Chapter 5

2022 Patent Report

May 2022

FUEL CELLS AND HYDROGEN OBSERVATORY

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Clean Hydrogen Partnership

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This report is based on data gathered for the Fuel Cells and Hydrogen Observatory by 31 December 2021. The authors believe that this information comes from reliable sources, but do not guarantee the accuracy or completion of this information. The Observatory and information gathered within it will continue to be revised. These revisions will take place annually and can also be done on a case by case basis. As a result, the information used as of writing of this report might differ from the changing data in the Observatory.

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Executive Summary

The Fuel Cells and Hydrogen Observatory is an ambitious project aiming to collect available valuable sector information in a single go-to source, making it available to all interested stakeholders.

Patents are tools to protect innovation. Most countries in the world operate a first-to-file system and so patent application statistics provide a bellwether for research and development activities. Further, because patent offices around the world classify patent applications according to a universally accepted classification system patent statistics can be conveniently separated into categories of interest. In short, patent statistics can be used to indicate who is doing what, where and when.

Purpose: The technology and market module of the FCHO presents a range of statistical data as an indicator of the health of the sector and the progress in market development over time.
https://www.fchobservatory.eu/observatory/technology-and-market

Scope: Patent data is presented on a global basis, especially for the top five Patent Offices worldwide.

The report spans January 2014 – December 2021.

Key Findings:
Over the period, the total number of patent filings in the fuel cell technology sector increased;
The USA and China appear to be the most important jurisdictions for filing fuel cell patent applications;
South East Asian automotive companies are the most prolific filers of patent applications;
The number of patent applications filed for specific chemistries appears to be fairly stable;
The number of mobile fuel cell patent filings far outpaces portable and stationary fuel cells and patent filings for hydrogen production dominate the hydrogen economy filings;
Battery technology applications show a marked incline in filings.

Previous Reports: The first report was published in 2021. This report is the 2nd report.

1. Introduction

The information in this report covers the period January 2014 – December 2021.

Patents are monopoly rights granted by Patent Offices in respect of inventions which are new, inventive and industrially applicable. Patents are territorial and are granted by individual national or regional patent offices in respect of those territories. As such, the geographical extent of filing of a patent application is an indicator of the perceived value an inventor has for the underlying invention.

Almost all countries around the world have adopted a 'first-to-file' system which awards the first inventor to file a patent application at a Patent Office. This means that inventors are encouraged to file patent applications early in the research and development process and, because of this, patent filing statistics are a significant marker of research and development activity. For many inventions patents are the only source of published technical information relating to the underlying principles upon which an invention is founded.

Patent applications are published eighteen months after filing. In many cases this is the first time the public can see information relating to the invention.

All patents are classified by experienced patent examiners according to patent classification systems. The universally accepted patent classification system is called the International Patent Classification (IPC). This means that the patent literature provides a vast and well-categorised resource which is readily divisible into relevant technical groupings.

During the process of seeking granted patent rights, the disclosed invention is assessed by patent examiners. In light of that assessment, many patent applications are abandoned before grant because the disclosed 'invention' is found to be old or obvious.

Accordingly, once a patent has been granted it is a valuable business tool which can be used to prevent others from operating in the defined area, in the territory covered by the patent. In most countries, patents expire twenty years after the date of filing.

This report examines the state of recent patent activity in the fuel cell space. The report provides statistical data across the world's major IP authorities concerning:

- **Total fuel cell activity:** providing a marker for fuel cell R&D activity in comparison with overall trends in patent filings
- **Major commercial patent filers:** providing a picture of the major layers in fuel cell patent filings
- **Major academic patent filers:** providing a view of the major academic filers
- **Patent activity by technology:** showing the trends in patent filings for major fuel Cell technologies
- **Patent activity in the hydrogen economy:** showing how production, storage and distribution of hydrogen is changing over time
- **Patent activity in the area of batteries:** showing the trends in patent filings and grant statistics of lithium and lead-acid batteries

Data was sourced in accordance with the methodologies described below.

1.1. Methodology

2014-2021 data was collected over the weeks commencing 28 February 2022 and 28 March 2022[1], except where otherwise stated.

Raw patent data was obtained from PatBase[2] by extraction using patent classification codes, except where otherwise stated.

Although the data was extracted in February and March 2022, because there is sometimes a lag in data from some patent offices reaching the databases the later data may be incomplete. Further, data may be subject to change as a result of re-assignment of classifications, which occurs periodically.

Global patent activity data was obtained from the World Intellectual Property Organization (WIPO)[3] and was only available up to 2020.

With regards to patent analysis, all patent applications are classified by their technology type according to the Cooperative Patent Classification (CPC) system.

The Cooperative Patent Classification (CPC) is an extension of the International Patent Classification (IPC) system and is jointly managed by the EPO and the US Patent and Trademark Office.[4] The CPC system has a more refined classification system and so this was the classification system of choice in extracting and manipulating the raw data.[5]

Fuel cells are classified in H01M8[6,7] and Y02E60/50. We have used those classification symbols to isolate fuel cell patent data.

[1] Data was downloaded in late February/March to allow for the database to ensure compilation of the 2021 dataset. The 2021 data may be subject to change, which will be reviewed in subsequent reports.

[2] PatBase is a commercial patent database product provided by MineSoft and RWS. It is considered to be an industry-leading database due to its coverage and data treatment protocols which seek to remove double counting of patent applications.

[3] https://www.wipo.int/publications/en/series/index.jsp?id=35

[4] https://www.epo.org/searching-for-patents/helpful-resources/first-time-here/classification/cpc.html

[5] Because classification is carried out by patent examiners, we are reliant on a correct classification being applied. Where plural classifications are applied the results will be abstracted into each data set. Accordingly, the data is likely to provide an indicator of trends rather than an absolute position.

[6] We note that WIPO accords fuel cell technology a wider classification http://www.wipo.int/classifications/ipc/en/ than simply H01M8* but cross referencing within those classifications identifies patent publications which are not fuel-cell related. Hence, we have used the more precise classification symbol than that proposed by WIPO.

[7] https://ipcpub.wipo.int/?notion=scheme&version=20220101&symbol=none&menulang=en&lang=en&viewmode=f&fipcpc=no&showdeleted=yes&indexes=no&headings=yes&notes=yes&direction=o2n&initial=A&cwid=none&tree=no&searchmode=smart

The full list of classifications used throughout the report are listed in Table 1.1.1.

Table 1.1.1. List of classification codes searched for each category.

Category	Classification Codes
Fuel Cells	H01M8, Y02E60/50
Direct Alcohol Fuel Cells and Direct Methanol Fuel Cells	H01M8/1011, Y02E60/523
Molten Carbonate Fuel Cells	H01M2008/147, Y02E60/526
Alkaline Fuel Cells	H01M8/083
Phosphoric Acid Fuel Cells	H01M8/086
Proton Exchange Membrane Fuel Cells	H01M8/1018, Y02E60/521
Solid Oxide Fuel Cells	H01M2008/1293 Y02E60/525
Mobile Fuel Cells	H01M2250/20
Stationary Fuel Cells	H01M2250/10
Portable Fuel Cells	H01M2250/30
Hydrogen Storage	Y02E60/32
Hydrogen Distribution	Y02E60/34
Hydrogen Production of Non-Carbon Containing Sources including Electrolysers	Y02E60/36

We have not truncated our search results to look only at patent applications at the European Patent Office (EPO) and US Patent & Trademark Office (USPTO), but rather have investigated the position globally and across the so-called 'Big 5' Patent Office group of China (State Intellectual Property Office – SIPO), Republic of Korea (Korean Intellectual Property Office – KIPO), Japan (Japan Patent Office – JPO), EPO and USPTO.

WIPO administers the Patent Cooperation Treaty (PCT), an international system which allows patent applicants to file a single patent application which covers approximately 153 territories worldwide.

Although patents are granted nationally, the PCT is an increasingly important system for the filing of patent applications and is included in the data, as indicated.

The list of fuel cell manufacturers and distributors was compiled from the patent statistics data.

Information on the top academic filers was obtained by filtering the results.

The data presented herein is publication data for the calendar years 2014 to 2021, with the exception that the data published by WIPO is presented for calendar years 2014 to 2020.

2. Fuel Cell Manufacturers and Distributors

The companies and organisations represented within this section are manufacturers and distributors of fuel cells.

2.1. Fuel Cell Manufacturers and Leading Research Organisations

Table 2.1.1 shows the top 20 companies and organisations identified in this review for filing fuel cell patent applications and the sector in which they operate.

Table 2.1.1. List of global fuel cell manufacturers and leading research organisations.

Name	Country	Sector
Toyota	Japan	Automotive
Hyundai	South Korea	Automotive
Honda	Japan	Automotive
Kia	South Korea	Automotive
Nissan	Japan	Automotive
General Motors (GM) Global Tech Operations	USA	Automotive
LG (Including LG Chemical Ltd and LG Fuel Cell Systems)	South Korea (HQ), USA, UK	Electronics
JX Nippon	Japan	Energy
Korea Research Institute (Including Inst of Ceramic, Eng and Tech, Inst Energy Research, Inst Mach and Materials, Inst Science and Tech, Inst Industrial Tech)	South Korea	Research
Panasonic	Japan	Electronics
Samsung	South Korea	Electronics
Commissariat Energie Atomique	France	Energy Research
Intelligent Energy	UK	Fuel Cells
Bloom Energy Corp	USA	Fuel Cells
Audi AG	Germany	Automotive
Dalian Inst Chem and Phys CAS	China	Research
Ford Motor Co	USA	Automotive
NGK (including NGK Spark Plug Co and NGK Insulators)	Japan	Electronics
Bosch GMBH	Germany	Engineering & Energy Tech
Volkswagen	Germany	Automotive

When looking at granted patents, the top 20 companies and organisations identified in this review differ from those of filed fuel cell patent applications (Table 2.1.1) only in two cases: Kyocera Corp and Daimler AG take the place of Dalian Inst Chem and Phys CAS and Volkswagen. The sector in which these additional two companies operate can be found in Table 2.1.2. The remaining 18 companies and organisations are the same for both published fuel cell applications and granted fuel cell patents.

Table 2.1.2. List of global fuel cell manufacturers and leading research organisations.

Name	Country	Sector
Kyocera Corp	Japan	Electronics
Daimler AG	Germany/USA	Automotive

2.2. Geographical Distribution

Turning to Figure 2.2.1, it is evident that Japan and South Korea have the largest presence amongst the top 20 distributors and manufacturers within the fuel cell sector, in terms of both manufacturers of published fuel cell patent applications (blue bars) and granted fuel cell patents (grey bars). Whilst countries such as the UK feature only one company within the top 20 distributors and manufacturers of fuel cells, they are a prominent entity (Intelligent Energy).

Figure 2.2.1: Top 20 Distributors and Manufacturers by country.

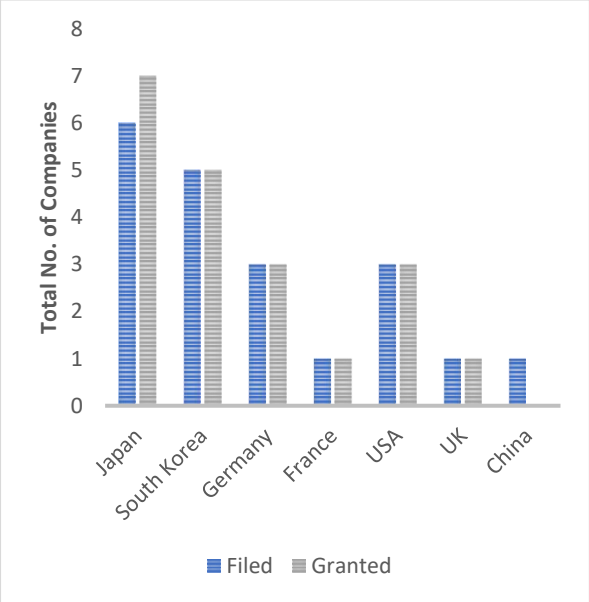
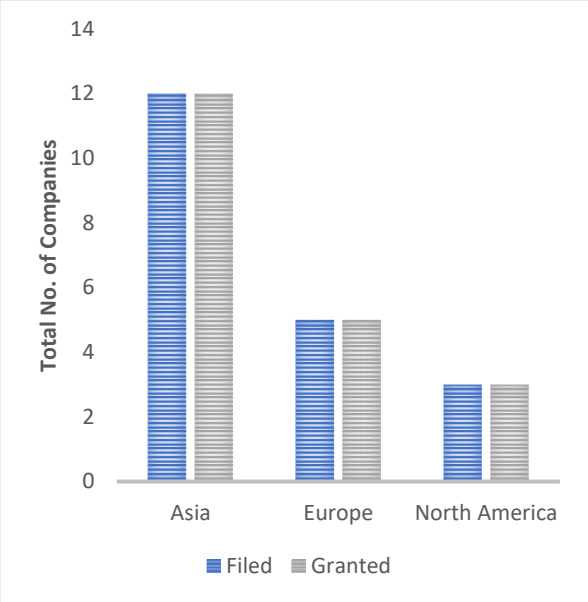


Figure 2.2.2: Top 20 Distributors and Manufacturers by continent.



Globally, 12 of the top 20 fuel cell companies of published applications and granted patents are located in Asia (Figure 2.2.2), with the rest of the top 20 companies located in Europe and North America.

3. Patent Analysis

3.1. Setting the Scene

To assist in quantifying patent activity in the fuel cells area, we first present data showing overall patent activity for the years 2014 to 2020.

Patent applications are typically published 18 months after filing. Although some applications are undoubtedly abandoned between filing and publication (and hence do not reach the public domain), the number of published patent applications provides an indication of the patent application filing position (with an 18-month lag).

Figure 3.1.1: Published total patent applications vs. published PCT patent applications for 2014 to 2020.

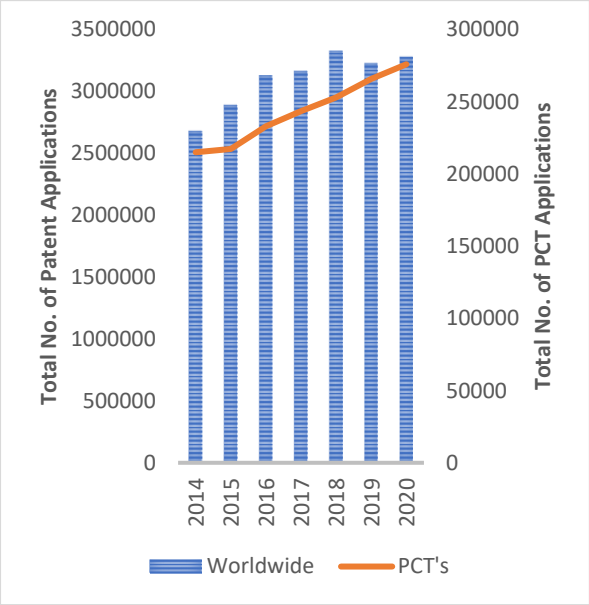


Figure 3.1.2: Published patent applications by top 5 offices for the years 2014 to 2020.

