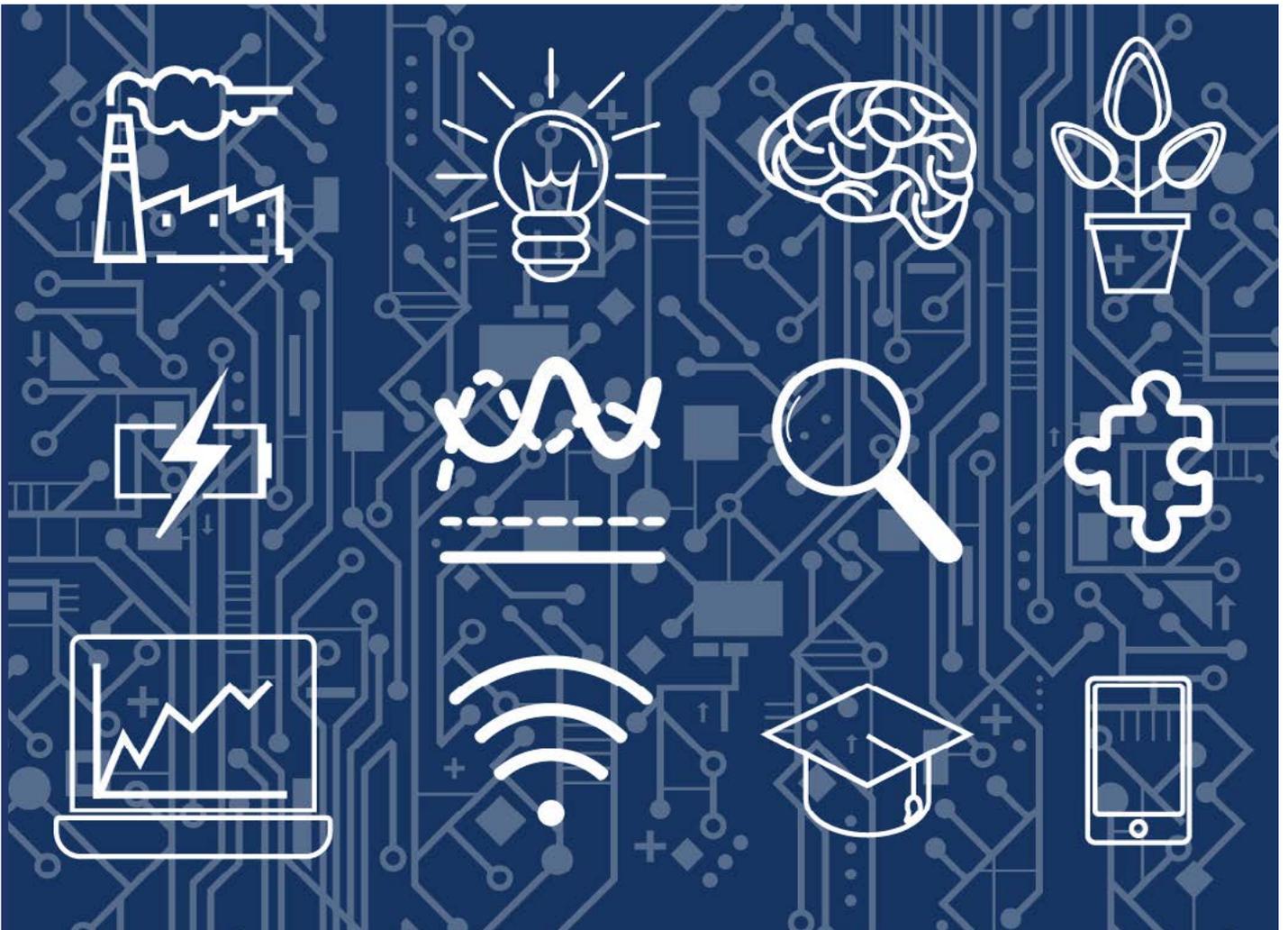




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## Greener vehicles

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



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Greener vehicles:

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

A worldwide overview of environmentally-friendly transportation patents

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# 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.<sup>1</sup>

The Energy White Paper (EWP)<sup>2</sup>, published in December 2020, and the Industrial Decarbonisation Strategy<sup>3</sup>, 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<sup>4</sup> the presidency of COP26 (26<sup>th</sup> UN Climate Change Conference of the Parties) and is hosting the COP26 UN Climate Change Conference in Glasgow in 2021.<sup>5,6</sup>

In November 2020 the UK government released a ten point plan for a green industrial revolution,<sup>7</sup> 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.

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<sup>1</sup> <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>

<sup>2</sup> <https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future>

<sup>3</sup> <https://www.gov.uk/government/publications/industrial-decarbonisation-strategy>

<sup>4</sup> Together with Italy: <https://www.ukcop26.org/ore-cop/>

<sup>5</sup> The conference was originally scheduled to take place in 2020, but has been postponed to 2021 in view of the COVID-19 pandemic

<sup>6</sup> UN Climate Change Conference UK 2020 (Conference) <https://www.ukcop26.org/the-conference/>

<sup>7</sup> <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<sup>8</sup> 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 low emission vehicle technologies (greener vehicles).

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.<sup>9</sup> The data coverage of this database is that of DOCDB, the European Patent Office's (EPO) database.<sup>10</sup>

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.

<sup>8</sup> <https://www.gov.uk/government/publications/promoting-innovation-and-growth-the-ipo-at-work-2020-21/innovation-and-growth-report-2020-21>

<sup>9</sup> <https://go.patentsight.com/BI2.0/bi/secure/src/resources/documentation/syntax-cheat-sheet/SyntaxCheatSheet.pdf?45be120476a49463f31ebcd79b10b19e>

<sup>10</sup> <https://www.epo.org/searching-for-patents/data/coverage/weekly.html>

## 1.2 Greener vehicles

The need to develop more environmentally friendly means of transportation, or 'greener' means of transport, features heavily in the government's ten-point plan for a green industrial revolution<sup>11</sup>.

Specifically, point 4 relates to accelerating the shift to zero emission vehicles, point 5 relates to green public transport, and point 6 relates to Jet Zero and Green Ships. The shift to zero emission vehicles is already in motion, with the UK government intending to end the sale of new petrol and diesel cars by 2030. This shift will see further development in technologies related to hybrid, electric, and hydrogen powered vehicles, as well as the development of infrastructure to sustain these vehicles. The development of these technologies will also assist in achieving point 5 through the use of hybrid, electric, and hydrogen powered public transport (e.g. buses and trams). Point 5 could also be developed with further focus on electrifying more railways. Point 6 can be achieved through developing more fuel-efficient aircraft and ships, the use of more sustainable fuels, as well as developing zero-emission aircraft and ships.

