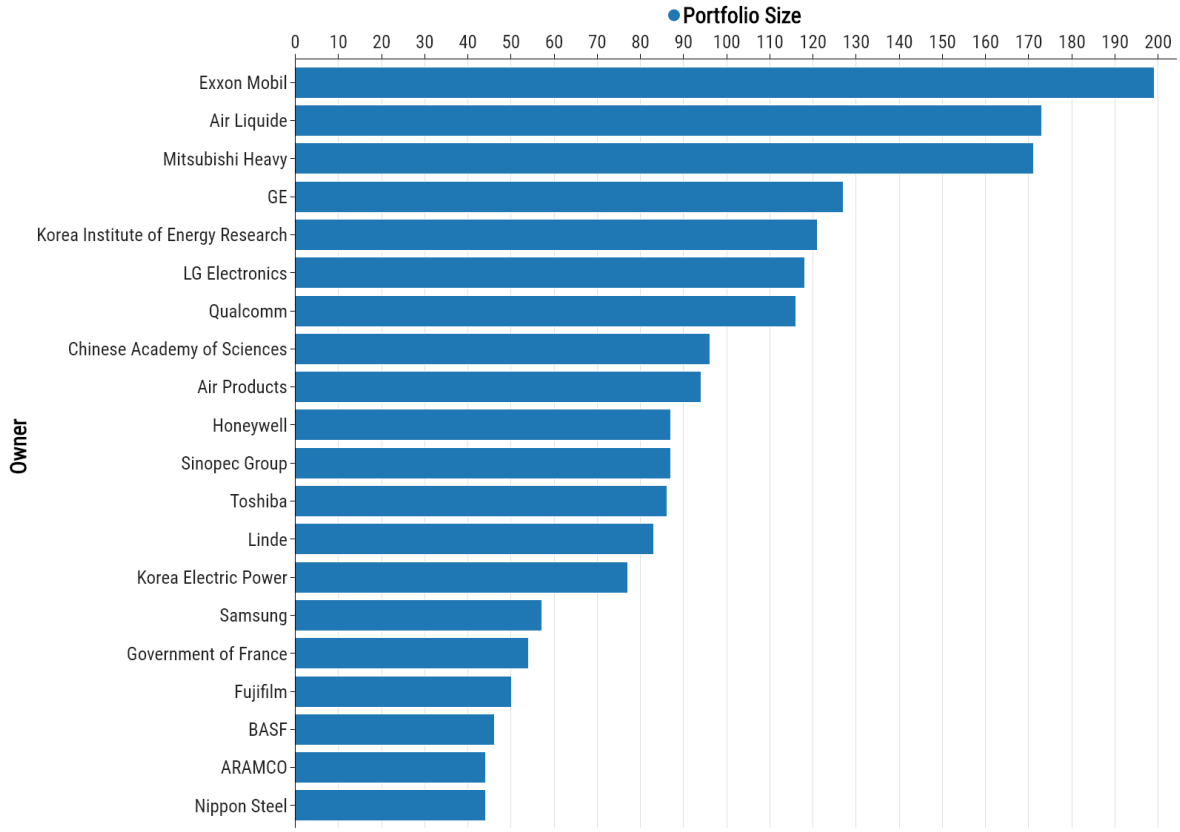


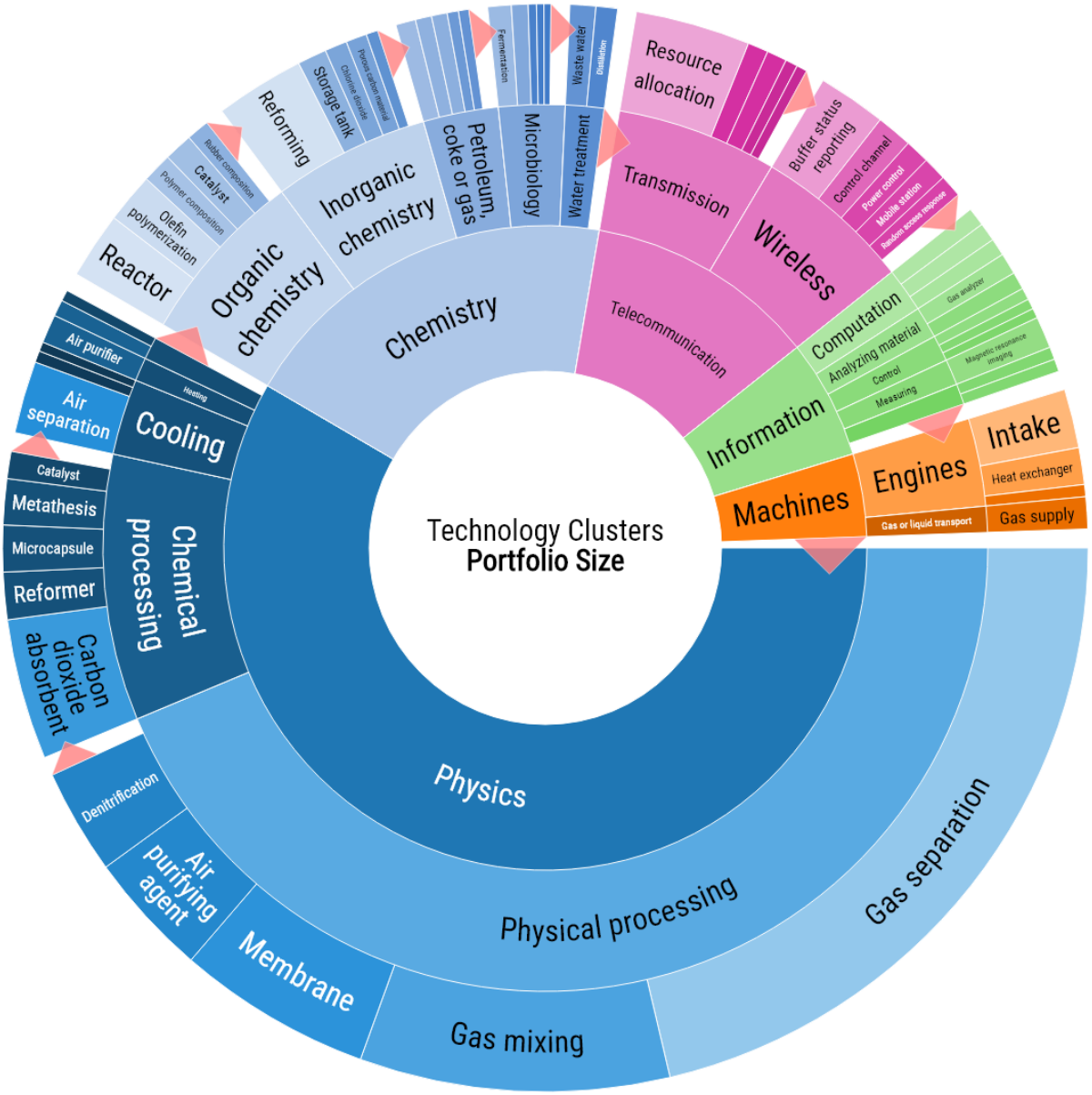
Figure 4 shows who owns patents relating to CCS. From this, we can see a mix of chemical and energy companies from multiple nations. The French Government also own a number of patents through the French Institute of Petroleum (IFPEN).[16] Around 26% of patents relating to CCS are owned by these top 20 owners.