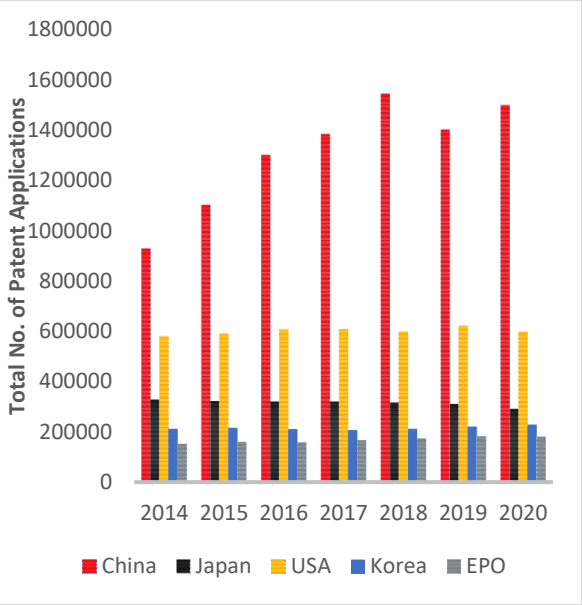


Figure 3.1.1 shows both the total number of patent applications published worldwide (blue bars) and those pursued via the PCT route (orange line) have risen year-on-year between 2014 and 2018. Whilst the number of PCT patent applications continues to rise between 2019 and 2021, the total number of patent applications published worldwide showed a marginal decline in 2019 and a subsequent increase in 2021.

The patent offices worldwide which are considered the most important, and which receive the largest numbers of filings, are those of China, Japan, the USA, Europe and the Republic of Korea. Figure 3.1.2 shows that whilst the trends in the number of published patent applications vary between the top 5 offices, their position relative to one another remains unchanged. China is the stand-out growth territory in terms of the absolute number of published patent applications, with the increase in filings attributed to both an increase in filings by Chinese residents and overseas innovators seeking local protection. We believe the increased growth in China is at least in part accounted for by the government initiatives, which provide various subsidies and other incentives. However, many Chinese businesses do not file patent applications in countries outside of China, which accounts for the lower relative increase in PCT filings, despite it becoming an ever more popular route for applicants.

3.2. Fuel Cell Patent Activity

3.2.1. Filing Statistics

Figure 3.2.1 shows the annual publication of fuel cell patents (orange line) in comparison to the total published patent application data (blue bars).

Figure 3.2.1: Published total patent applications vs. published fuel cell patent applications for 2014 to 2020.

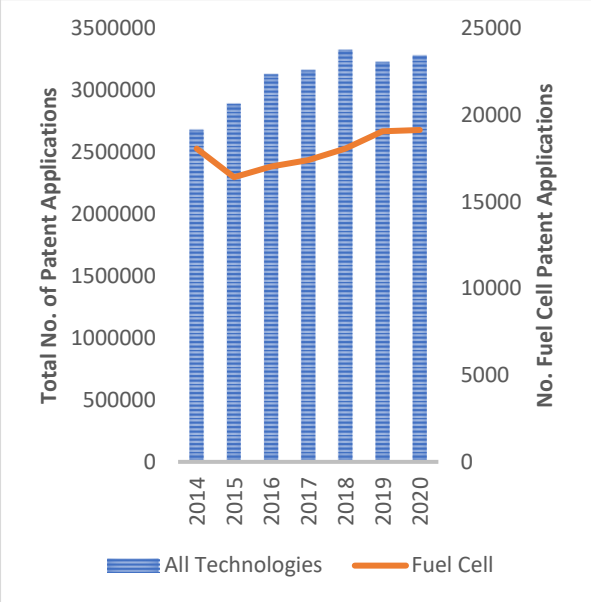
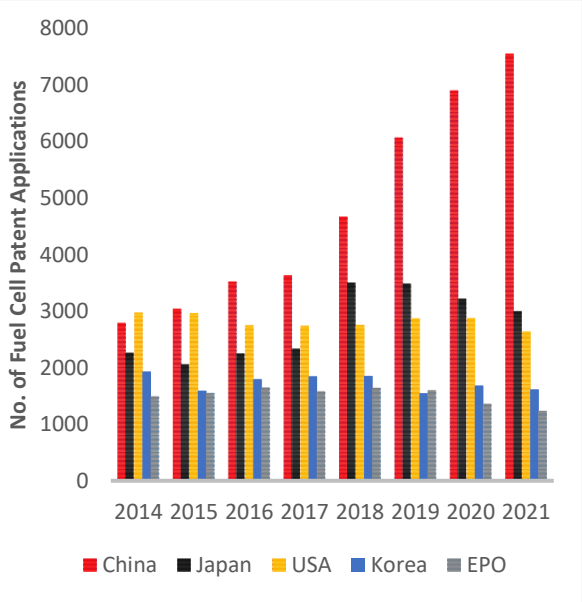


Figure 3.2.2: Published fuel Cell patent applications for the top 5 Patent Offices for 2014 to 2021.[8]



The total number of patent filings increased annually between 2014 and 2018, with slight decreases observed in 2019 and 2020. These decreases may be attributed to the impact of COVID-19.

Similarly, the number of fuel cell patent filings increased between 2015 and 2019 and was shown to level-off in 2020. Again, the lack of an increase in filings in 2020 may be attributed to the impact of COVID-19.

The publication data for fuel cell applications published at the top 5 offices between 2014 and 2021 is shown in Figure 3.2.2.

A large increase in filings at the Chinese patent office is observed between 2014 and 2021. In contrast, filings at the Japanese patent office, US Patent Office, Chinese Patent Office and Korean Patent Office remain relatively stable over the period.

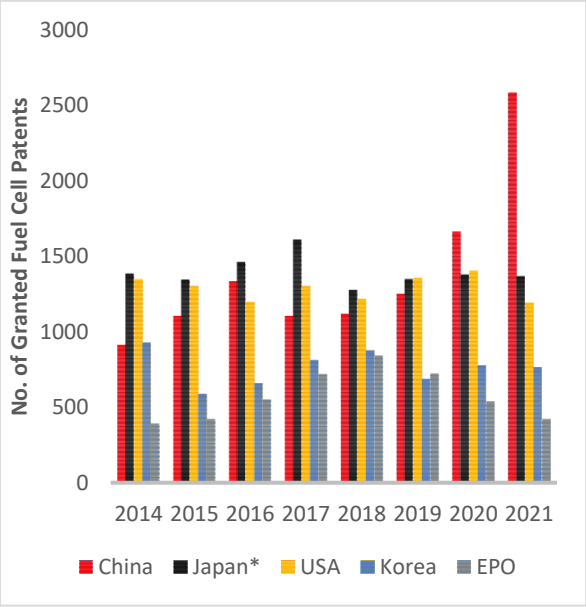
It is clear that the Chinese Patent Office is becoming an increasingly important office for publishing fuel cell patent applications. This has implications both for fuel cell business wanting to operate in China and for all patent applications when considering prior art searching because of the increasing amount of prior art available only (or perhaps for the first time) in the Chinese language.

[8] 2014-2017 data for JP was obtained from Espacenet on 17 May 2022 using the appropriate patent classification codes.

3.2.2. Granted Fuel Cell Patents

The number of patents granted is not an effective metric for determining the growth of research and development of fuel cell technology because grant of patents is, at least in part, under the authority of the examiners and the local law under in which they operate. However, it is a useful metric for businesses because it is granted patents which principally affect a business' freedom-to-operate in a specific territory.

Figure 3.2.3: Granted fuel Cell patents for the top 5 Patent Offices for 2014 to 2021.[8]



Similar trends to the published fuel cell applications are observed with the number of granted fuel cell patents.

The Chinese Patent Office has become an increasingly important territory for granting fuel cell patents since 2019. Businesses wishing to commercialise their fuel cell technology world-wide must continue to consider their patent position in all of the top five patent offices.

3.2.3. Assignee Data

The data presented below shows the top 10 filers of patent applications (Figure 3.2.4) and granted patents (Figure 3.2.6) in the area of fuel cells recorded annually from 2014 to 2021 at the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

The top 10 filers for both the published fuel cell applications and the granted fuel cell patents predominantly comprise the same entities. The top 10 lists are dominated by large Japanese corporations, with Toyota steadily in the leading position. Automotive companies dominate the statistics.

3.2.3.1. Filing Statistics

The overall top 10 filers of published fuel cell patent applications for the years 2014 to 2021 are shown in Figure 3.2.4.

Figure 3.2.4: Top ten filers of published fuel Cell patent applications at the top 5 Patent Offices for 2014 to 2021.

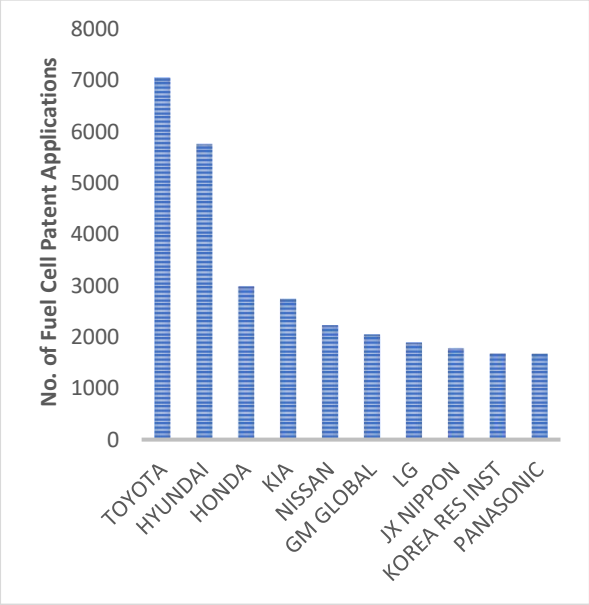
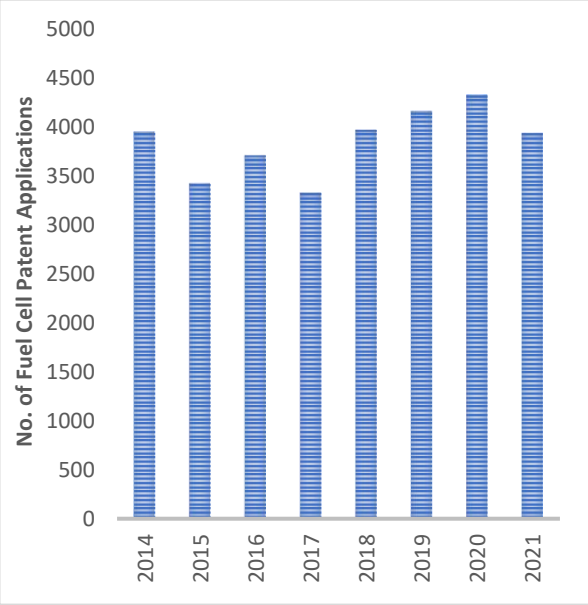


Figure 3.2.5: Number of patent applications published by top 10 filers for the years 2014 to 2021.



As expected, the top 10 are dominated by Japanese and South Korean corporations, with the US (General Motors (GM) Global Tech Operations) making up the remainder.

Toyota appears to be the dominant filer of fuel cell patent applications, with Hyundai taking second place for the period 2014 to 2021. This demonstrates that South East Asian automotive businesses are consistently leading the way in patent filings and, it would be imagined, in fuel cell R&D activity.

Figure 3.2.5 shows the cumulative number of fuel cell patent applications published by the top 10 filers from 2014 to 2021. The overall number of published fuel cell patent applications of the top 10 filers fluctuates around 3300. The data shows stability in the number of fuel cell patents published by the top 10 filers.

3.2.3.2. Granted Fuel Cell Patents

The overall top 10 filers of granted fuel cell patents for the years 2014 to 2021 are shown in Figure 3.2.6.

Figure 3.2.6: Top ten filers of published fuel Cell patent applications at the top 5 Patent Offices for 2014 to 2021.

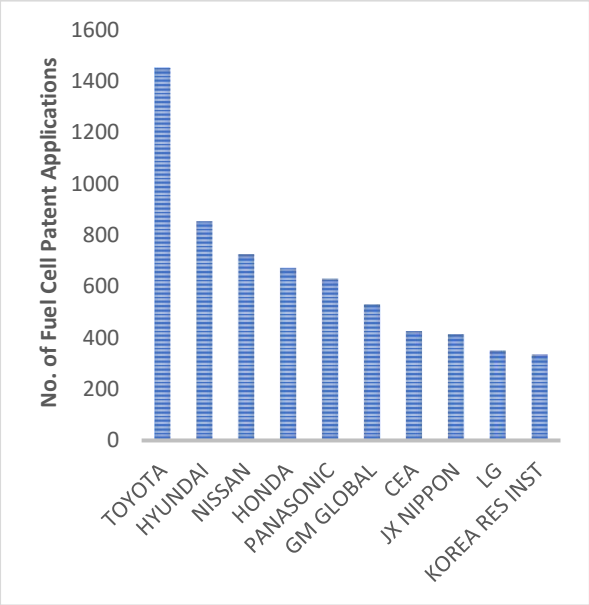
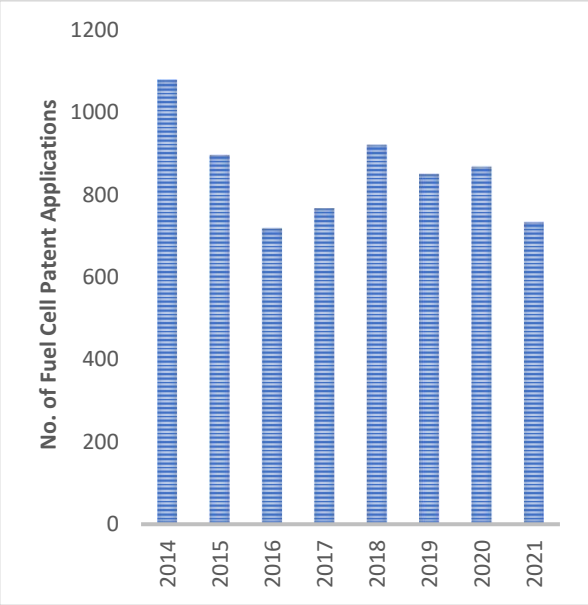


Figure 3.2.7: Number of patent applications published by top 10 filers for the years 2014 to 2021.