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<sup>11</sup> [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/936567/10\\_POINT\\_PLAN\\_BOOKLET.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf)

## 2. Greener vehicles

### 2.1 Worldwide patent landscape

Figure 1: Number of active greener vehicle patent families worldwide per priority (first filing) year, 2001-2018

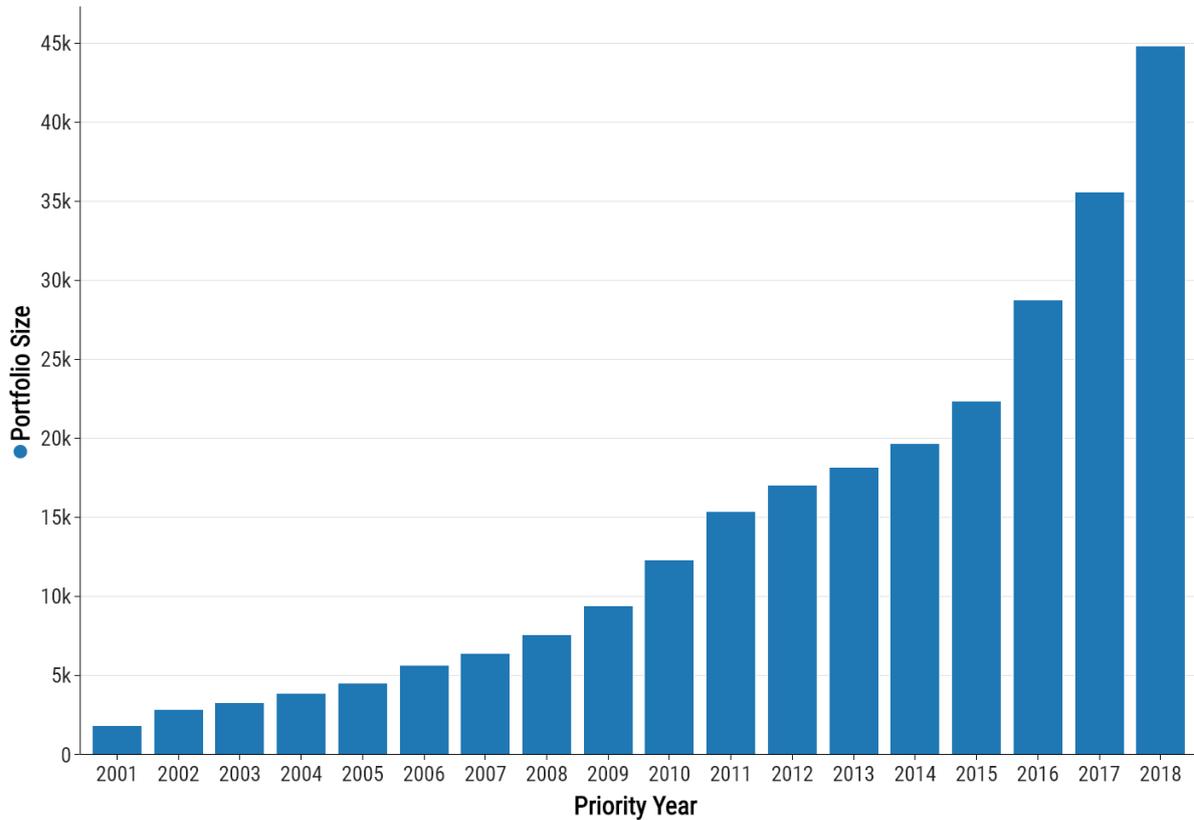


Figure 1 shows the number of active patent families globally (259,641 patent families), grouped by priority year. There has been a substantial increase in patents being filed each year across this time period, with the growth accelerating in more recent years. This may be a reflection of worldwide efforts to develop more sustainable transport solutions. The number of active patent families filed each year has increased nearly six-fold in the ten years from 2008 to 2018.

Figure 2: World map showing authorities protected by greener vehicle patents, 2001-2018

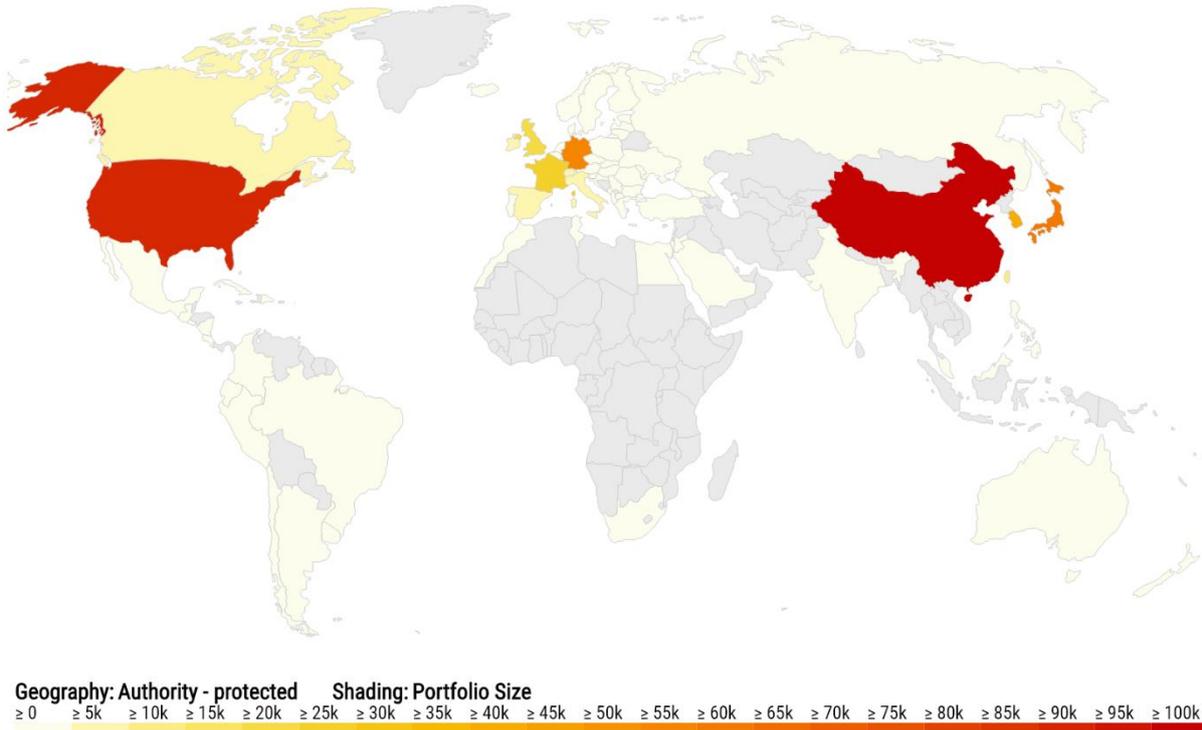


Figure 2 shows that China and the US are the most protected authorities worldwide. This is followed by Japan, Germany and South Korea. This is a reflection of both relative market size as well as general propensity to patent in these countries