[16] https://www.ifpenergiesnouvelles.com/

Figure 5: Bubble chart showing CCS patent portfolio size per year, 2001-2018, grouped by owner

Figure 5 shows how the annual filings of different owners has changed from 2001-2018. We can see that Exxon Mobil increased their number of filings of active patent families between 2011-2016. LG electronics entered the sector in 2009, significantly increasing their portfolio size until 2011, then maintained a smaller number of filings each year from 2012 onwards.

Figure 6: Sunburst chart showing technology clusters of CCS 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 6 shows that 17% of patents relating to CCS are focused on gas separation, and 2.8% of patents focus on caron dioxide absorbents.

2.2 UK patent landscape

Figure 7: Number of CCS patent families active in the UK, grouped by priority (first filing) year, 2001-2018

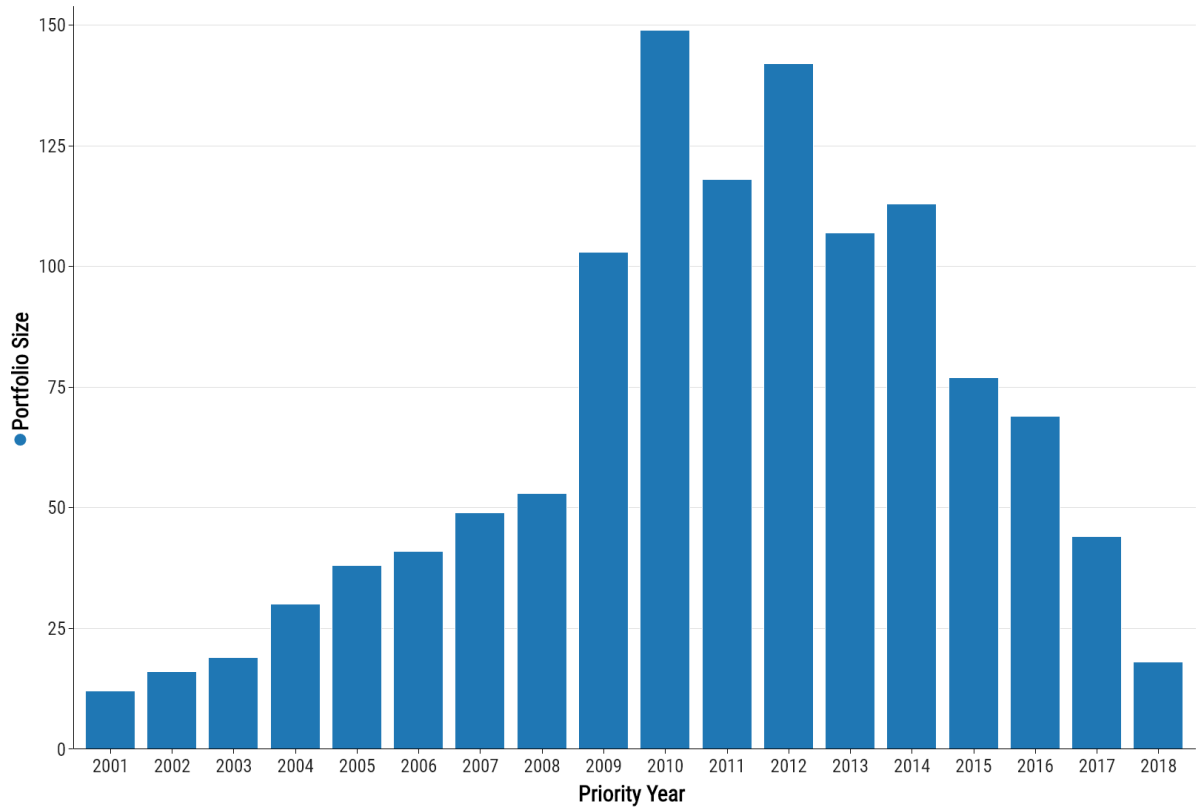


Figure 7 shows the number of patent families being filed each year which are active in the UK (1198 in total). From this we can see there was an increase from 2001-2010, where the number of active patent families filed each year increased. After 2010, the growth rate of active patent families in the UK appears to have been decreasing.