The trend in statistics relating to the number of granted fuel cell patents of the top 10 filers largely reflects that of the published patent applications, shown in Figure 3.2.4.

There is only one change in the top 10 filers between publication and granted fuel cell patents, with CEA taking the place of KIA.

Toyota remains dominant, retaining the position of top filer in every year between 2014 and 2021 except for 2016 where it is second only to Hyundai.

Unsurprisingly, given the filing statistics, Toyota, Nissan, Hyundai, Panasonic and CEA feature in the top 10 patentees annually.

Figure 3.2.7 shows the cumulative number of fuel cell patents granted by the top 10 filers from 2014 to 2021. The overall number of granted fuel cell patent applications of the top 10 filers fluctuates around 800.

3.2.4. Academic Patent Filers

3.2.4.1. Geographic Distribution

The geographical distribution of the top 20 university filers of both published fuel cell patent applications (blue bars) and granted fuel cell patents (grey bars), for the years 2014 to 2021, are shown in Figures 3.2.8 and 3.2.9.

Out of the universities which filed fuel cell patent applications in the period 2014 to 2021, Chinese universities are by far the most dominant, accounting for over half of the top 20 university filings (Figure 3.2.8). In comparison, the USA and South Korea are the leading university recipients of granted fuel cell patents for the period 2014 to 2021 (Figure 3.2.8), which likely indicates that these Universities have been filing patent applications in this space for a longer time than Chinese Universities.

Figure 3.2.8: Top 20 university fuel Cell applications by country.

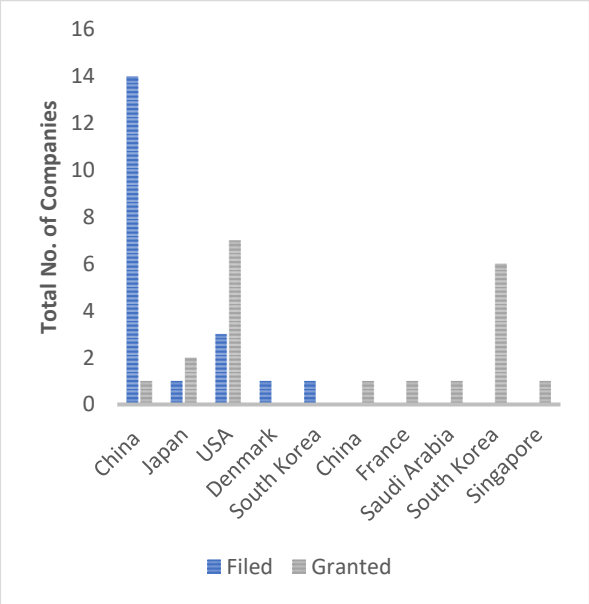
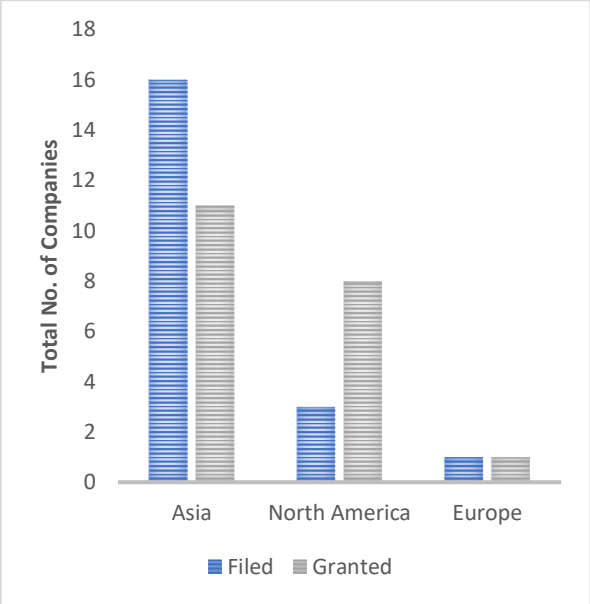


Figure 3.2.9: Distribution of the top 20 university fuel Cell patent applicants by continent.



Asia is the dominant continent in terms of the publication and grant of academic fuel cell patents. Globally, 80% of the top 20 university filers of fuel cell patent applications and 55% of the top 20 university filers of granted fuel cell patents are located in Asia (Figure 3.2.9).

Given that many universities do not progress patent applications to grant for various reasons, it is notable that the major academic players in this space consistently seek to obtain granted patents. This may be due to close ties with commercial entities in the countries of interest.

3.2.4.2. Filing Statistics

The data presented below shows the top 10 university filers of patent applications (Figure 3.2.10) in the area of fuel cells recorded annually (from 2014 to 2021). In each case the bars show the absolute number of patent applications or patents associated with each University.

Figure 3.2.10: Top ten university filers of fuel Cell patent applications at the top 5 Patent Offices for 2014 to 2021.

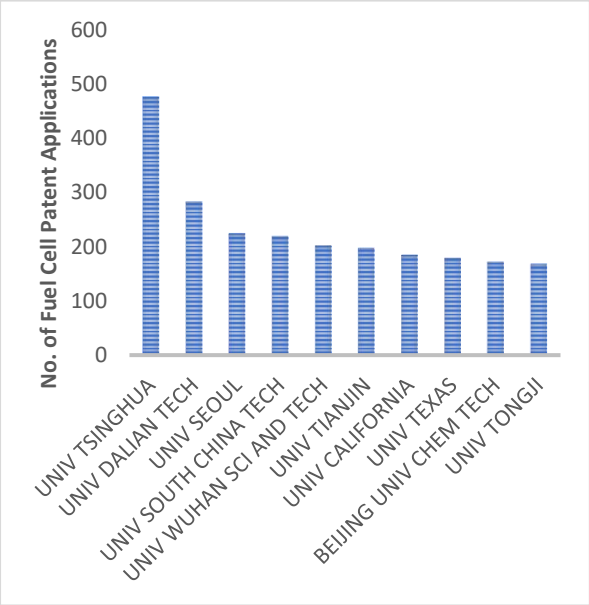
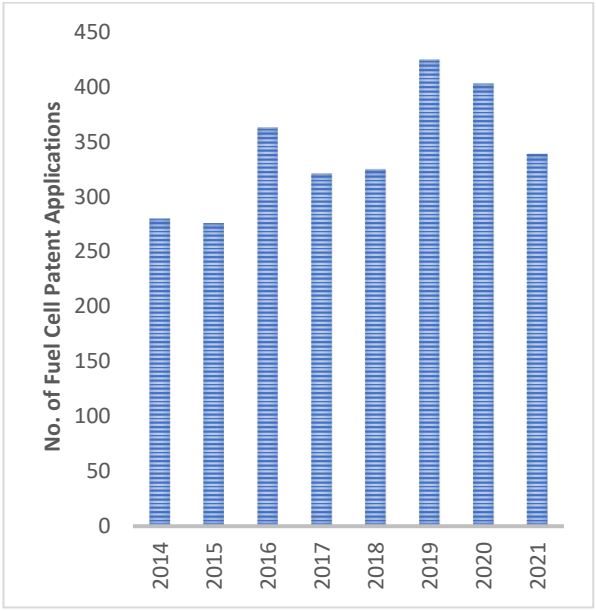


Figure 3.2.11: Number of patent applications published by top 10 university filers for the years 2014 to 2021.



The top 10 academic filers are dominated by Chinese universities.

The University of Tsinghua is the leading university filer of fuel cell patent applications.

The University of Tsinghua appears to be, worldwide, the most dominant filer of fuel cell applications, featuring in the top three university filers annually from 2014 to 2021. However, there is a great variance in the number of filings reported with a low of 44 in 2017 and a high of 89 in 2019.

Figure 3.2.11 shows the cumulative number of fuel cell patent applications published by the top 10 university filers from 2014 to 2021.

The number of published fuel cell patent applications of the top 10 filers showed an overall increase from 2014 to 2019. However, a notable decline in the number of fuel cell patent applications published by the top 10 universities was seen in 2020 and again in 2021. The decline in fuel cell applications from 2019 to 2020 appears to be a cumulative effect and is not simply accounted for by a large decrease from a single entity. This decrease may be attributed to the impact of COVID-19.

3.2.4.3. Granted Fuel Cell Patents

The overall top 10 university filers of granted fuel cell patents for the years 2014 to 2021 is shown in Figure 3.2.12.

Figure 3.2.12: Top ten university filers of granted fuel Cell patents at the top 5 Patent Offices for 2014 to 2021.

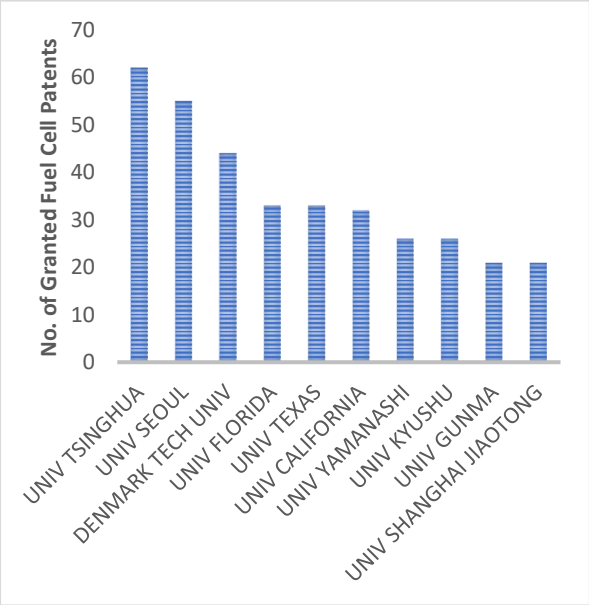
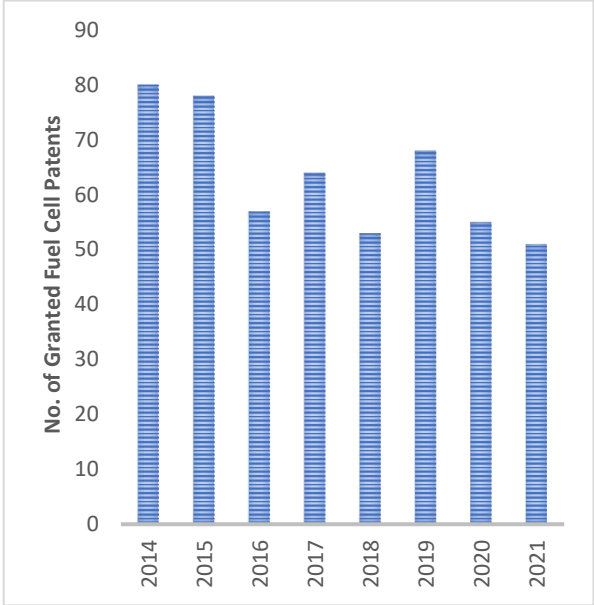


Figure 3.2.13: Number of patents granted to the top 10 university filers for the years 2014 to 2021



The trend in patent statistics relating to the number of granted fuel cell patents of the top 10 university filers largely reflect that of the published patent applications, shown in Figure 3.2.10. The University of Tsinghua remains in first place.

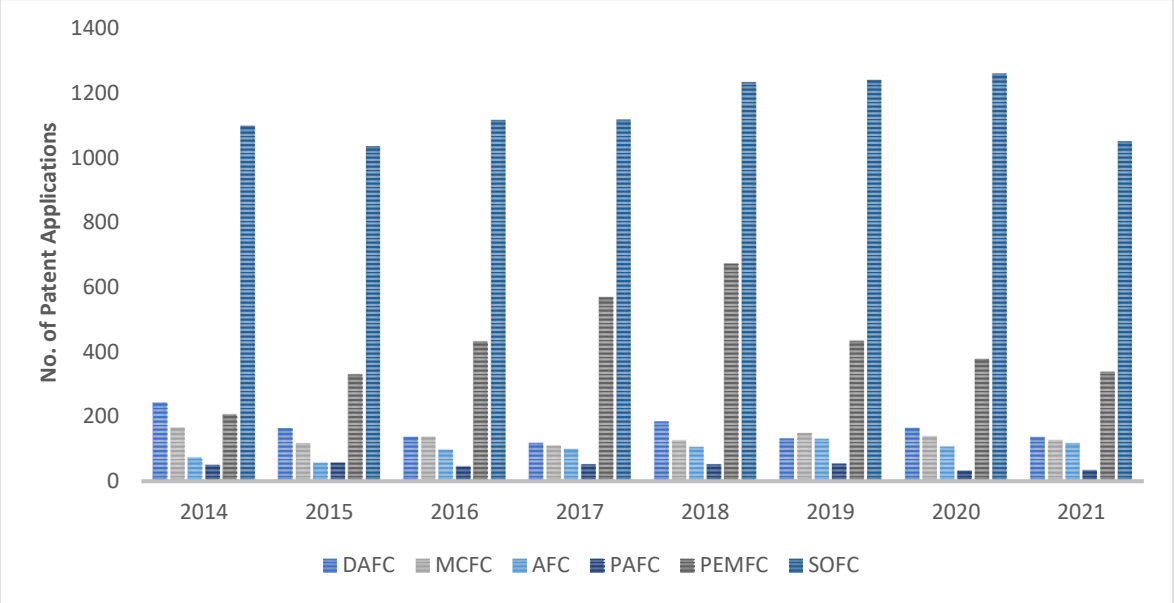
Figure 3.2.13 shows the cumulative number of fuel cell patents granted by the top 10 university filers from 2014 to 2021.

Whilst fluctuations in the numbers of granted fuel cell patents are observed (Figure 3.2.13), there is a notable decline between the numbers reported between 2019 and 2021, as observed with the number of published fuel cell applications (Figure 3.2.11).

3.3. Fuel Cell Chemistry

The data presented below compares filing statistics according to fuel cell chemistry. The fuel cell chemistries analysed in this section include: direct alcohol fuel cells (DAFCs), molten carbonate fuel cells (MCFCs), alkaline fuel cells (AFCs), phosphoric acid fuel cells (PAFCs), proton exchange membrane (PEMFCs) and solid oxide fuel cells (SOFCs).