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

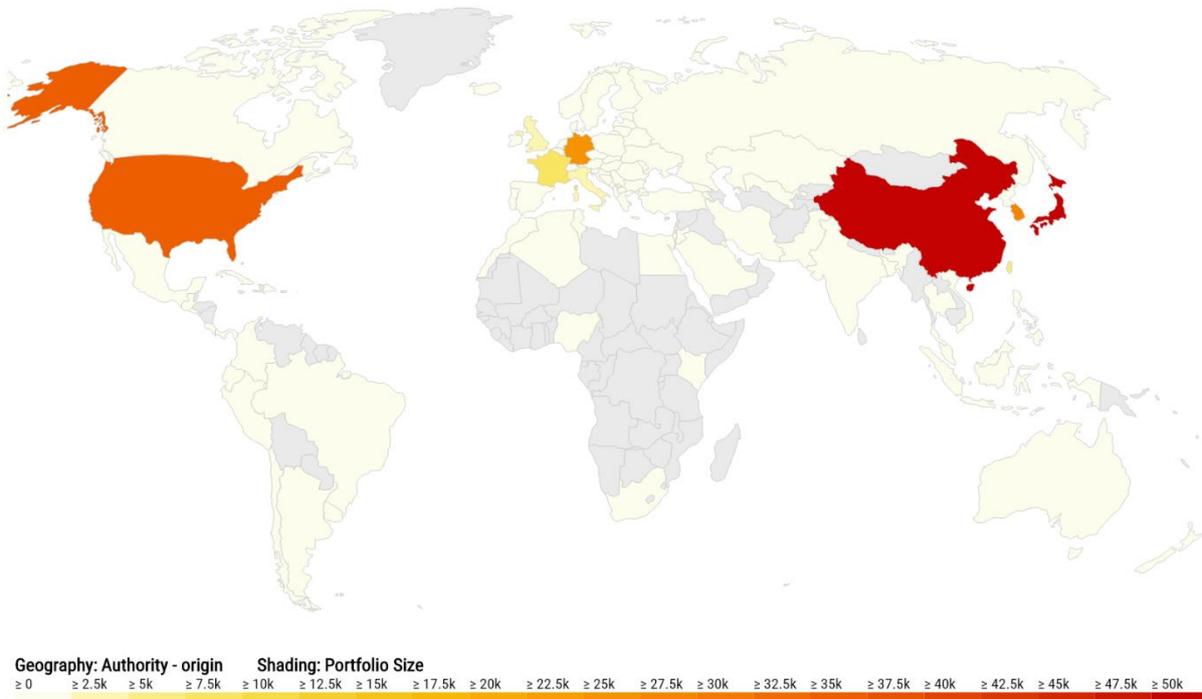


Figure 3 looks at where greener vehicle patents are being invented, and it is clear to see from this that both China and Japan feature prominently. Japan has a number of large automotive manufacturers, which may be a reason that it features so heavily in this map.

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.

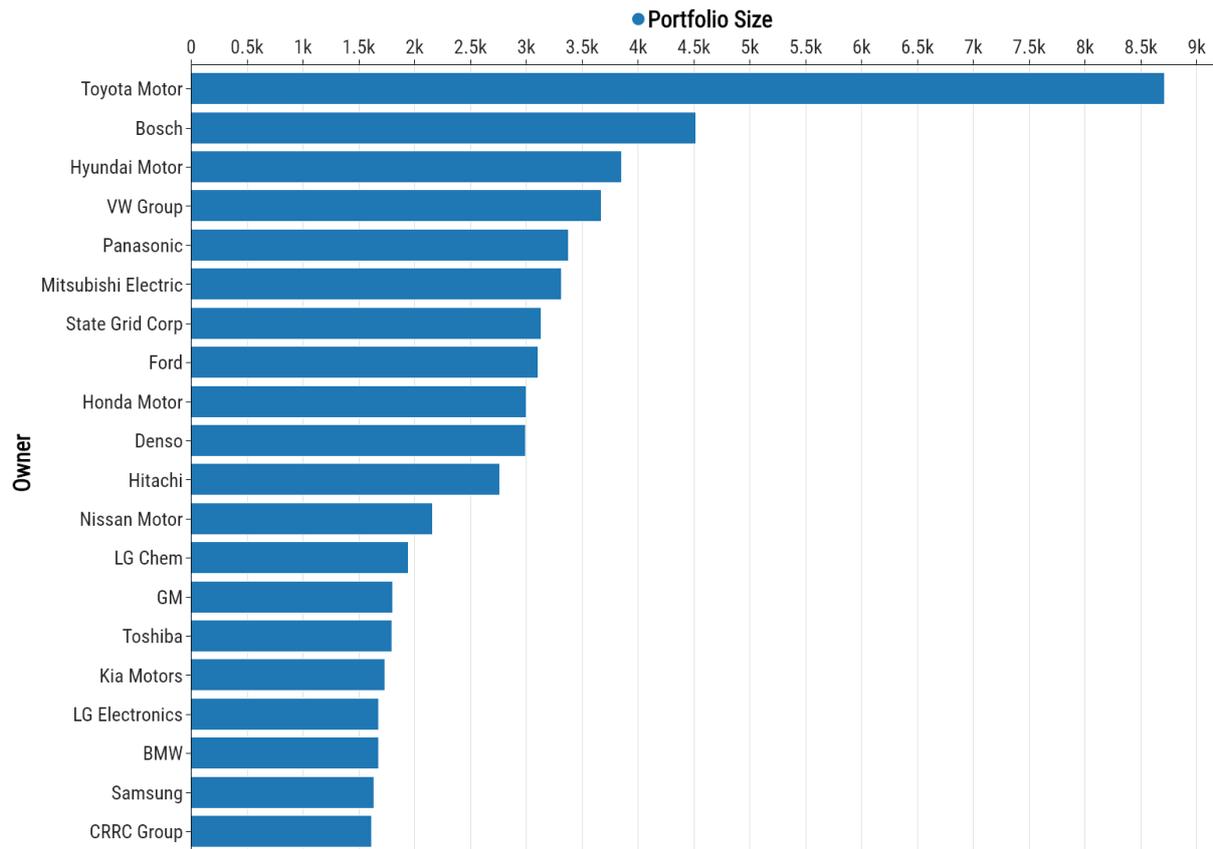
Table 1: Relative Specialisation Index (RSI) of selected nations for greener vehicle patents, 2001-2018

Country	Relative Specialisation Index
Germany	0.422
France	0.281
<b>United Kingdom</b>	<b>0.068</b>
USA	0.022
Canada	0.017
India	0.006
South Korea	-0.019
China	-0.030
Australia	-0.069
Japan	-0.078

Table 1 shows the Relative Specialisation Index (RSI)<sup>12</sup> of the top 10 patenting countries for greener vehicles. Germany is the most specialised country in this field. The UK has a value slightly above zero, indicating that it is producing slightly more greener vehicles as you would expect given the absolute level of patenting within the UK.