Figure 8: Number of CCS patent families invented in the UK, grouped by priority (first filing) year, 2001-2018

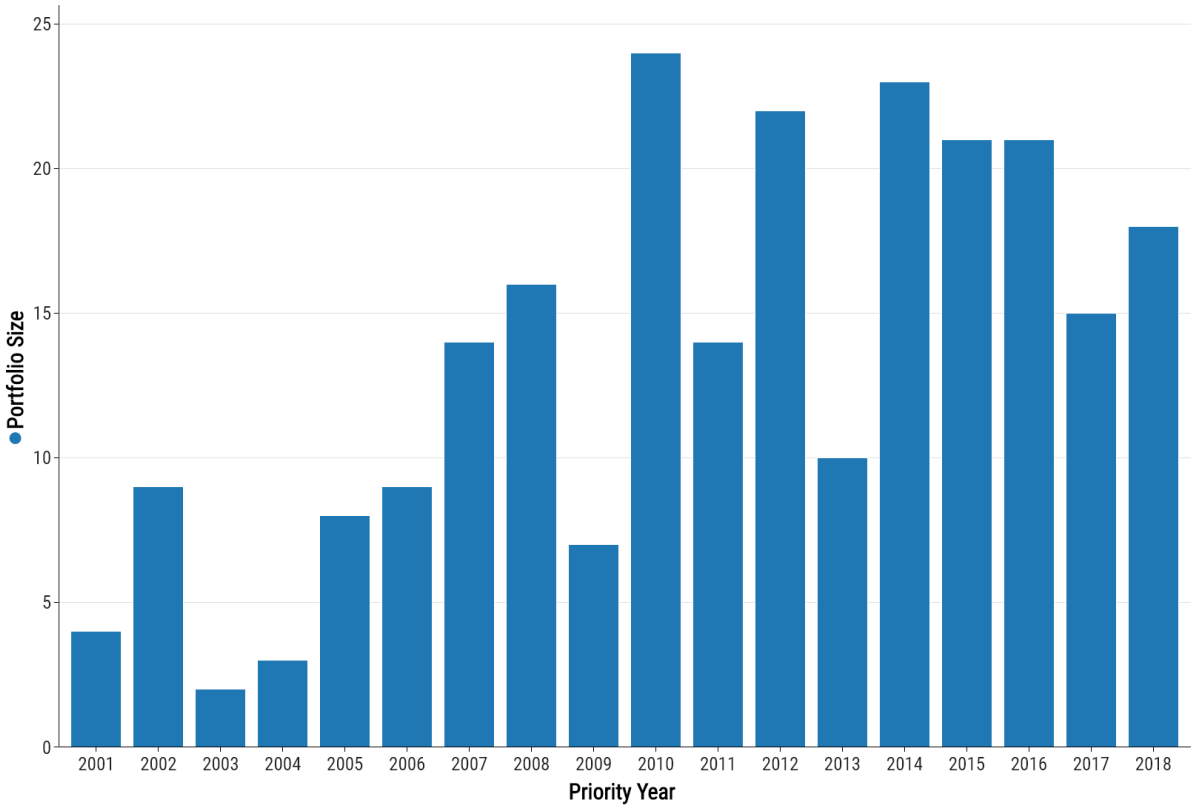


Figure 8 shows how the number of active patent families invented in the UK being filed has changed from 2001-2018. There has been a general increase over this time period, with a peak in growth rate in 2010, which mirrors the peak seen in Figure 7. Unlike Figure 7 however, there doesn't appear to have been the same decrease after 2010, suggesting that CCS patents are still being invented at a similar rate in the UK since then.

Figure 9: World map showing where CCS patents active in the UK are being invented, 2001-2018