Figure 3.3.1: Total patent applications at the top 5 patent offices for 2014 to 2021.[8]



The data clearly shows that applications for SOFCs dominate the fuel cell chemistry sector, with PEMFCs being the second most popular. The data also shows that across the board there has been stabilisation in the number of patent applications being filed worldwide for these specific fuel cell types, perhaps because of the maturity of the sector.

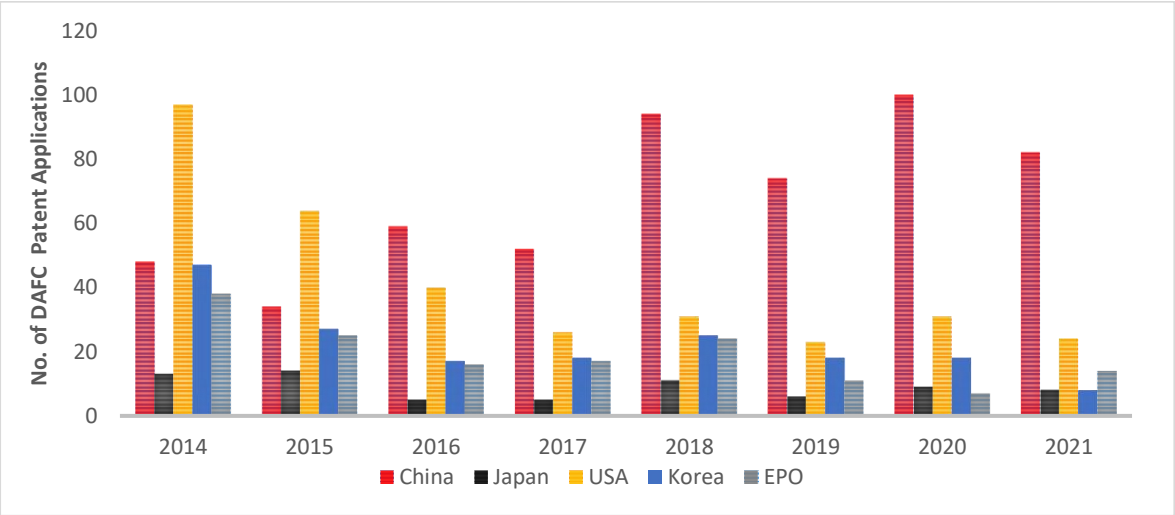
The following data presents the number of patent applications filed, according to fuel cell chemistry, for the years 2014 to 2021, at the top 5 offices.

Also presented are the top 10 filers of patent applications for each of the individual fuel cell chemistries, for the years 2014 to 2021, for each of the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

3.3.1. Direct Alcohol Fuel Cells

Figure 3.3.2 shows the total patent filings for direct alcohol fuel cells across the top 5 patent offices.

Figure 3.3.2: Direct alcohol fuel cell patent applications for 2014 to 2021.[8]



The data shows that filings at the USPTO, EPO and KPIO were historically highest in 2014 but that interest in filing patent applications in this technology has significantly waned over the following years. However, the number of DAFC patent applications filed at the SIPO shows an overall increase over the period, with the highest number of filings recorded in 2020.

Figure 3.3.3 shows the top 10 assignees of DAFC patent applications, e.g. direct methanol fuel cells, for the top 5 offices over the period 2014 to 2021. The top filers are dominated by Korean entities.

Figure 3.3.4 shows the cumulative number of DAFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021. Whilst fluctuations in the numbers of published DAFC patent applications are observed (Figure 3.3.4), there is a notable overall decline between 2014 and 2021.

Figure 3.3.3: Top ten filers of DAFC patent applications at the top 5 Patent Offices for 2014 to 2021.

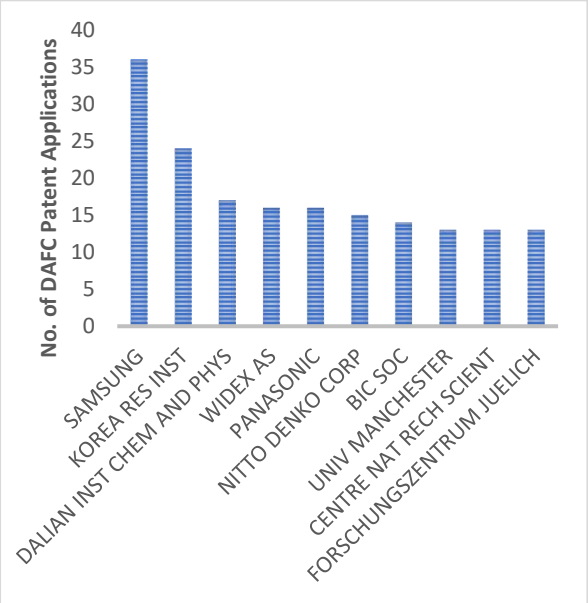
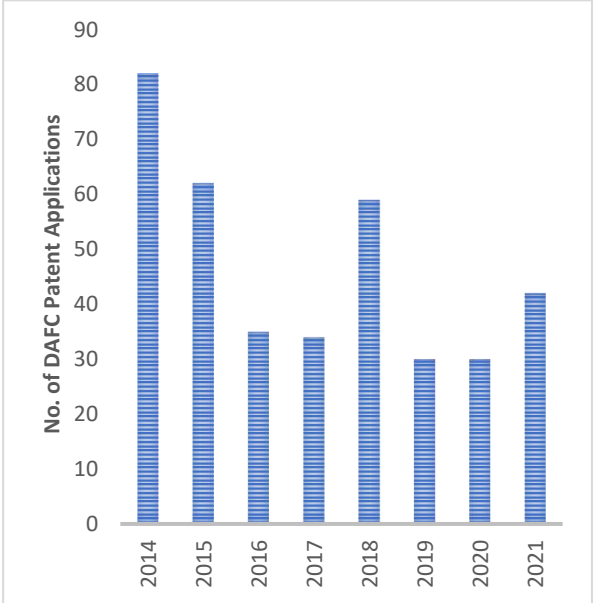


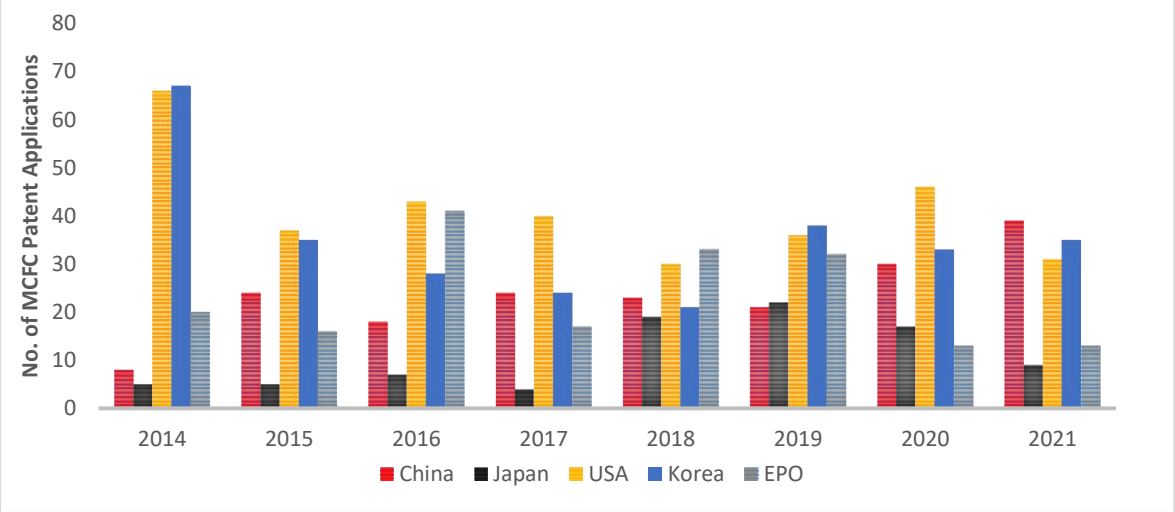
Figure 3.3.4: Number of DAFC patent applications published by the top 10 filers for the years 2014 to 2021.



3.3.2. Molten Carbonate Fuel Cells

Figure 3.3.5 shows the total patent filings for molten carbonate fuel cells across the top 5 patent offices.

Figure 3.3.5: Molten carbonate fuel cell patent applications for 2014 to 2021.[8]



The data shows that filings at the USPTO and KIPO, were historically the highest in 2014 but that interest in filing patent applications in this technology in these jurisdictions has significantly waned over the following years. The SIPO, JPO and EPO show fluctuations in the number of patent filings over the period 2014 to 2021.

Figure 3.3.6 shows the top 10 assignees of MCFC patent applications for the top 5 offices over the period 2014 to 2021. The top filers are FuelCell Energy Inc (USA) and Exxon Mobil (USA).

Figure 3.3.7 shows the cumulative number of MCFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021. Whilst filings of MCFC applications by the top 10 filers were highest in 2014, the number of filings fluctuates around 90 for the period 2015 to 2021 (Figure 3.3.7).

Figure 3.3.6: Top ten filers of MCFC patent applications at the top 5 Patent Offices for 2014 to 2021.

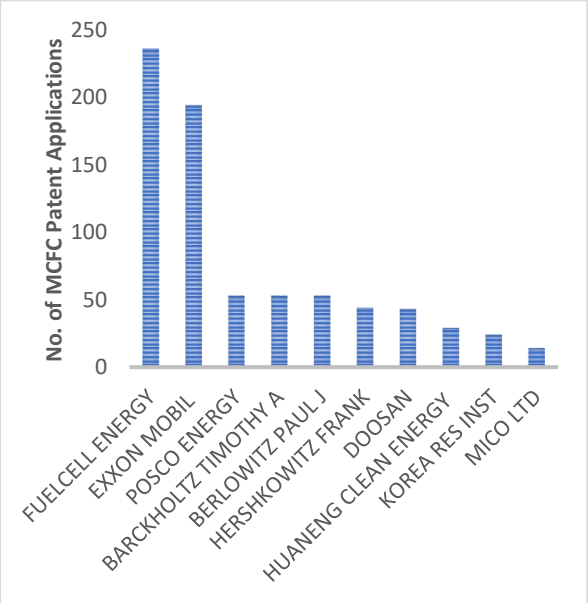
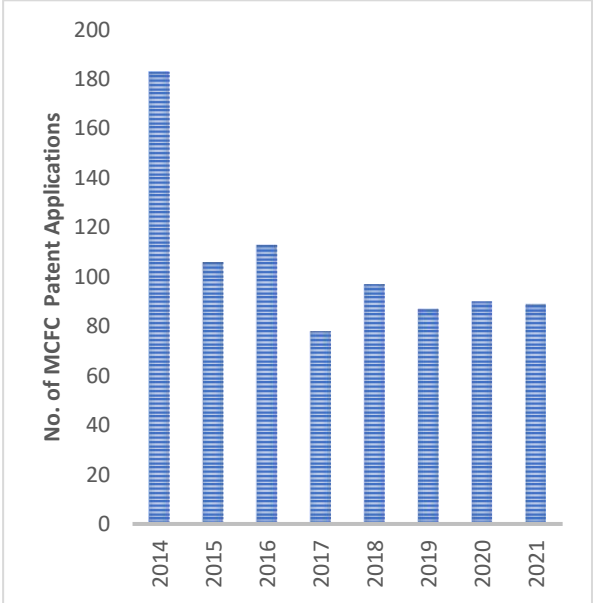


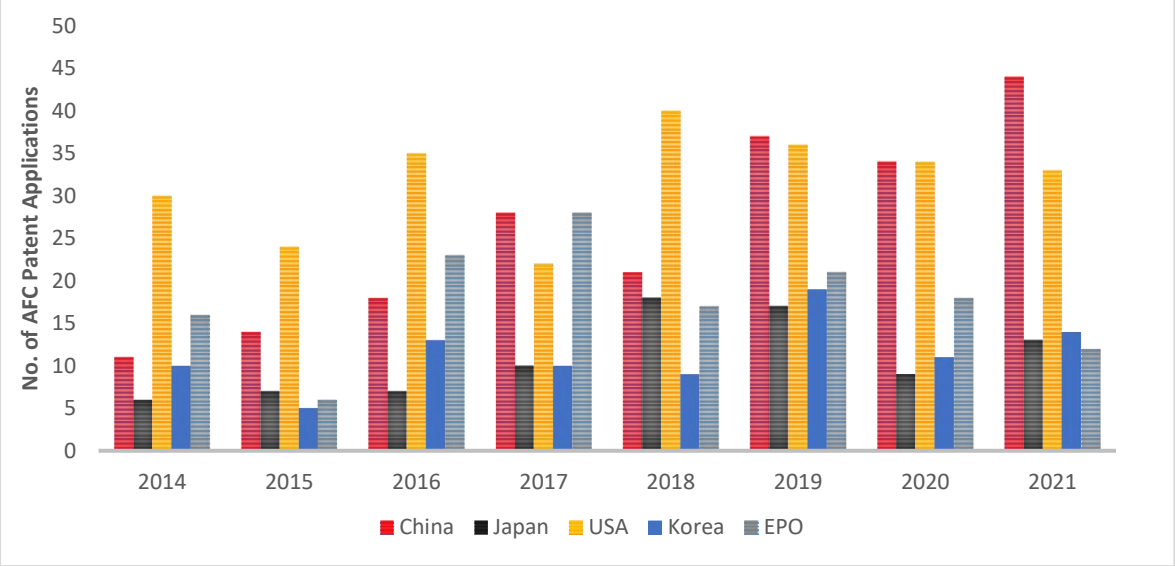
Figure 3.3.7: Number of MCFC patent applications published by the top 10 filers for the years 2014 to 2021.



3.3.3. Alkaline Fuel Cells

Figure 3.3.8 shows the total patent filings for alkaline fuel cells across the top 5 patent offices.

Figure 3.3.8: Alkaline fuel cell patent applications for 2014 to 2021.[8]



All 5 offices show variations in the number of AFC patent applications published between 2014 and 2021. However, despite the fluctuation in the number of filings, the USPTO and SIPO appear to be the most important filing jurisdictions for this technology.

Figure 3.3.9 shows the top 10 assignees of AFC patent applications for the top 5 offices over the period 2014 to 2020. The top filers are BASF Corp (USA), Aquahydrex Pty Ltd (Australia) and NGK (Japan).

Figure 3.3.10 shows fluctuations in the cumulative number of AFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.3.9: Top ten filers of AFC patent applications at the top 5 Patent Offices for 2014 to 2021.