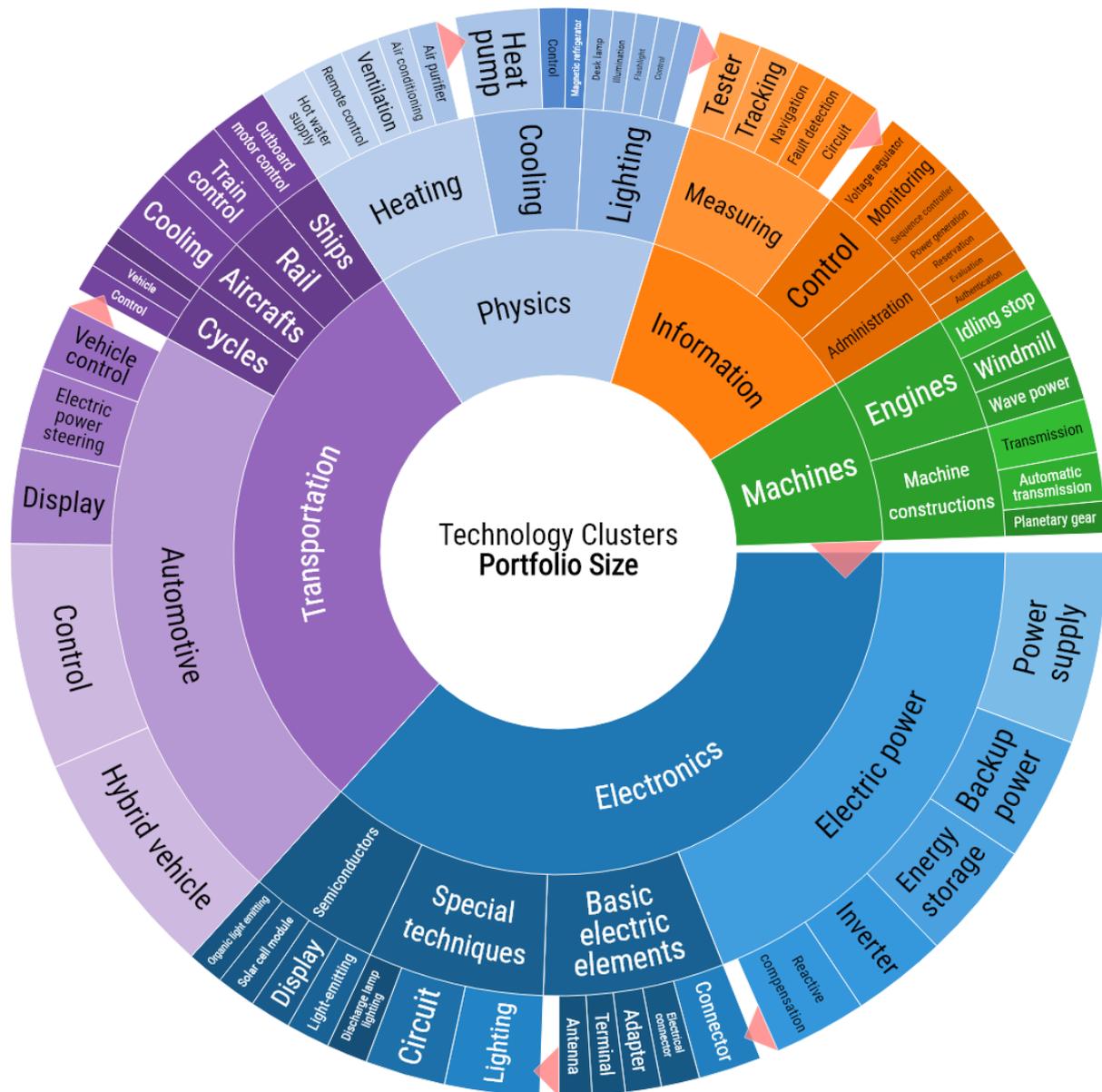
<sup>12</sup> See Appendix C for details of how the Relative Specialisation Index (RSI) is calculated

Figure 4: Top 20 owners of active greener vehicle patent families, 2001-2018



As expected, automotive companies feature heavily in Figure 4. The presence of electrical companies such as Bosch is explained by digging into the detail of individual patents, which reveal a number of patents relating to electrical components contained within vehicles (e.g. battery technology). Around 23% of patents relating to greener buildings are owned by these top 20 owners.

Figure 5: Sunburst chart showing the technology clusters for greener vehicle patents, 2001-2018



Sunburst charts such as Figure 5 provide a quick and intuitive understanding of a technology area, including the categories of inventions that are protected and in what proportions. Here we see that electronics make up a substantial proportion of patents relating to greener vehicles. This may be a reflection of how much the automotive industry is focusing on electric-based solutions for greener transportation. Within transportation, hybrid vehicles occupy the largest cluster, which may be reflecting the current increasing popularity of hybrid vehicles.

## 2.2 UK patent landscape

It is useful to consider how the greener vehicles patent landscape looks in the UK.

Figure 6: Number of greener vehicle patents patent families active in the UK, grouped by priority (first filing) year, 2001-2018

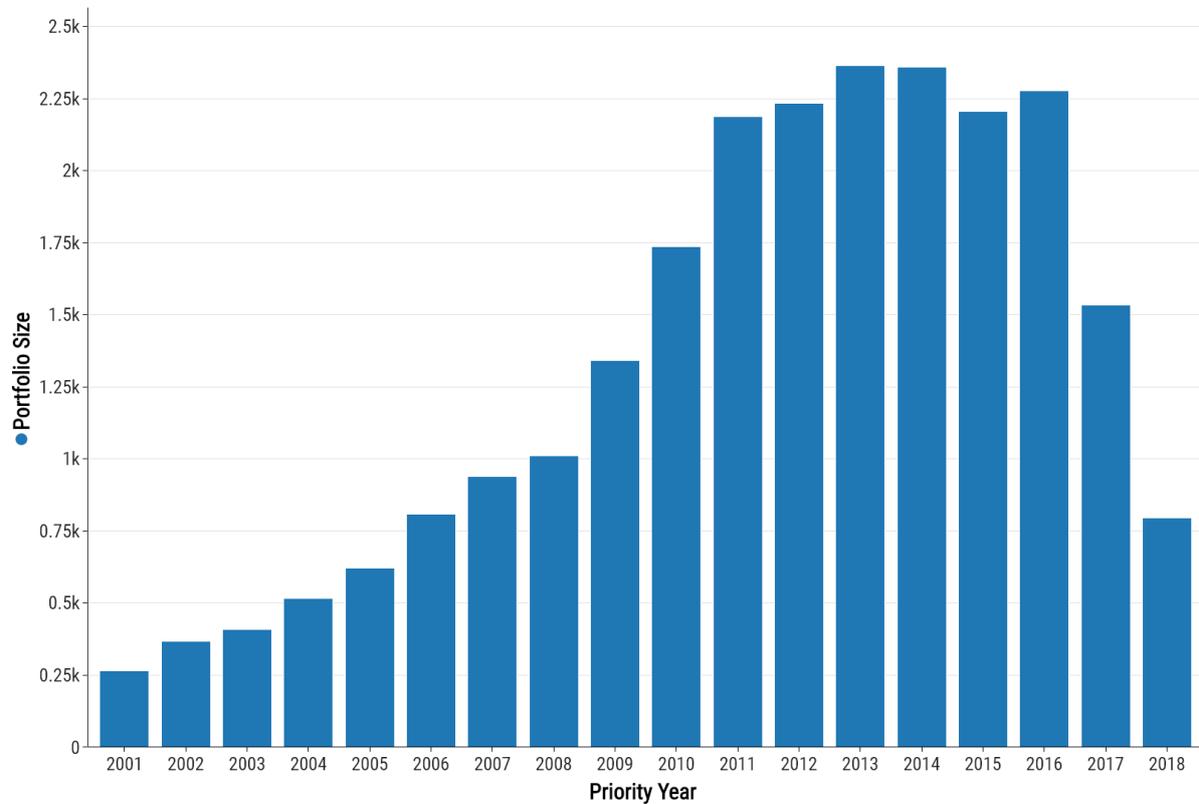


Figure 6 shows the number of active patent families filed each year in the UK which relate to greener vehicles. From 2001 to 2016, there was a large increase in the number of active patent families being filed each year, with nearly ten times more active patent families with a priority date in 2016 compared to 2001.