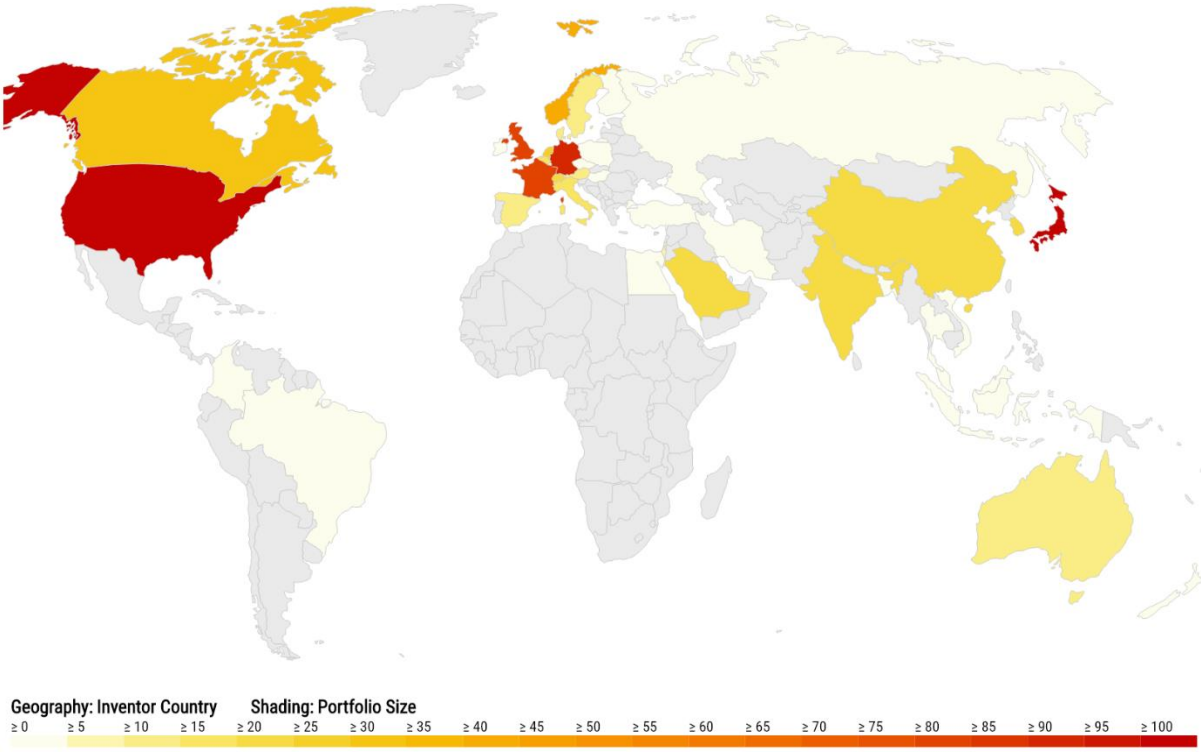


Figure 9 above shows where CCS patents active in the UK are being invented. Here we can see that the US and Japan are most dominant, followed by the UK, France and Germany. China does not appear to be as prevalent in this map as might be expected given its activity in many other technology areas.

Figure 10: Top 10 owners of CCS patents active in the UK, 2001-2018

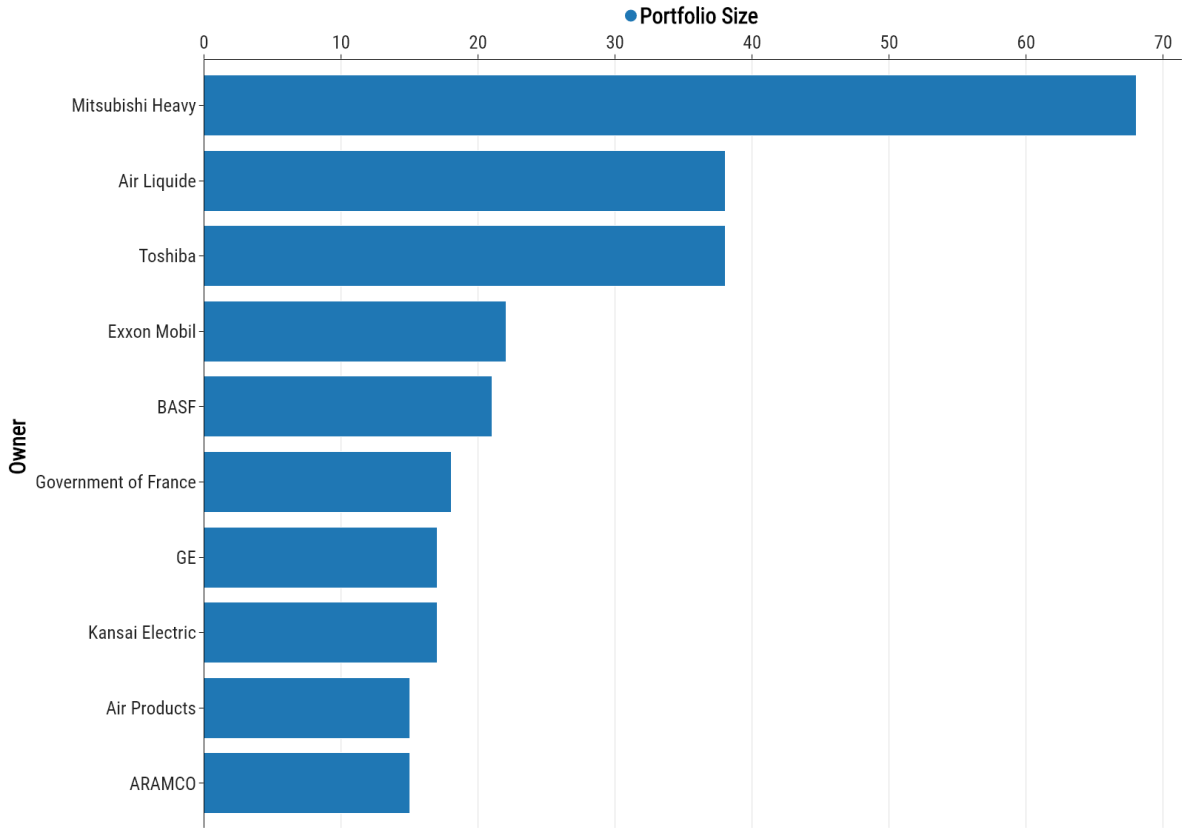


Figure 10 shows that the top owners of patents active in the UK broadly follows trends seen globally. Mitsubishi Heavy appear to have a substantially larger portfolio of active patents in the UK compared to other owners. Around 36% of CCS patents active in the UK appear to be owned by these top 10 owners.

Figure 11: Bubble chart showing number of CCS patent families active in the UK per year 2001-2018, grouped by owner