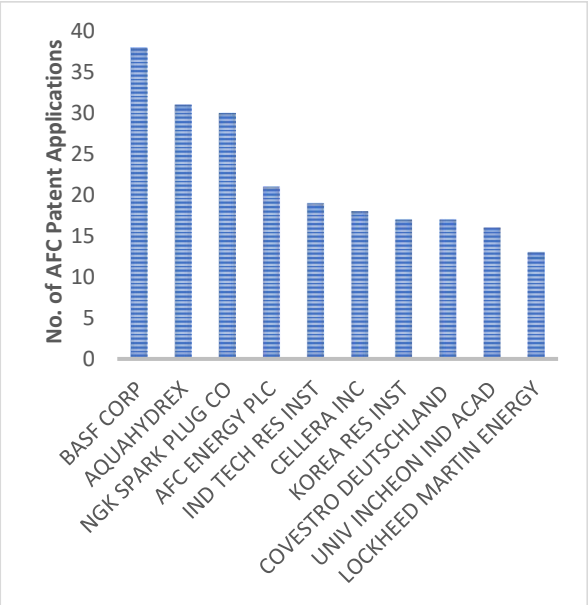
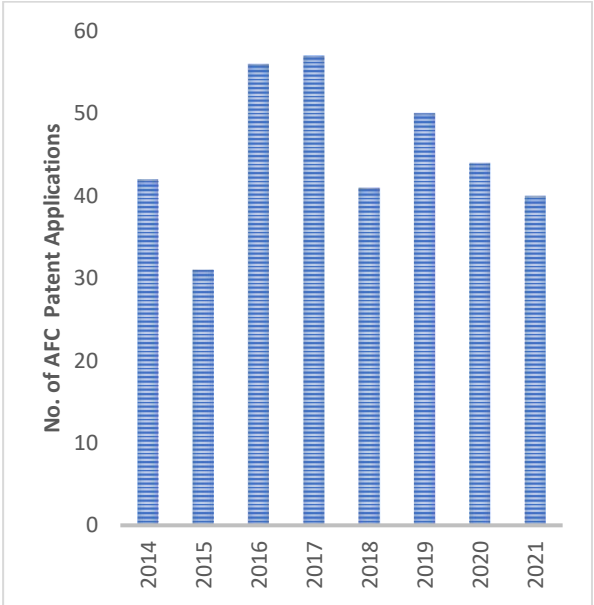


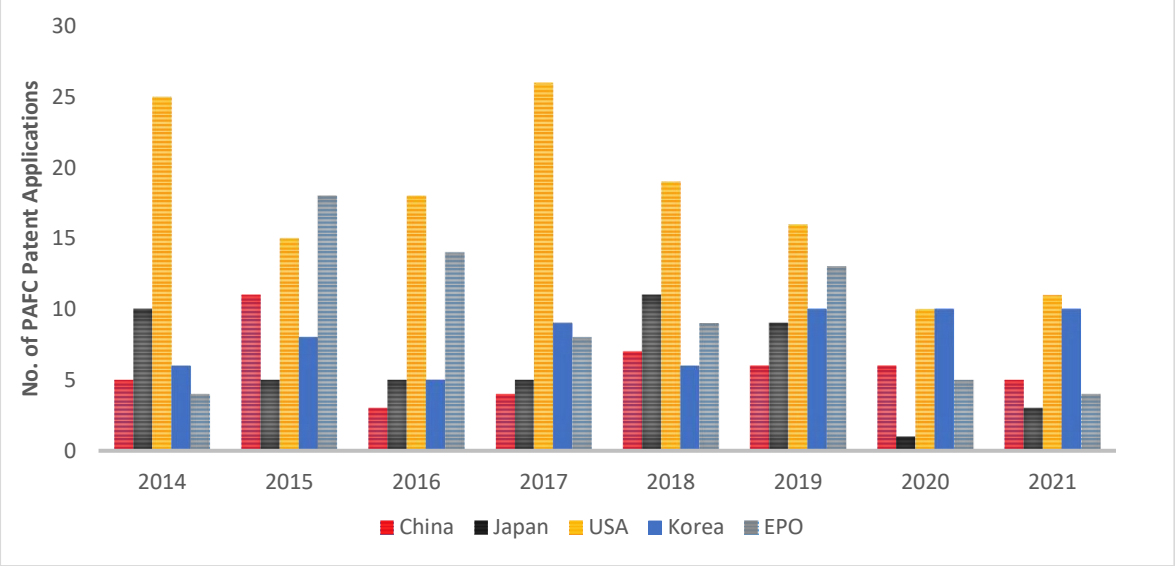
Figure 3.3.10: Number of AFC patent applications published by the top 10 filers for the years 2014 to 2021.



3.3.4. Phosphoric Acid Fuel Cells

Figure 3.3.11 shows the total patent filings for phosphoric acid fuel cells across the top 5 patent offices.

Figure 3.3.11: Phosphoric acid carbonate fuel cell patent applications for 2014 to 2021.[8]



All 5 offices show variations in the number of PAFC patent applications published between 2014 and 2021 by the top filers. Despite an overall decline over the period 2014 to 2021, the USPTO again appears to be the most important filer.

Figure 3.3.12 shows the top 10 assignees of PAFC patent applications for the top 5 offices over the period 2014 to 2021. Doosan (Korea) are by far the leading filers of PAFC patent applications.

Figure 3.3.13 shows fluctuations in the cumulative number of PAFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.3.12: Top ten filers of PAFC patent applications at the top 5 Patent Offices for 2014 to 2021.

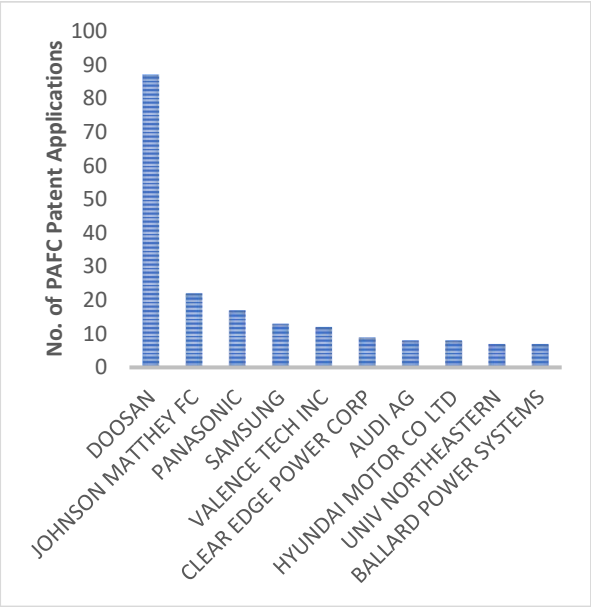
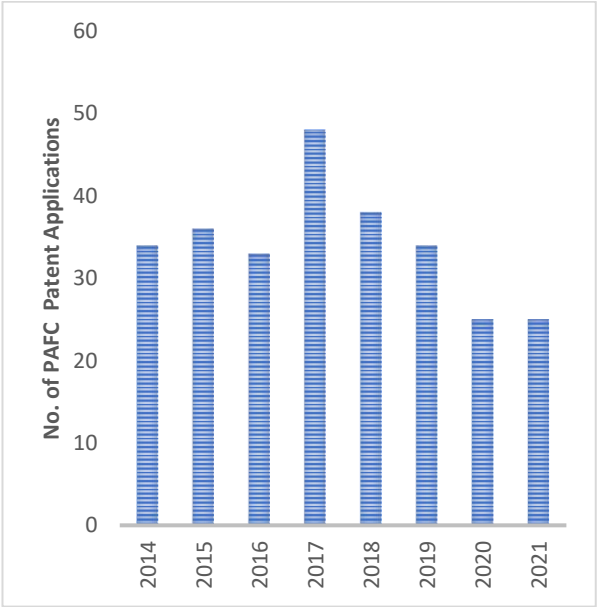


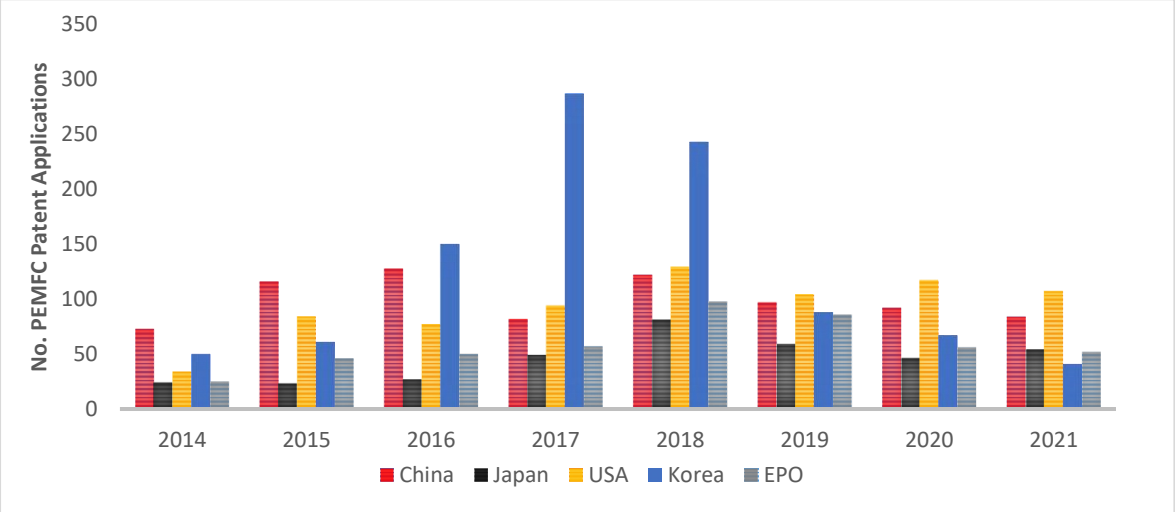
Figure 3.3.13: Number of PAFC patent applications published by the top 10 filers for the years 2014 to 2021.



3.3.5. Proton Exchange Membrane Fuel Cells

Figure 3.3.14 shows the total patent filings for proton exchange membrane fuel cells across the top 5 patent offices.

Figure 3.3.14: Proton exchange membrane fuel cell patent applications for 2014 to 2021.[8]



All 5 offices show variations in the number of PEMFC patent applications published between 2014 and 2021.

Figure 3.3.15 shows the top 10 assignees of PEMFC patent applications for the top 5 offices over the period 2014 to 2021. Many of the top 10 filers come from the automotive sector, with Toyota (China, USA and Japan) the overall top filer.

Figure 3.3.16 shows fluctuations in the cumulative number of PEMFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.3.15: Top ten filers of PEMFC patent applications at the top 5 Patent Offices for 2014 to 2021.

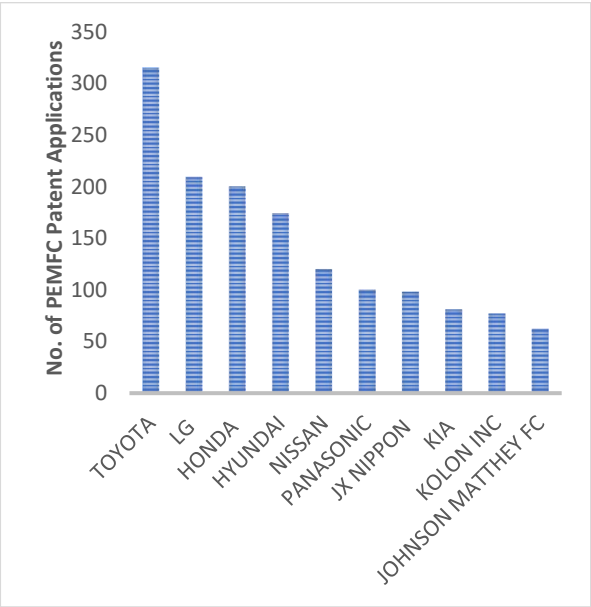
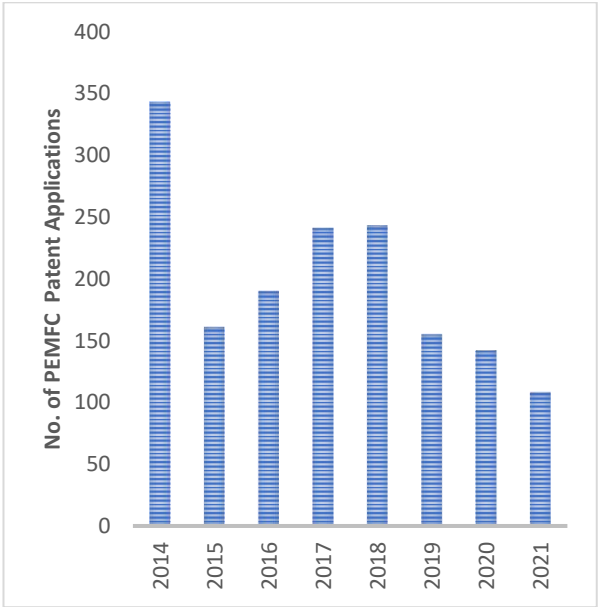


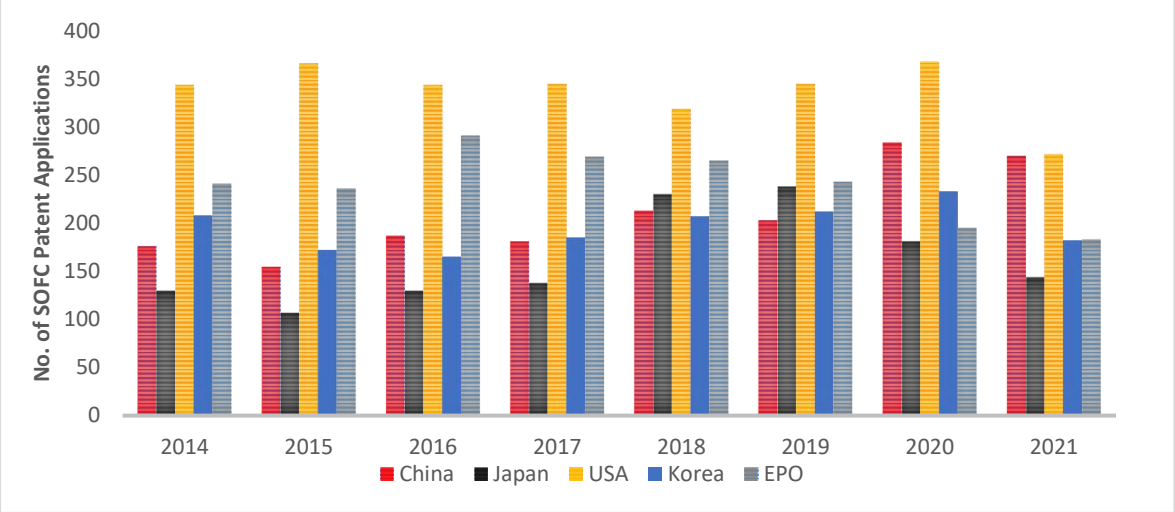
Figure 3.3.16: Number of PEMFC patent applications published by the top 10 filers for the years 2014 to 2021.