Figure 7: World map showing where greener vehicle patents active in the UK were invented, 2001-2018

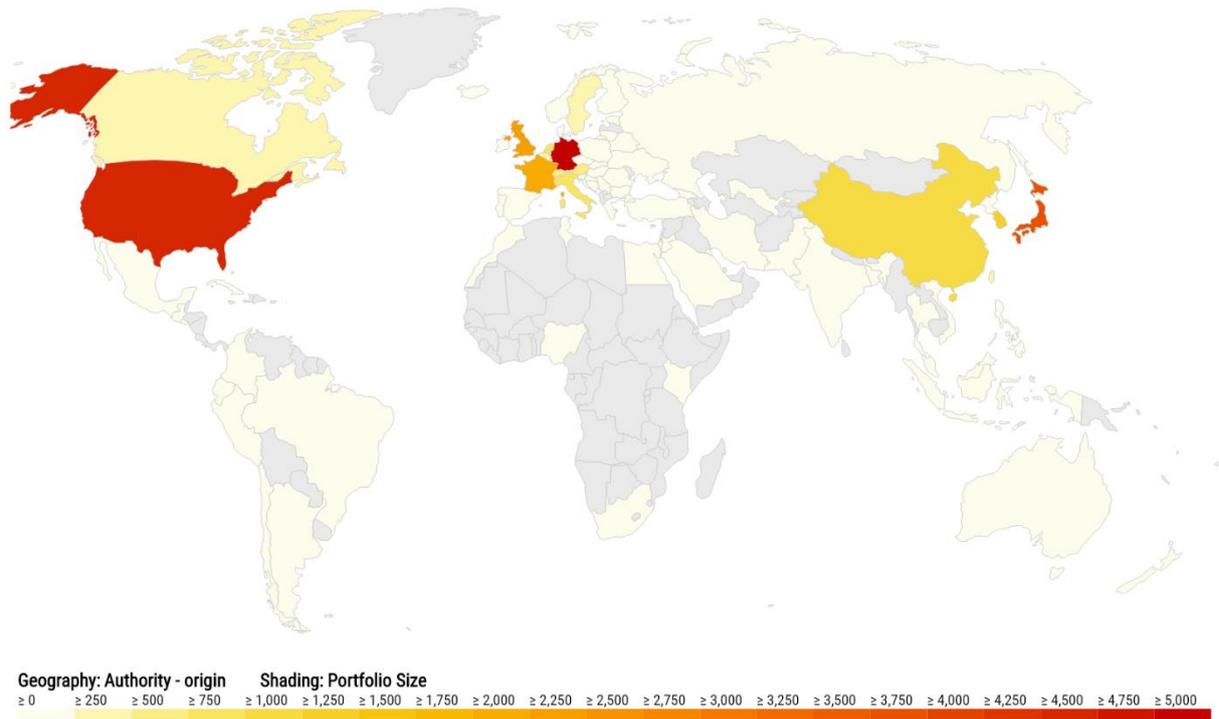


Figure 7 shows that a significant proportion of patents active in the UK are invented in Germany, the US and Japan. This broadly follows worldwide trends, but German inventors appear more prominently here compared to the worldwide activity shown in Figure 3.

Figure 8: Top 20 owners of greener vehicle patents which are active in the UK, 2001-2018

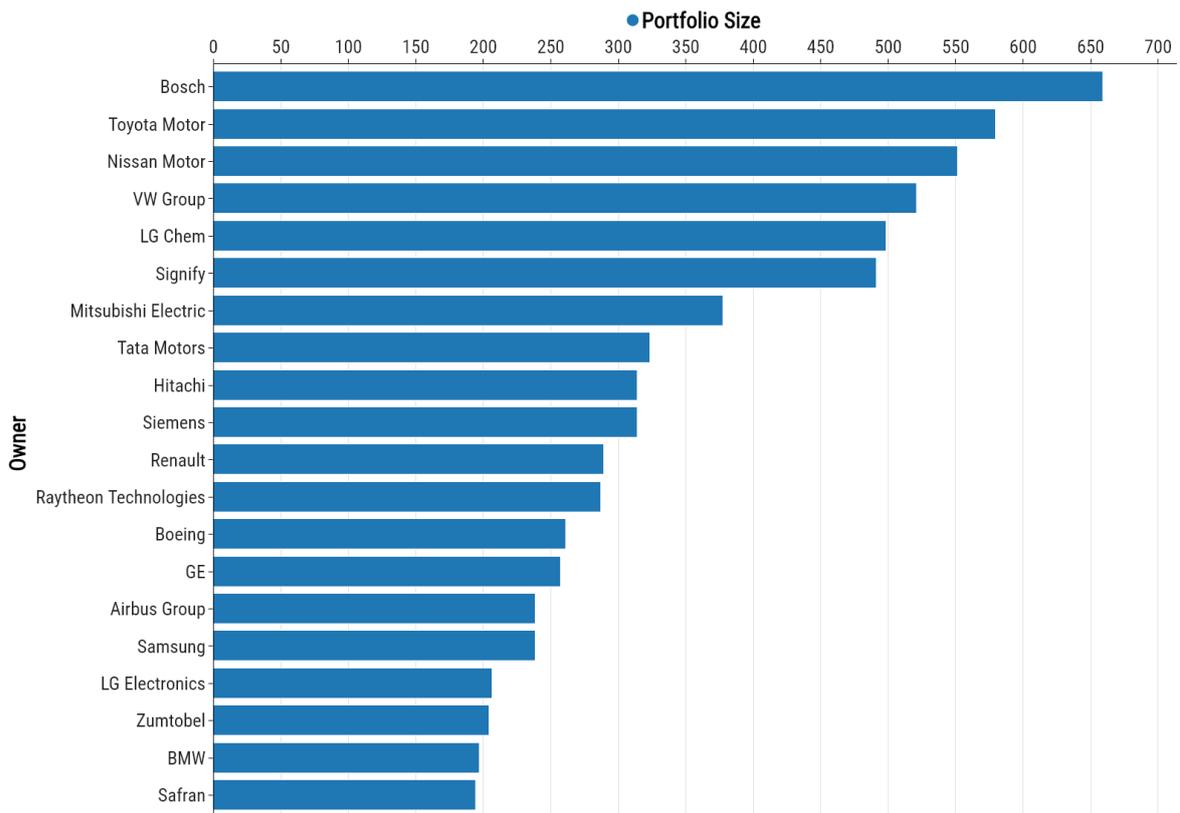


Figure 8 follows a similar trends to those seen globally (Figure 4), with automotive and electrical companies having the largest portfolios. The presence of Boeing and Airbus Group shows that in the UK, activity in the aerospace industry is evident within transportation as a whole. 29% of patents active in the UK, relating to greener vehicles, are owned by these top 20 owners.

Figure 9: Number of active greener vehicle patent families invented in the UK, grouped by priority (first filing) year 2001-2018