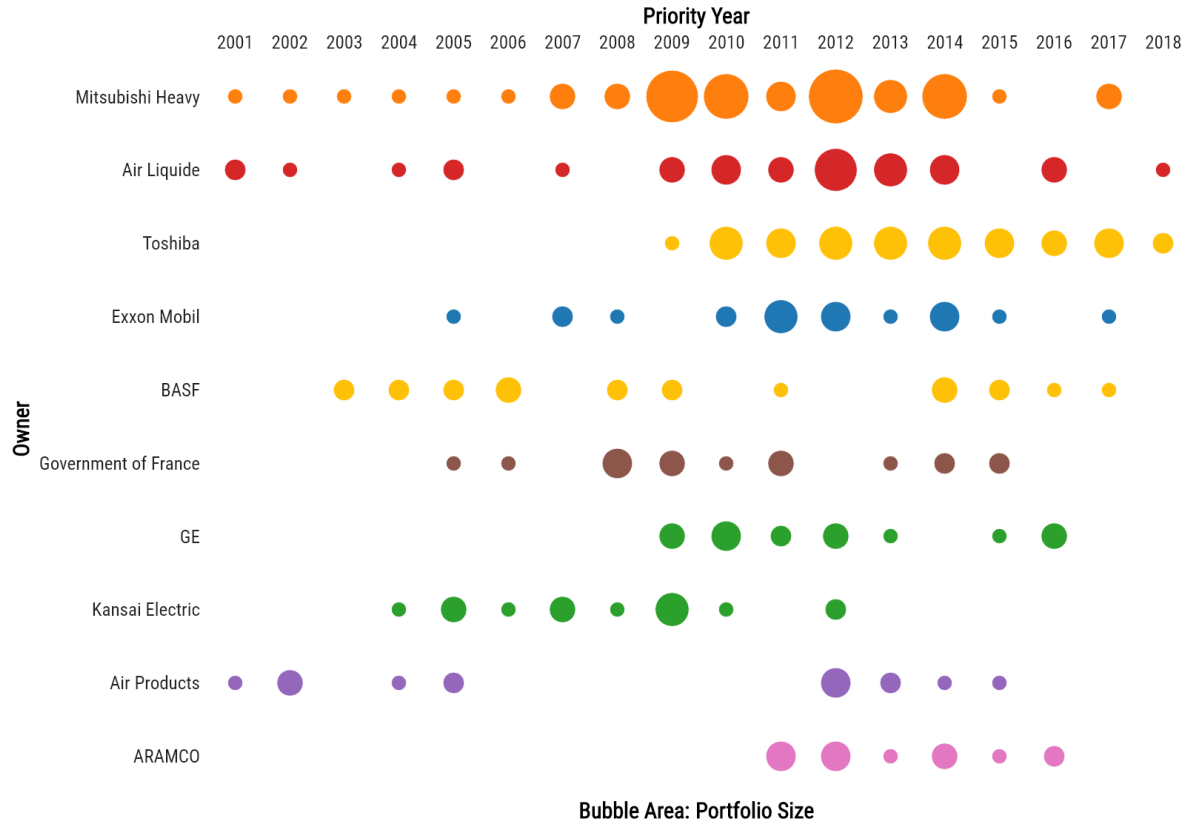


Figure 11 shows that Mitsubishi Heavy had a larger growth in portfolio size from 2009-2014, but appear to have decreased the number of active patent families filed each year from 2015 onwards.

3. Carbon Capture, Usage and Storage (CCUS)

This section looks specifically at CCUS rather than CCS in general.

3.1 Worldwide patent landscape

Figure 12: Number of active CCUS patent families, grouped by priority (first filing) year, 2001-2018