3.3.6. Solid Oxide Fuel Cells

Figure 3.3.17 shows the total patent filings for solid oxide fuel cells across the top 5 patent offices.

Figure 3.3.17: Solid oxide fuel cell patent applications for 2014 to 2021.[8]



As observed with the number of PEMFC patent filings (Figure 3.3.14), all 5 offices show variations in the number of SOFC patent applications published between 2014 and 2021.

Figure 3.3.18 shows the top 10 assignees of MCFC patent applications for the top 5 offices over the period 2014 to 2021. The top filers are NGK (Japan) and LG (Korea).

Figure 3.3.19 shows the cumulative number of MCFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021. Whilst filings of MCFC patent applications by the top 10 filers were historically highest in 2014, an overall decrease in published MCFC patent applications by the top 10 filers is observed between 2015 and 2021 (Figure 3.3.19).

Figure 3.3.18: Top ten filers of SOCFC patent applications at the top 5 Patent Offices for 2014 to 2021.

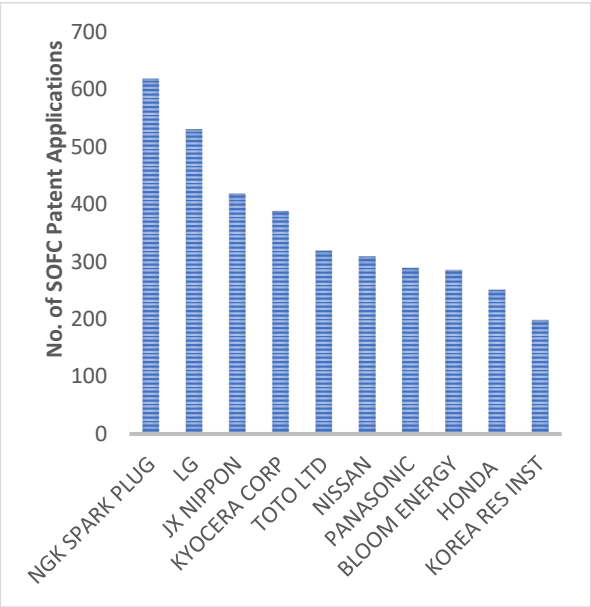
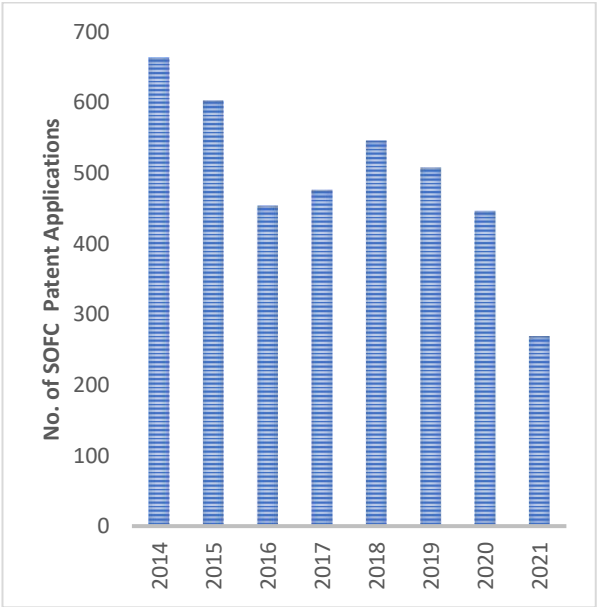


Figure 3.3.19: Number of SOCFC patent applications published by the top 10 filers for the years 2014 to 2021.



3.3.7. Summary

The number of filings within each sector appears to fluctuate across the period, with an overall marginal decline in the number of filings.

SOFCs dominate the fuel cell chemistry sector. However, even this sector shows a decline in patent filings between 2020 and 2021.

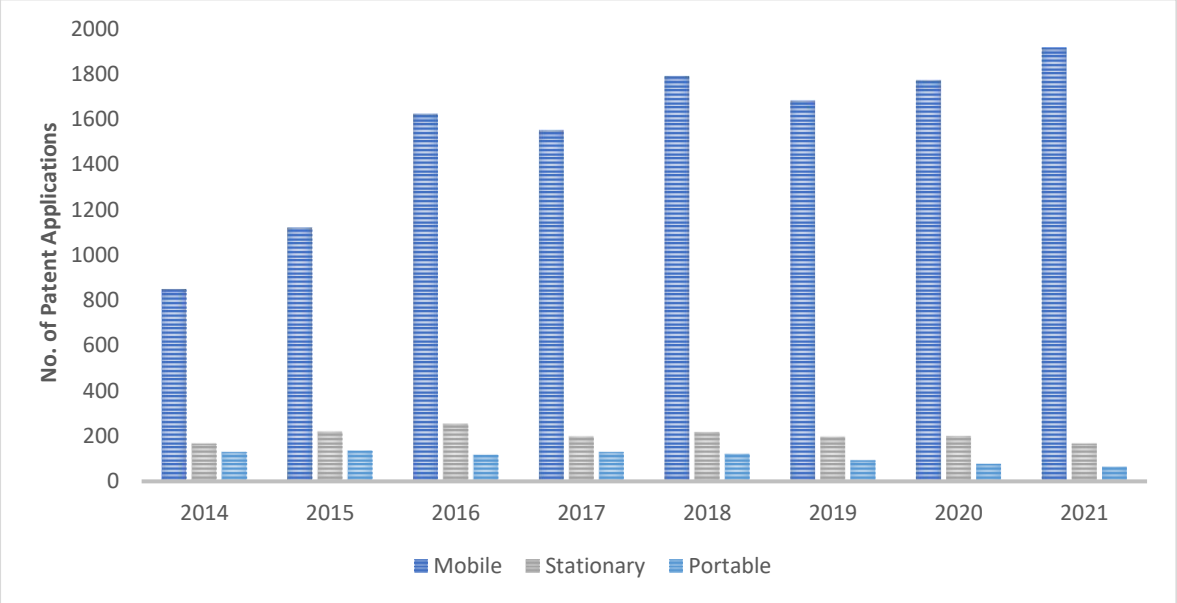
This decrease may be as a result of the later data sets being incomplete or it may be attributed to the impact of COVID-19.

3.4. Fuel Cell Deployment

The data presented below compares filing statistics according to fuel cell deployment, consisting of: mobile fuel cells, stationary fuel cells and portable fuel cells.

Figure 3.4.1 shows the change in total filings across the period at the top five offices for each of the fuel cell types.

Figure 3.4.1: Total patent applications at the top 5 patent offices for 2014 to 2021.[8]



The data in Figure 3.4.1 clearly shows that applications for mobile fuel cells dominate, with stationary and portable fuel cells being far behind. It is notable that total filings in mobile fuel cells appears to be fairly robust across the period whereas filings for stationary and portable fuel cells appear to be on the decline. We speculate that this may relate to improvements in battery technologies which are obvious technological competitors in portable applications, at least.

The following data presents the number of patent applications filed, according to fuel cell deployment, or the years 2014 to 2021, at the top 5 offices.

Consistently, the USPTO appears to be the office handling the most patent applications for fuel cell deployment.

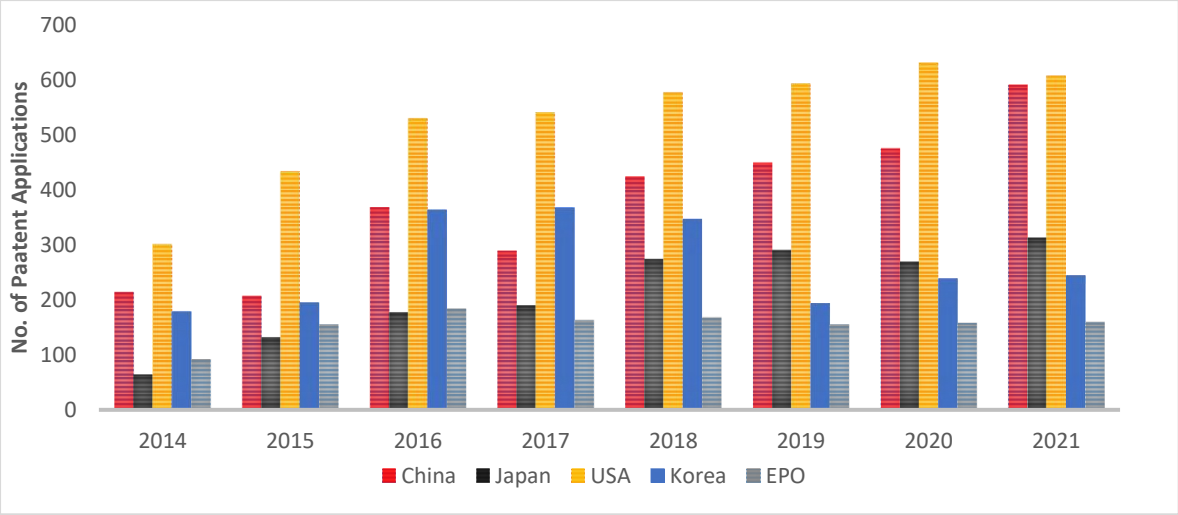
Also presented are the top 10 filers of patent applications for mobile, stationary and portable fuel cell, for the years 2014 to 2021, for each of the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

Along with automotive companies such as Toyota and Hyundai, Exxon Mobil and Panasonic feature highly in the top 10 assignees.

3.4.1. Mobile Fuel Cells

Figure 3.4.2 shows the total patent filings for mobile fuel cells across the top 5 patent offices.

Figure 3.4.2: Mobile fuel cell patent applications for 2014 to 2021.[8]



Over the period, the USPTO appears to be publishing a greater number of mobile fuel cell patent applications than the other major offices, with the EPO publishing the least. Filings at the SIPO have increased significantly over the period 2014 to 2021.

Figure 3.4.3 shows the top 10 assignees of mobile fuel cell patent applications for the top 5 offices over the period 2014 to 2021. The top 10 assignees are unsurprisingly dominated by automotive companies with Toyota (China, Japan and USA) and Hyundai (Korea) being the top filers.

Figure 3.4.4 shows the cumulative number of mobile fuel cell patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021. An overall increase in published mobile fuel cell patent applications by the top 10 filers is observed between 2014 and 2021 (Figure 3.4.4).

Figure 3.4.3: Top ten filers of mobile patent applications at the top 5 Patent Offices for 2014 to 2021.

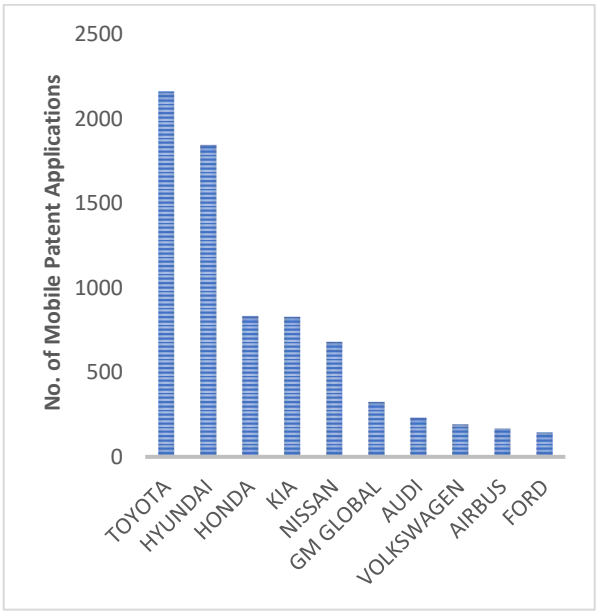
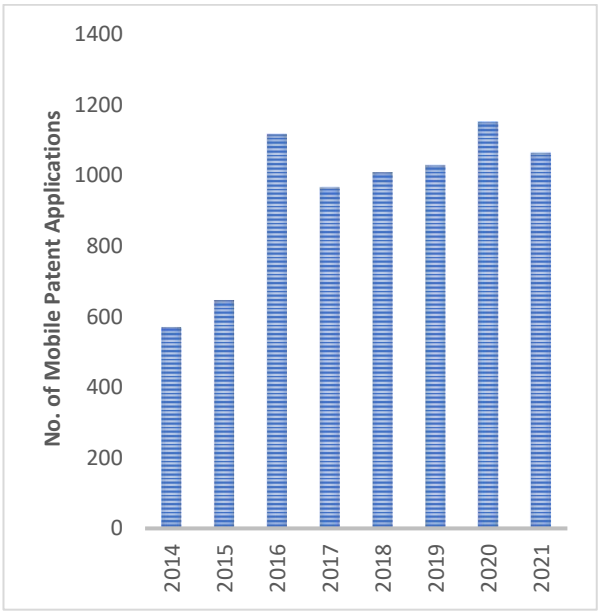


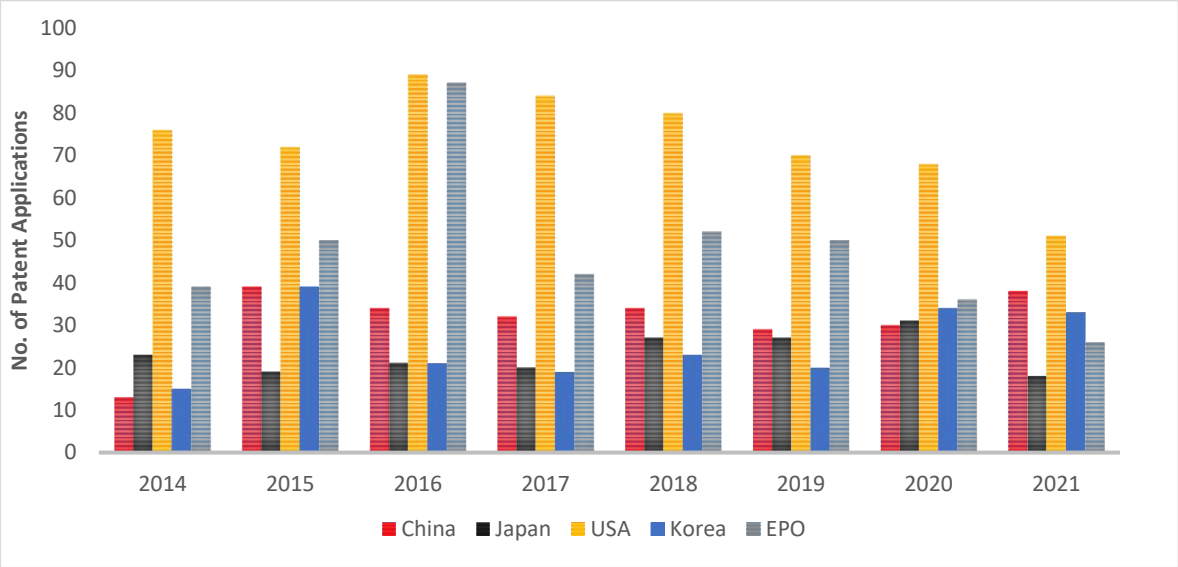
Figure 3.4.4: Number of mobile patent applications published by the top 10 filers for the years 2014 to 2021.