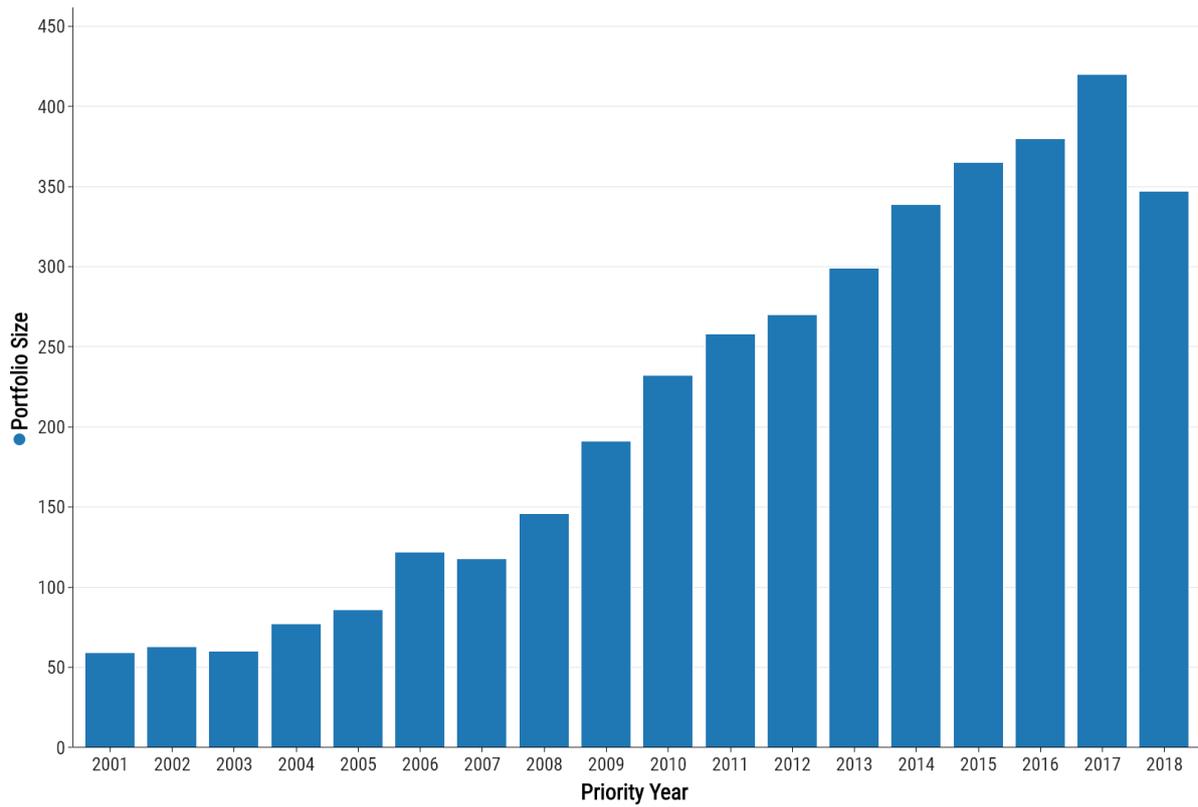


Figure 9 shows the trend of active patent families invented in the UK. When looking at this, the trend broadly follows the trend of patent families active in the UK, with a substantial increase in growth rate from 2001-2016, and a slight decrease in 2017-2018.

Figure 10: Top 20 owners of greener vehicle patent families invented in the UK, 2001-2018

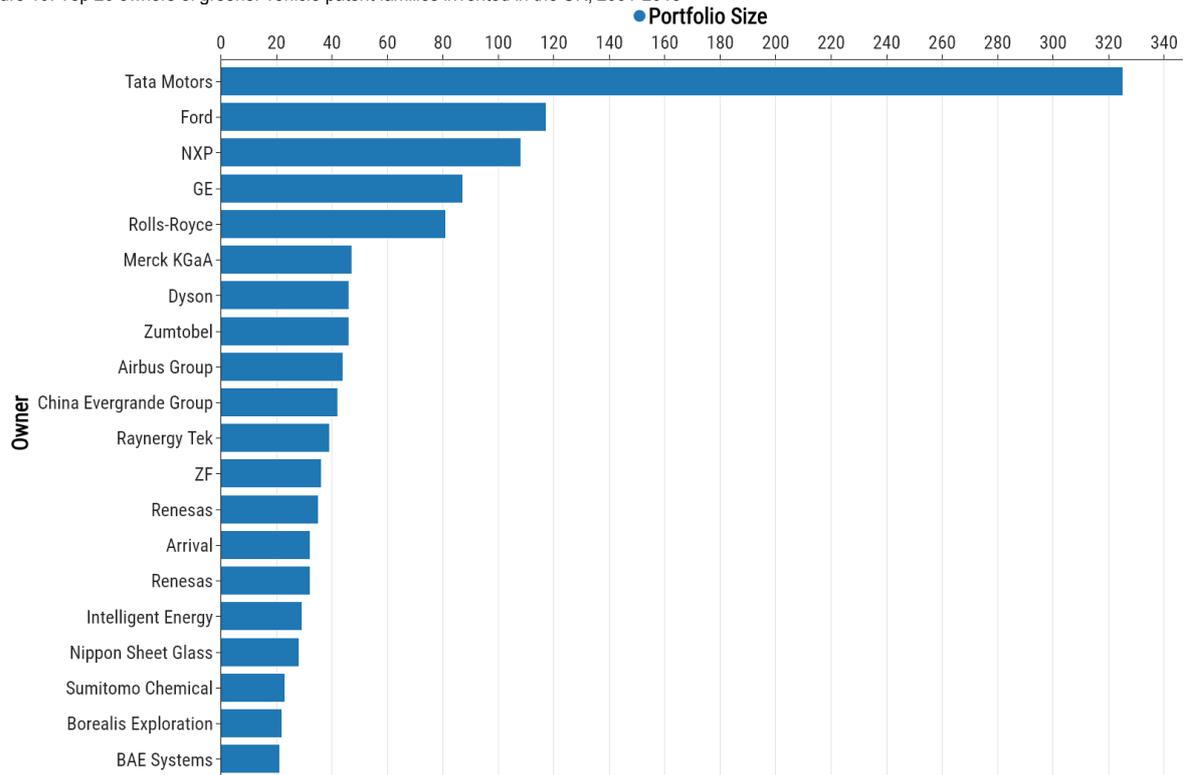


Figure 10 shows the owners of greener vehicle patents invented in the UK. Tata Motors (Jaguar Land Rover) has a substantially larger portfolio size compared to other owners.<sup>13</sup> Other UK based companies are also evident here, including Rolls Royce, Dyson and BAE Systems. 32% of patents invented in the UK which relate to greener vehicles are owned by these top 20 owners.

<sup>13</sup> <https://www.tmetc.com/>

### 3. Jet Zero

The UK government has established the Jet Zero Council, to help develop new technologies to achieve net zero aviation. It intends to achieve this through a combination of:

- System efficiencies
- Sustainable aviation fuels
- Zero emission flight
- Markets and removals
- Influencing consumers<sup>14</sup>.

The first three points of these are most likely to be reflected in patenting trends since these relate to technological developments. The following patent landscapes look specifically at trends relating to the development of more environmentally friendly aviation.

Figure 11: Number of active Jet Zero patent families by priority (first filing) year, 2001-2018