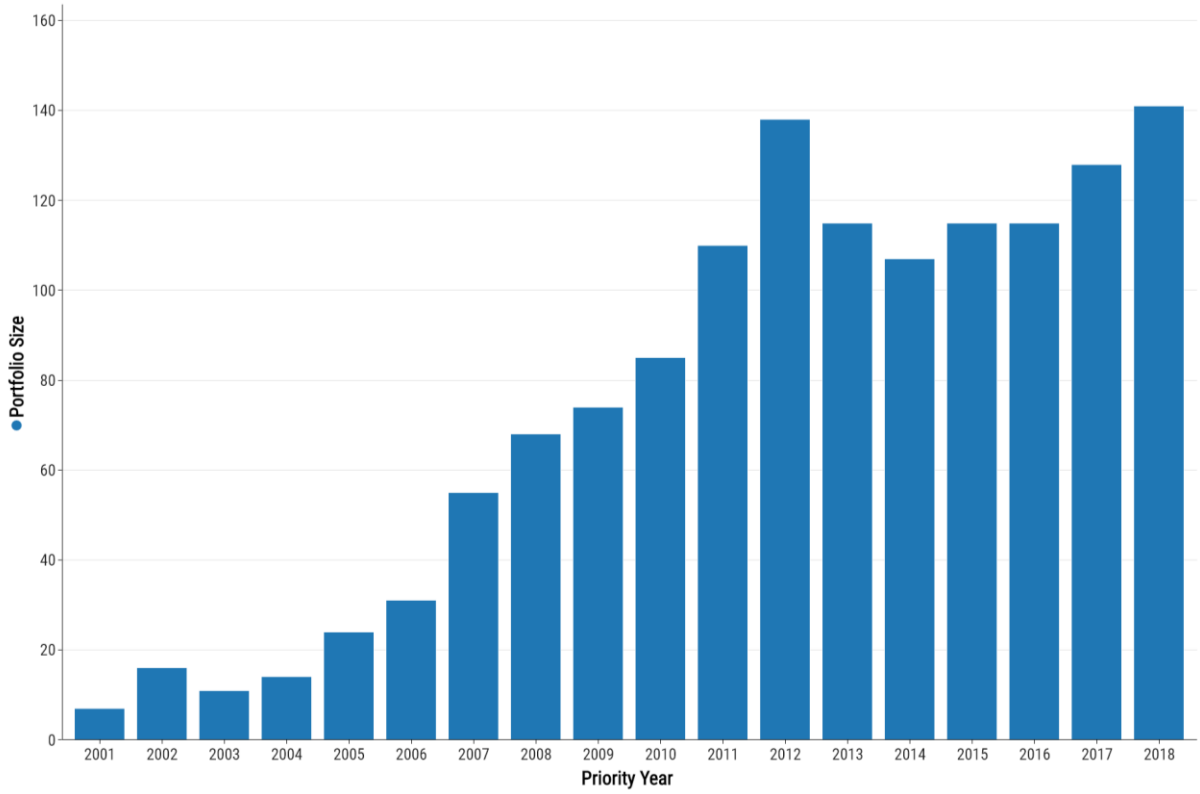
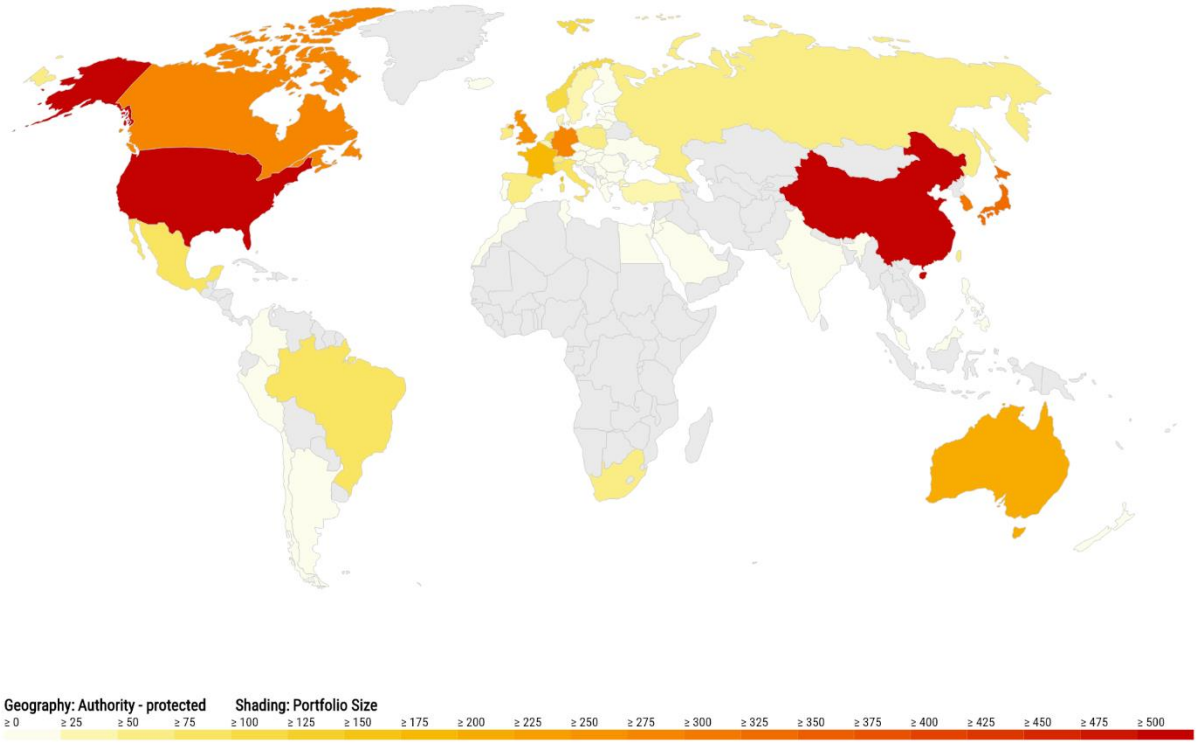


Figure 12, above, shows how the number of active patent families filed each year relating to CCUS (1,354) has increased over time, with a significant increase in patenting activity from 2003-2012. From 2012-2018, the number of active patent families filed per year appears to have remained more consistent, suggesting a relatively stable level of innovation in this field.

Figure 13: World map showing where CCUS patents are being protected, 2001-2018



The map in Figure 13 broadly matches the trends seen in Figure 2, where China and the US feature heavily, with notable activity in Europe, Australia and Canada as well as in South Korea and Japan. This suggests that activity in CCS and CCUS broadly correlate with each other geographically.

Table 2: Relative Specialisation Index (RSI) of selected nations for CCUS patents, 2001-2018

Country	Relative Specialisation Index
Australia	0.883
Canada	0.638
India	0.602
United Kingdom	**0.177**
South Korea	0.123
USA	0.090
France	-0.043
China	-0.167
Japan	-0.249
Germany	-0.321

Table 2 shows the Relative Specialisation Index (RSI)[17] of the top 10 patenting countries for CCUS. As for CCS, Australia is the most specialised country for CCUS related technologies, with a higher value for CCUS compared to CCS, suggesting that Australia is more specialised in the CCUS field. A value of above zero for the UK indicates that the UK is more specialised in this filed since it is producing more patents compared to what would be expected given the absolute levels of patenting within the UK. The UK does however have a slightly lower value for CCUS compared to CCS, suggesting that it is slightly less specialised in the field of CCUS.