3.4.2. Stationary Fuel Cells

Figure 3.4.5 shows the total patent filings for stationary fuel cells at the major patent offices for the period 2014 to 2020.

Figure 3.4.5: Stationary fuel cell patent applications for 2014 to 2021.[8]



The USPTO appears to be publishing a greater number of stationary fuel cell patent applications than the other major offices over the period 2014 to 2021.

Figure 3.4.6 shows the top 10 assignees of stationary fuel cell patent applications for the top 5 offices over the period 2014 to 2021. The top two filers over the period are Exxon Mobil (China, USA and Korea) and Panasonic (EP).

Figure 3.4.7 shows the cumulative number of stationary fuel cell patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021. An overall decrease in published stationary fuel cell patent applications by the top 10 filers is observed between 2014 and 2021 (Figure 3.4.7).

Figure 3.4.6: Top ten filers of stationary patent applications at the top 5 Patent Offices for 2014 to 2021.

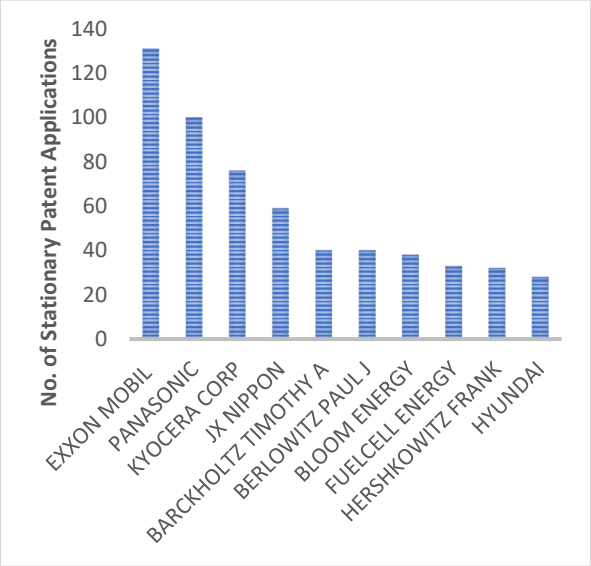
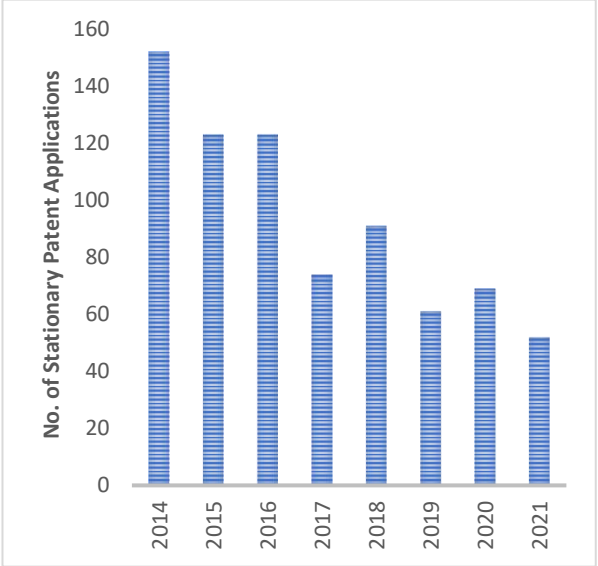


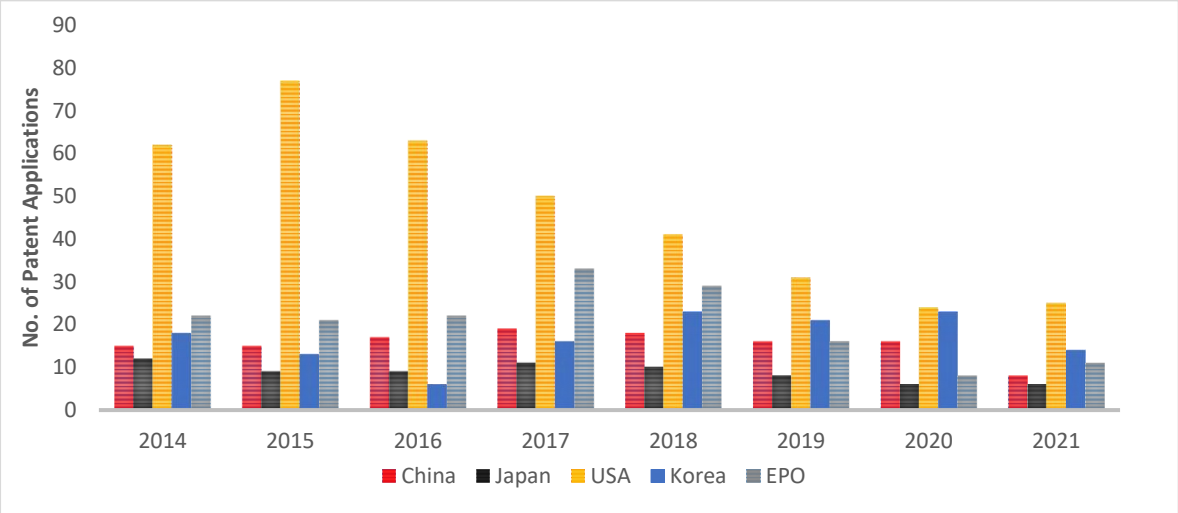
Figure 3.4.7: Number of stationary patent applications published by the top 10 filers for the years 2014 to 2021.



3.4.3. Portable Fuel Cells

Figure 3.4.8 shows the total patent filings for portable fuel cells at the major patent offices for the period 2014 to 2020.

Figure 3.4.8: Portable fuel cell patent applications for 2014 to 2021.[8]



The figures for patent filings at the USPTO show a marked decline over the period. Filings at the JPO appear to be trending downwardly whilst the remaining offices (EPO, KIPO and SIPO) show fluctuations between 2014 and 2021.

Figure 3.4.9 shows the top 10 assignees of portable fuel cell patent applications for the top 5 office over the period 2014 to 2021. Intelligent Energy (China, the USA and Europe) are the top filer of portable fuel cell patent applications over the period.

Figure 3.4.10 shows the cumulative number of portable fuel cell patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021. An overall decrease in published portable fuel cell patent applications by the top 10 filers is observed between 2014 and 2021 (Figure 3.4.10).

Figure 3.4.9: Top ten filers of portable patent applications at the top 5 Patent Offices for 2014 to 2021.

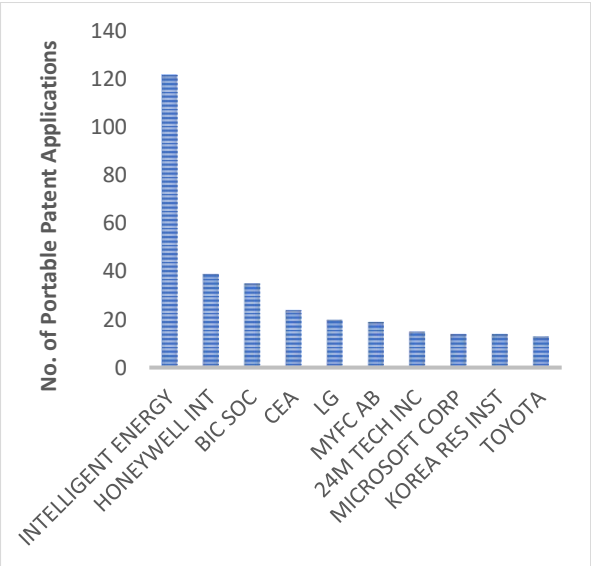
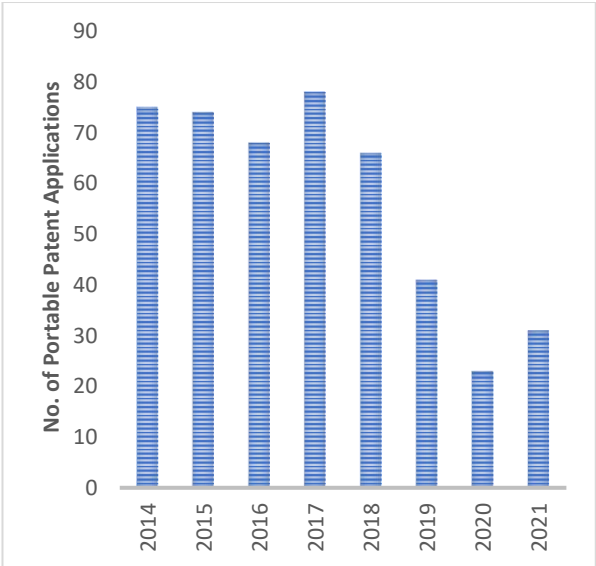


Figure 3.4.10: Number of portable patent applications published by the top 10 filers for the years 2014 to 2021.



3.4.4. Summary

Whilst the number of mobile fuel cell patent applications being filed at the top 5 offices over the period 2014 to 2021 appears to be stabilising, the number of stationary and portable fuel cells appears to be on the decline.

Whilst the US is still the most important territory for filing portable fuel cells, they are also the territory that have showed the greatest decline in the number of applications filed.

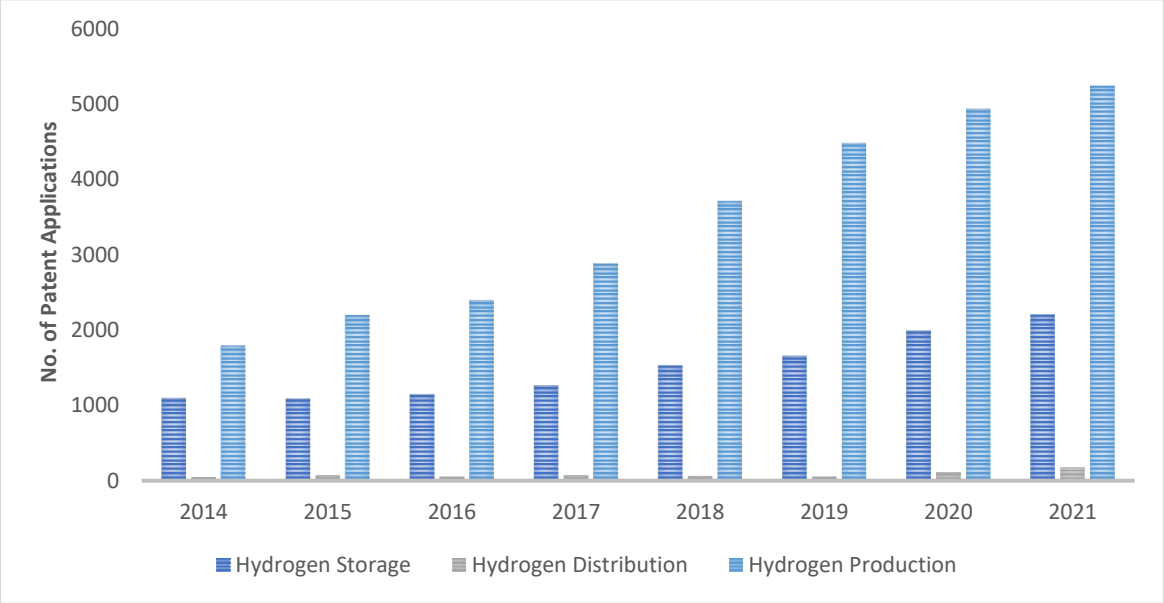
We speculate that this marked decline may relate to greater focus in competing battery technologies.

3.5. Hydrogen Production, Distribution and Storage

The data presented below compares filing statistics for hydrogen storage, hydrogen distribution and hydrogen production.

Figure 3.5.1 shows the total filings across the period at the top five offices for hydrogen storage, hydrogen distribution and hydrogen production.

Figure 3.5.1: Total patent applications at the top 5 patent offices for 2014 to 2021.[8]



The data in Figure 3.5.1 clearly shows that hydrogen production is the dominant field of endeavour followed by hydrogen storage and then hydrogen distribution but that, across the piece, the number of filings appears to be increasing.

The following data presents the number of patent applications filed, according to hydrogen production, distribution and storage, for the years 2014 to 2021, at the top 5 offices.

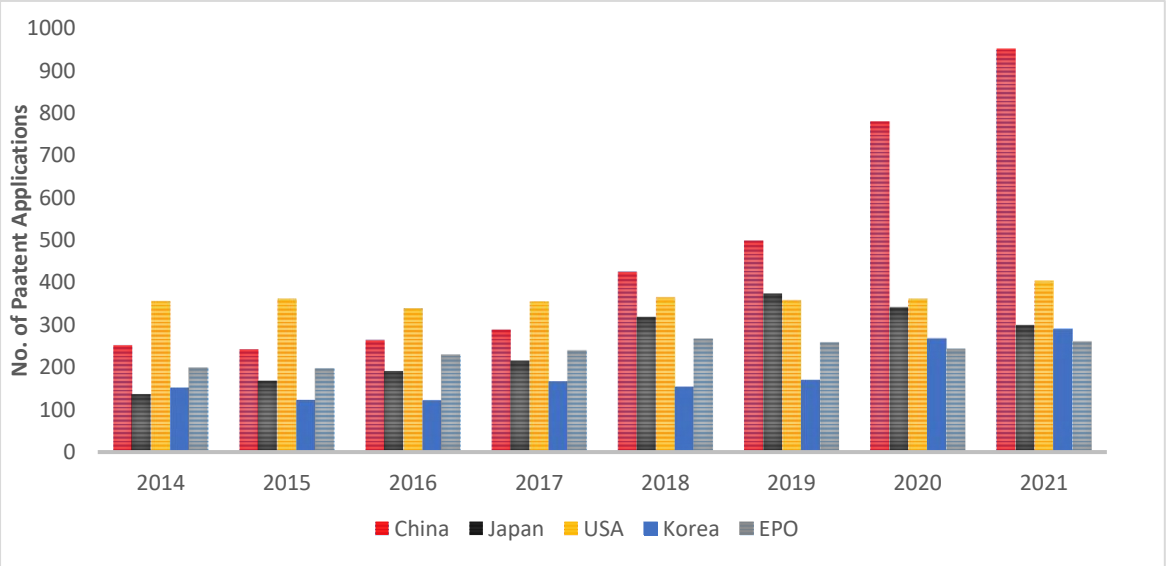
The data shows that China is the most important jurisdiction for businesses filing patent applications in these categories.