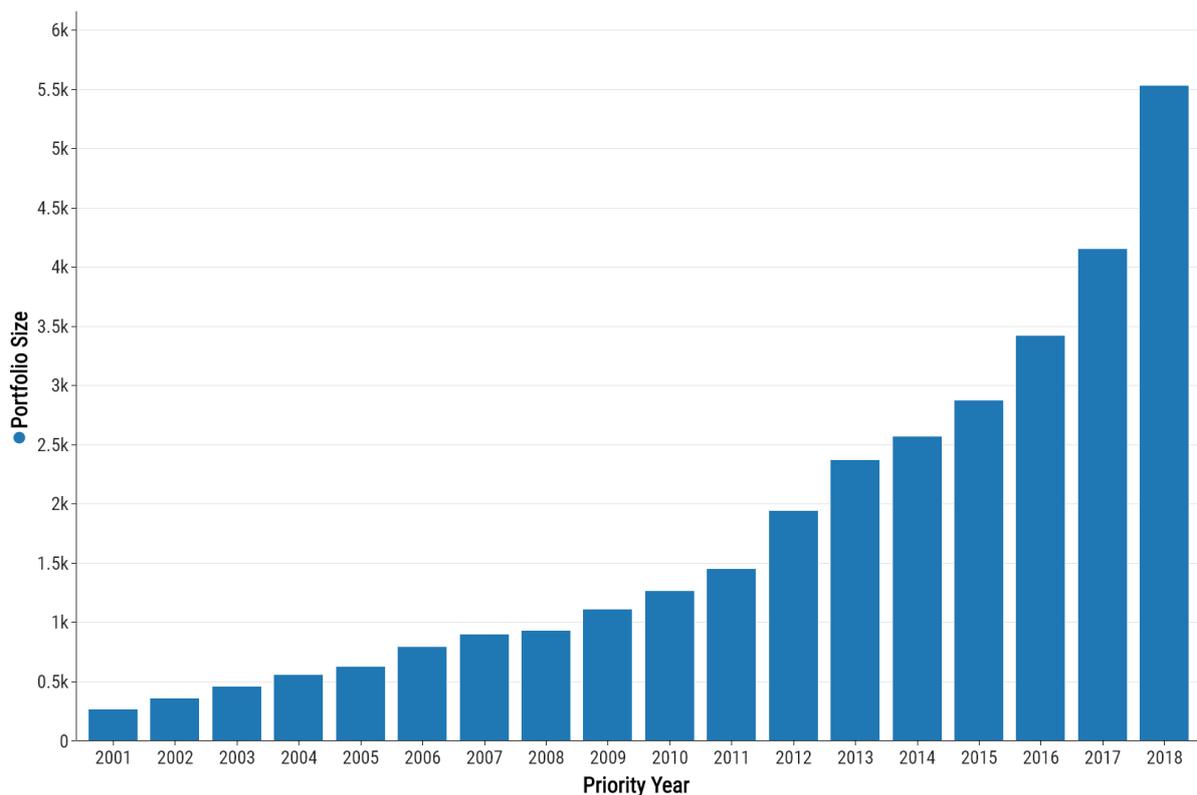
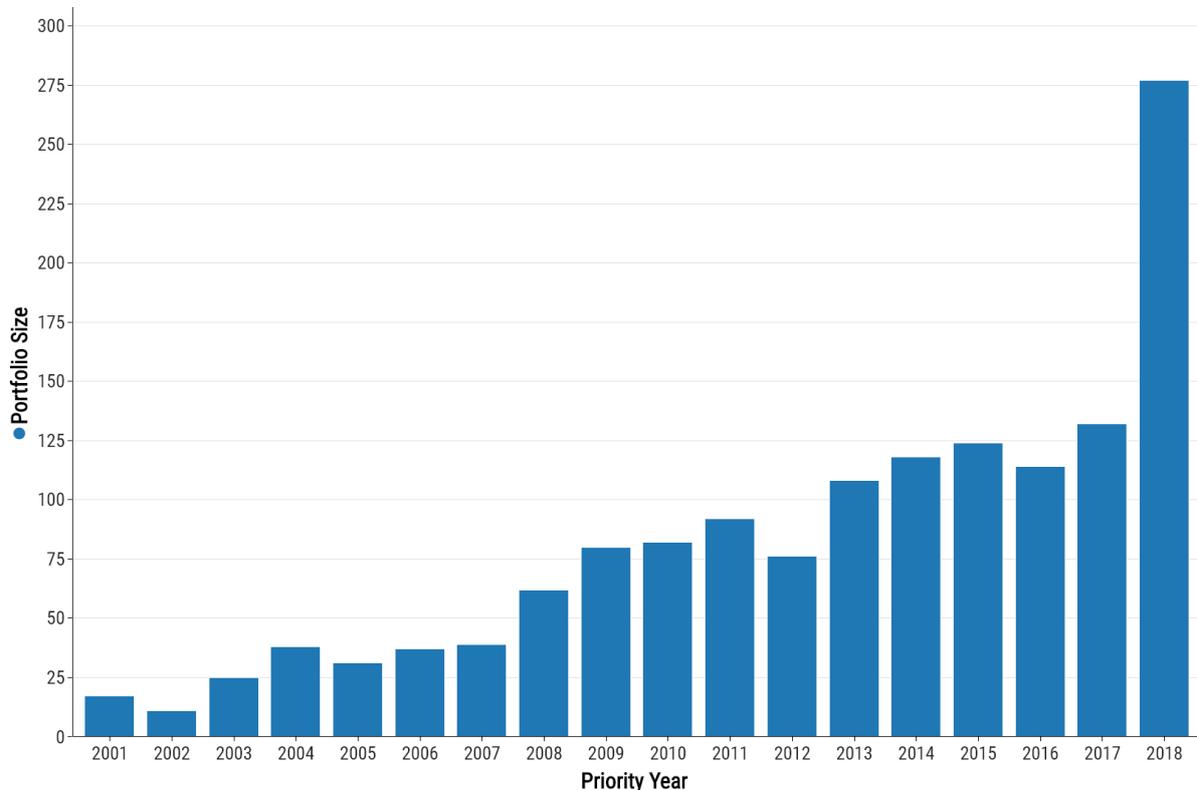


Figure 11 shows that there has been a steady increase in Jet Zero related patent families filed each year from 2001-2018. There are currently 31,627 active patent families in this area. The increase in the number of active patent families filed each year appears to have accelerated in recent years, with the number of active patent

<sup>14</sup> <https://www.gov.uk/government/consultations/achieving-net-zero-aviation-by-2050>

families filed each year doubling from 2014 to 2018. This suggests that this area is a rapidly growing sector.

Figure 12: Number of active Jet Zero patent families invented in the UK, by priority (first filing) year, 2001-2018



Looking at the UK picture, as shown in Figure 12, there has been a steady increase in the number of active patent families over this time period, with a large spike in the number of active patent families with a priority date in 2018. Further investigation shows that the majority of patent within this 2018 spike are owned by Rolls-Royce, and could be a reflection of the company's efforts to become net zero carbon by 2050.<sup>15</sup>

<sup>15</sup> <https://www.rolls-royce.com/media/press-releases/2020/05-06-2020-rr-puts-net-zero-carbon-by-2050-at-the-heart-of-future-innovation-and-growth.aspx>