Figure 14: Top 20 owners of CCUS patents, 2001-2018

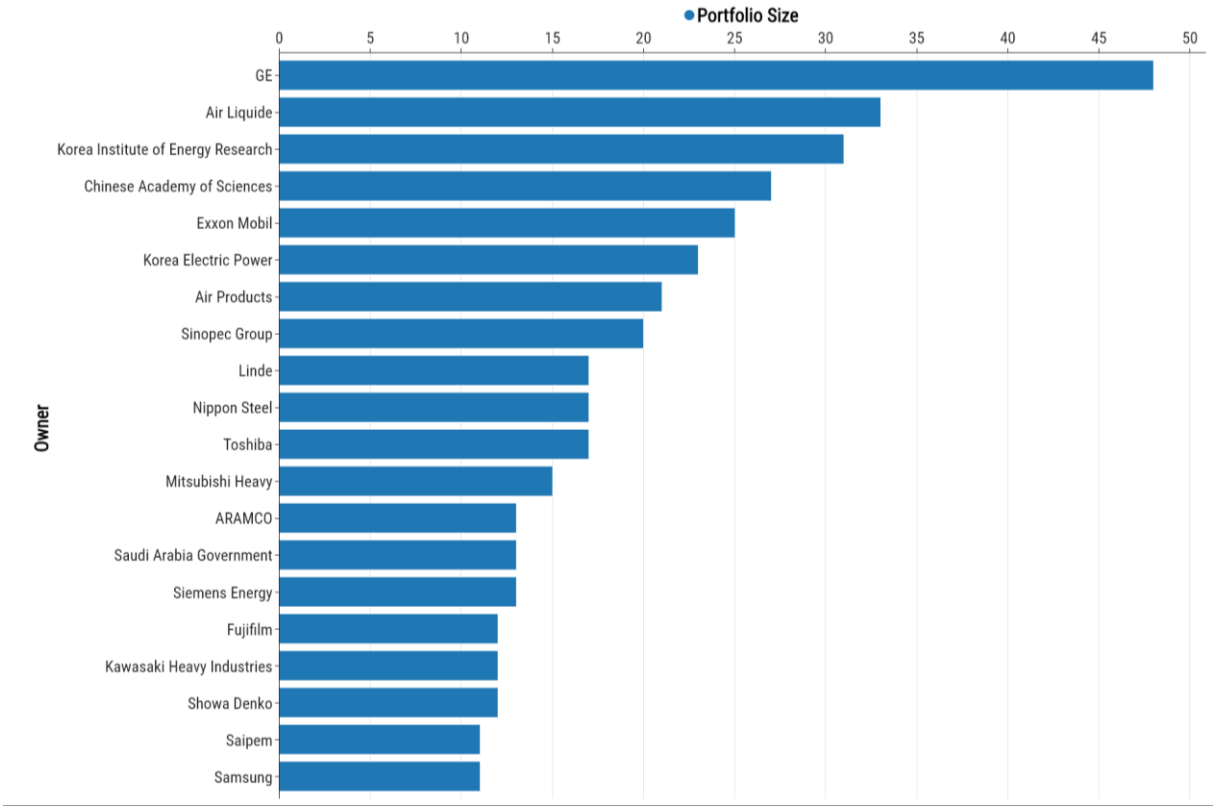


Figure 14 shows that the same mix of owners own patents relating to CCUS as already own patents relating to CCS in general, with GE the most dominant patentee over this time period. This suggests that GE may be more focused on development within CCUS compared to other owners. Around 29% of patents relating to CCUS are owned by these top 20 owners.

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

3.2 UK patent landscape

Figure 15: Number of CCUS patents active in the UK, grouped by priority (first filing) year, 2001-2018

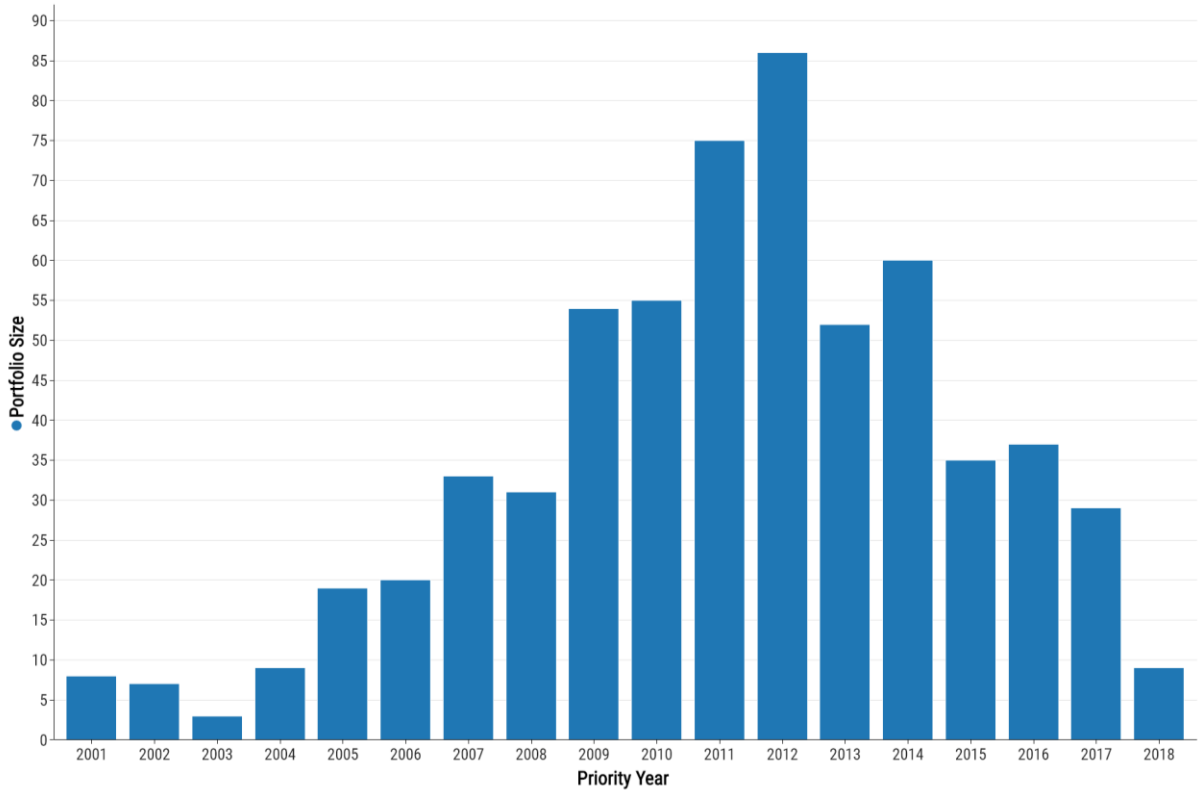


Figure 15 shows a similar trend to that seen in Figure 7, but is showing a slightly later peak in patenting activity at around 2012 rather than in 2010. Following this, there is an apparent decline in patenting activity per year, suggesting a slower rate of growth in these later years.

Figure 16: Number of CCUS patents invented in the UK, grouped by priority (first filing) year, 2001-2018

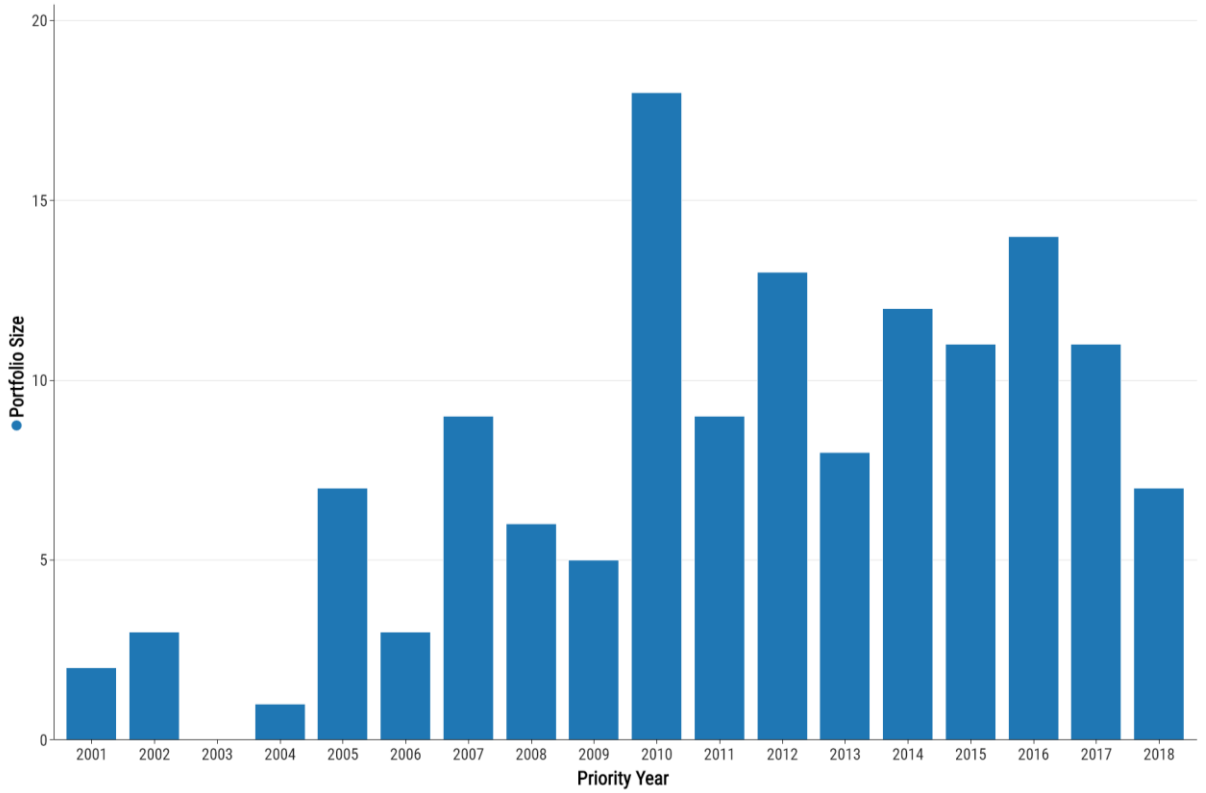


Figure 16 shows how the number of active patent families invented in the UK has changed from 2001-2018. There has been a general increase in filings per year over this time period, with a peak in 2010, which mirrors the peak seen in Figure 8. As in Figure 8, the growth rate of patents invented in the UK does not appear to have followed the same decline as patents active in the UK.

4. Conclusions

CCS is a significant area of patenting activity which has seen a significant increase in patent applications in recent years. Globally, this activity is led by US companies such as Exxon Mobil. Owners of patents relating to CCS are seeking protection in the US, China and in other jurisdictions such as multiple nations in Europe.

Looking specifically at the UK landscape, there appeared to be a peak in patenting activity in 2010-2014. The majority of this activity is by owners based outside of the UK, most prominently Mitsubishi Heavy. Patents filed by UK-based companies appeared to hit a peak in 2010, and have remained fairly stable from 2014 onwards.

When looking at CCUS specifically, it is clear that the patterns seen both worldwide and within the UK broadly follow the same trends as seen with CCS in general. This is suggesting that innovation in CCS in general is closely related to innovation specifically in CCUS.

BEIS have published a number of reports investigating CCS and CCUS in recent years. One of these pieces of work looks at next generation technologies which may be used to facilitate CCUS.[18]

The field of CCS is rapidly developing, and as the government is significantly investing in the development of CCUS facilities in the UK, the trends in patenting activity in this area may change over the coming years.

[18] https://www.gov.uk/government/publications/call-for-ccus-innovation-literature-review-benchmarking-report-and-calculator

Appendices

Appendix A: Search strategy

For this study, the LexisNexis worldwide patent database was interrogated using PatentSight[19].

A.1 Carbon Capture and Storage (CCS)

(CPC=(Y02C20/40) or tac=(CCS or (carbon* captur*))) AND PriorityDate=(2001-01-01 TO 2018-12-31)

A.2 Carbon Capture, Usage and Storage (CCUS)

CPC=(Y02C20/40) and tac=(CCUS or (use* or usag* or util*)) AND PriorityDate=(2001-01-01 TO 2018-12-31)

Appendix B: Classification definitions

Y02C20/00 Capture or disposal of greenhouse gases

Y02C20/40 of CO2

[19] 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: research@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: November 2021
SR00136288