Figure 13: Top 20 owners active Jet Zero patent families, 2001-2018

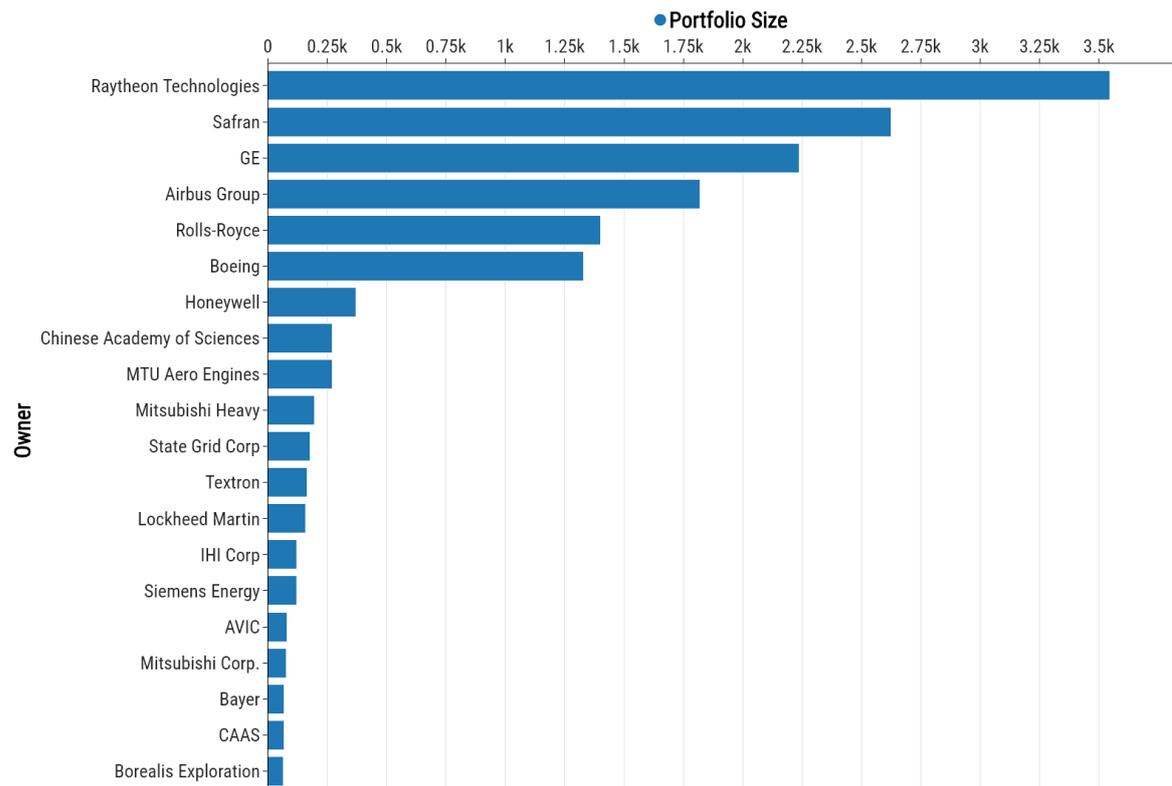


Figure 13, showing the top owners of Jet Zero patent families worldwide, shows that a number of aerospace companies are active in this area, as would be expected. This may be indicative of multiple owners working to develop more environmentally friendly technologies within this field. Rolls-Royce's presence within this chart shows the UK is playing a role in this area. A number of other owners (e.g. Airbus, Raytheon, Safran) also have sites in the UK. 41% of patents in this field are owned by the top six owners.

Table 2: RSI of selected nations for Jet Zero patents, 2001-2018

<b>Country</b>	<b>Relative Specialisation Index</b>
France	1.00
<b>United Kingdom</b>	<b>0.61</b>
Canada	0.28
USA	0.12
India	0.11
Germany	0.08
China	0.04
Australia	-0.03
South Korea	-0.22
Japan	-0.44

Looking at the RSI values for Jet Zero, it is clear that France is heavily specialised in this area compared to other nations. The UK also shows a higher degree of specialisation in Jet Zero compared to greener vehicles in general.

## 4. Conclusions

This report has attempted to cover greener modes of transport in general. It should be noted that this is a broad field, covering automobiles, public transport, shipping and aviation. There are numerous attempts to improve efficiency and lower the environmental impact across all of these modes of transport. This is reflected in the government's ten point plan for a green industrial revolution in that greener modes of transport are mentioned in three out of the ten points. This report has combined these points into a single document in order to provide a high-level summary of the patent landscape of greener vehicles in general, as well as focusing on Jet Zero as a specific example.

Considering greener vehicles in general, there has been a substantial increase in patenting activity from 2001-2018. This may be reflective of worldwide attempts to develop more environmentally friendly modes of transport. These worldwide attempts can be reflected in the UN's sustainable development goals<sup>16</sup> as well as international treaties such as the Paris Agreement.<sup>17</sup>

The UK appears to be performing relatively strongly, where the number of active patent families by owners with UK addresses has increased from 2001-2018. This is also reflected in the Relative Specialisation Index (RSI) score being above zero.

When looking at Jet Zero in particular, it appears that companies in the aviation industry are working to develop technologies to achieve the goal of net zero-emission aviation. The activity in this area appears to be accelerating, and UK companies appear to be playing a role in this, with Rolls-Royce substantially increasing its patent portfolio in 2018. The RSI value for the UK in relation to Jet Zero is also high, suggesting that the UK is more specialised in this field than would be expected given the absolute levels of patenting within the UK.

In summary, the field of greener vehicles continues to grow, with some areas such as Jet Zero appearing to be growing at a fast rate. This growth may be a reflection of international and domestic attempts to develop technologies to facilitate greener modes of transportation.

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<sup>16</sup> <https://sdgs.un.org/goals>

<sup>17</sup> <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>

## Appendices

### Appendix A: Search strategy

For this study, the LexisNexis worldwide patent database was interrogated using PatentSight<sup>18</sup>.

#### A.1 Greener vehicles

(tac=((vehic\* or car or cars or motorcar\* or automob\* or transport\* or bus or van or bike\* or motorbik\* or autobus\* or train\* or rail\* or locomotiv\* or ship\* or boat\* or yacht\* or plane\* or airplan\* or aeroplan\* or aircraft\*) near5 (green\* or ((carbon\* or CO2) NEAR3 (low\* or zero\* or none\* or "no" or reduc\* or neutral\*)) or electric\*)) OR IPC=(B60L, B61C3, B63H9) OR CPC=(Y02T)) AND PriorityDate=(2001-01-01 TO 2018-12-31)

(TitleAbstractClaims=((vehic\* or car or cars or motorcar\* or automob\* or transport\* or bus or van or bike\* or motorbik\* or autobus\* or train\* or rail\* or locomotiv\* or ship\* or boat\* or yacht\* or plane\* or airplan\* or aeroplan\* or aircraft\*) near5 (green\* or ((carbon\* or CO2) NEAR3 (low\* or zero\* or none\* or "no" or reduc\* or neutral\*)) or electric\*)) OR IPC=(B60L, B61C 3, B63H 9) OR CPC=(Y02T) ) AND PriorityDate=(2001-01-01 TO 2018-12-31) and ActiveIn=(GB)

(TitleAbstractClaims=((vehic\* or car or cars or motorcar\* or automob\* or transport\* or bus or van or bike\* or motorbik\* or autobus\* or train\* or rail\* or locomotiv\* or ship\* or boat\* or yacht\* or plane\* or airplan\* or aeroplan\* or aircraft\*) near5 (green\* or ((carbon\* or CO2) NEAR3 (low\* or zero\* or none\* or "no" or reduc\* or neutral\*)) or electric\*)) OR IPC=(B60L, B61C 3, B63H 9) OR CPC=(Y02T) ) AND PriorityDate=(2001-01-01 TO 2018-12-31) And InventedIn=(GB)

#### A.2 Jet Zero

(CPC=(Y02T 50) OR TAC=("jet zero" or (sustain\* or green\* or eco\*) near5 (flight\* or fly\* or airplan\* or aeroplan\* or jet or plan\*))) AND PriorityDate=(2001-01-01 TO 2018-12-31)

(CPC=(Y02T 50) OR TAC=("jet zero" or (sustain\* or green\* or eco\*) near5 (flight\* or fly\* or airplan\* or aeroplan\* or jet or plan\*))) AND PriorityDate=(2001-01-01 TO 2018-12-31) AND InventedIn=(GB)

### Appendix B: Classification Definitions

B60L	PROPULSION OF ELECTRICALLY-PROPELLED VEHICLES
B61C3/00	Electric locomotives or railcars

<sup>18</sup> <https://go.patentsight.com/BI2.0/bi/secure/src/resources/documentation/syntax-cheat-sheet/SyntaxCheatSheet.pdf?45be120476a49463f31ebcd79b10b19e>

B63H9/00	Marine propulsion provided directly by wind power
Y02T	CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORTATION
Y02T50/00	Aeronautics or air transport

## Appendix C: Relative Specialisation Index (RSI)

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.

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