Also presented are the top 10 filers of patent applications for hydrogen storage, distribution and production, for the years 2014 to 2021, for each of the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

3.5.1. Hydrogen Storage

Figure 3.5.2 shows the total patent filings for hydrogen storage across the top 5 patent offices.

Figure 3.5.2: Hydrogen storage patent applications for 2014 to 2021.[8]



Patent filings at the EPO, JPO, KIPO and USPTO appear to have been relatively flat between 2014 and 2021. In comparison, patent filings in China show a marked incline between 2017 and 2021.

Figure 3.5.3 shows the top 10 assignees of hydrogen storage patent applications for the top 5 offices over the period 2014 to 2021. Toyota (China, USA and Japan) are the top filer over the period.

Figure 3.5.4 shows the cumulative number of hydrogen storage patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.5.3: Top ten filers of hydrogen storage patent applications at the top 5 Patent Offices for 2014 to 2021.

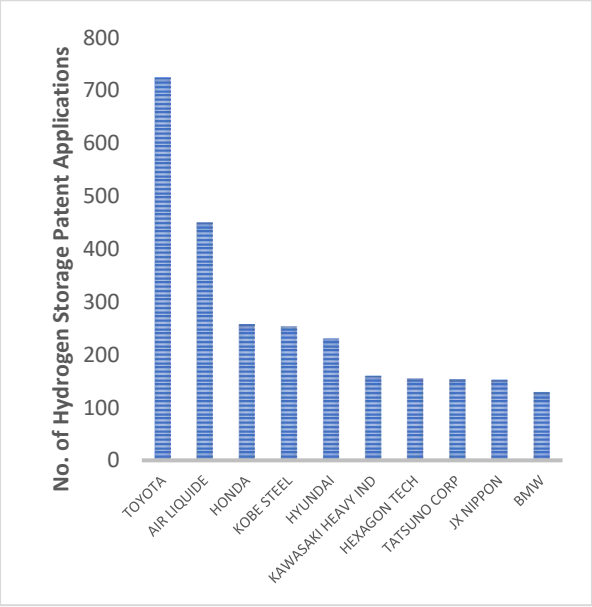
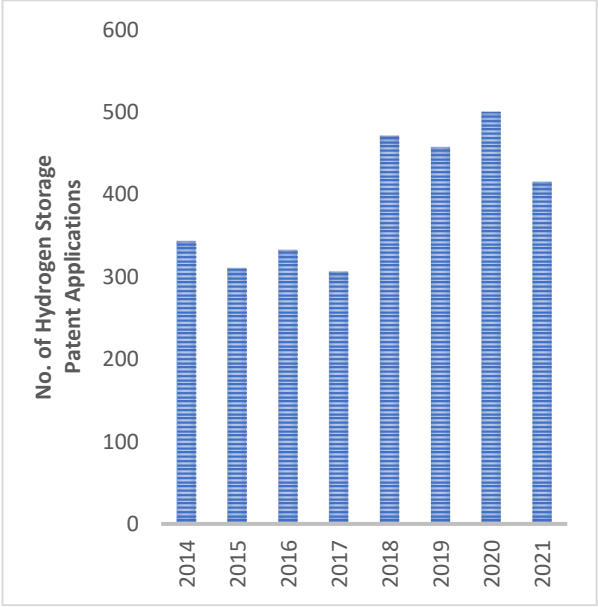


Figure 3.5.4: Number of hydrogen storage patent applications published by the top 10 filers for the years 2014 to 2021.



3.5.2. Hydrogen Distribution

Figure 3.5.5 shows the total patent filings for hydrogen distribution across the top 5 patent offices.

Figure 3.5.5: Hydrogen distribution patent applications for 2014 to 2021.[8]

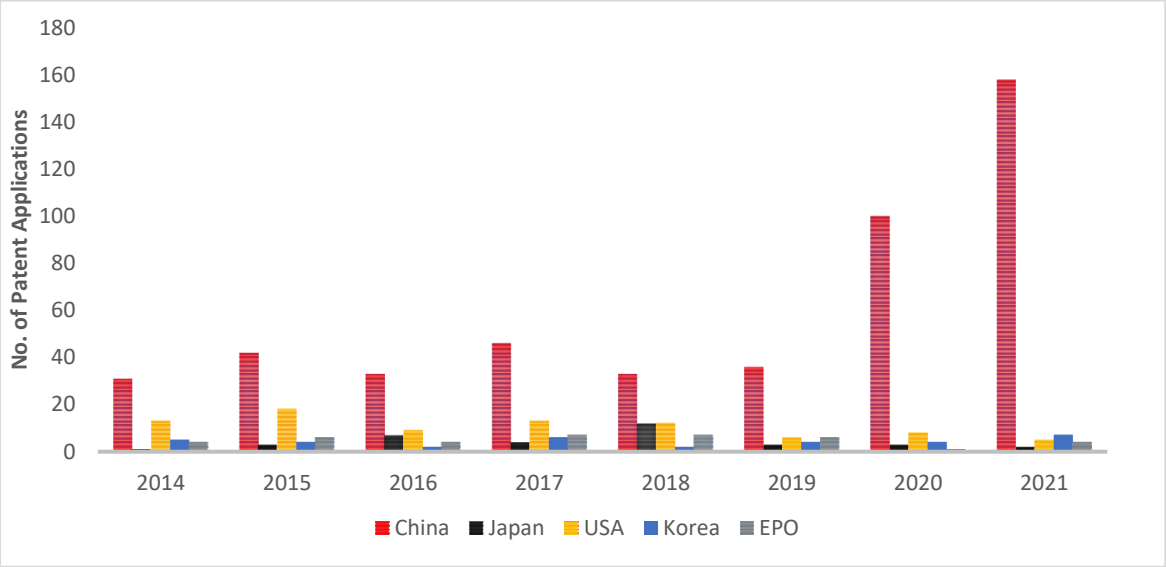


Figure 3.5.5 shows that China is the single most important jurisdiction for hydrogen distribution patent applications. Very few applications are filed in the remaining jurisdictions (Europe, Japan, USA and Korea).

Figure 3.5.6 shows the top 10 assignees of hydrogen distribution patent applications for the top 5 offices over the period 2014 to 2021. China Petroleum and Chem (China) are the top filer over the period.

Figure 3.5.7 shows a fluctuation in the cumulative number of hydrogen distribution patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.5.6: Top ten filers of hydrogen distribution patent applications at the top 5 Patent Offices for 2014 to 2021.

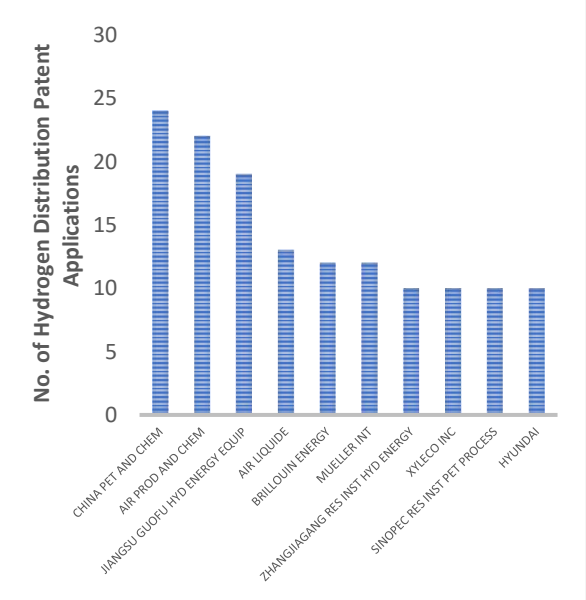
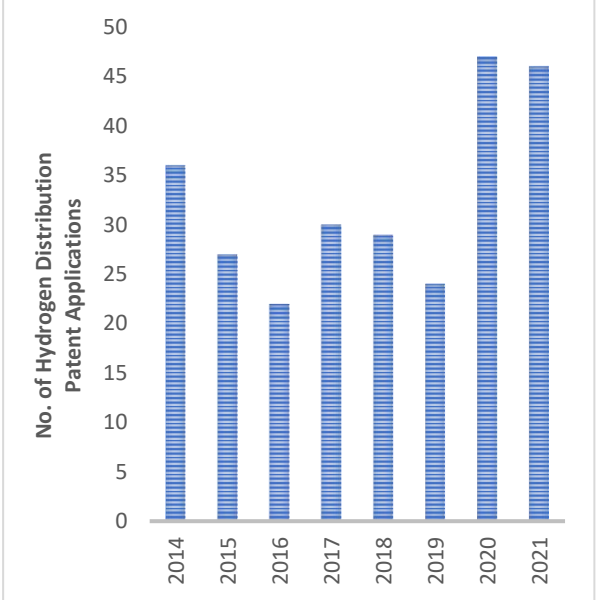


Figure 3.5.7: Number of hydrogen distribution patent applications published by the top 10 filers for the years 2014 to 2021.



3.5.3. Hydrogen Production Non-Carbon Containing Sources including Electrolysis

3.5.3.1. Filing Statistics

Figure 3.5.8 shows the total patent filings for hydrogen production from electrolysis across the top 5 patent offices.

Figure 3.5.8: Hydrogen production patent applications for 2014 to 2021.[8]

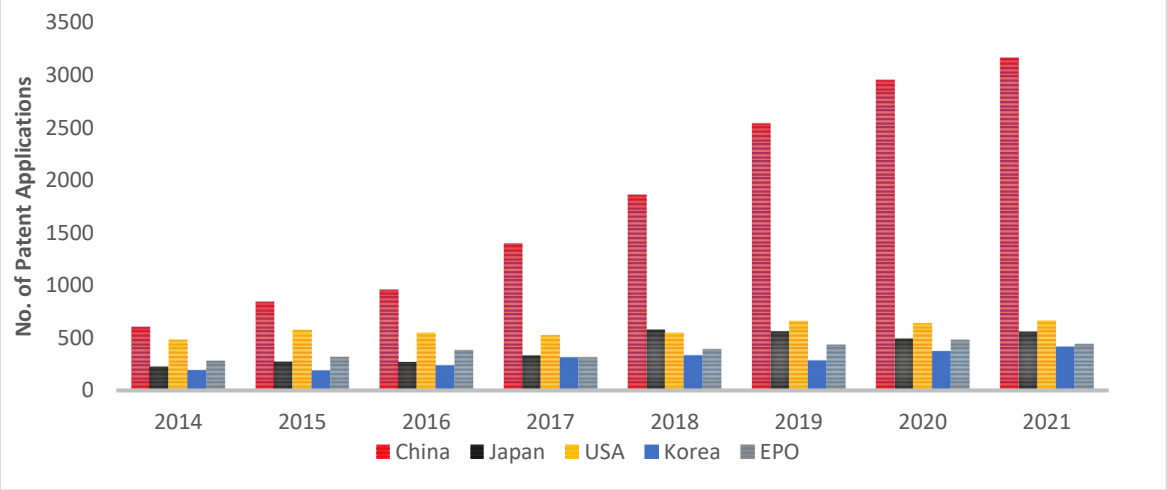


Figure 3.5.8 shows that China is a very important jurisdiction for hydrogen production patent applications and that the number of filings appears to be increasing over the period 2014 to 2021. Significantly fewer applications are filed in the remaining jurisdictions (Europe, Japan, USA and Korea).

Figure 3.5.9 shows the top 10 assignees of hydrogen production patent applications for the top 5 offices over the period 2014 to 2021. The top filers are Toshiba (Japan), Panasonic (Japan) and CEA (France).

Figure 3.5.10 shows the cumulative number of hydrogen production patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.5.9: Top ten filers of hydrogen production patent applications at the top 5 Patent Offices for 2014 to 2021.

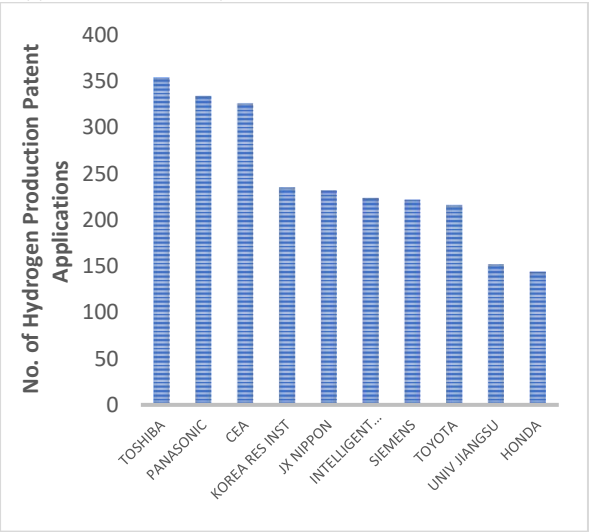
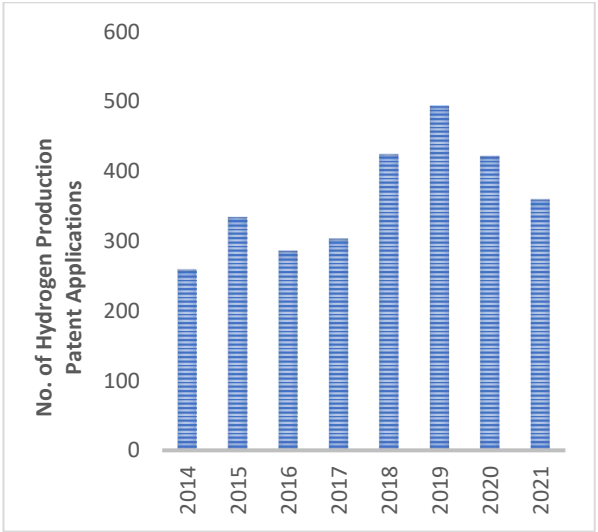


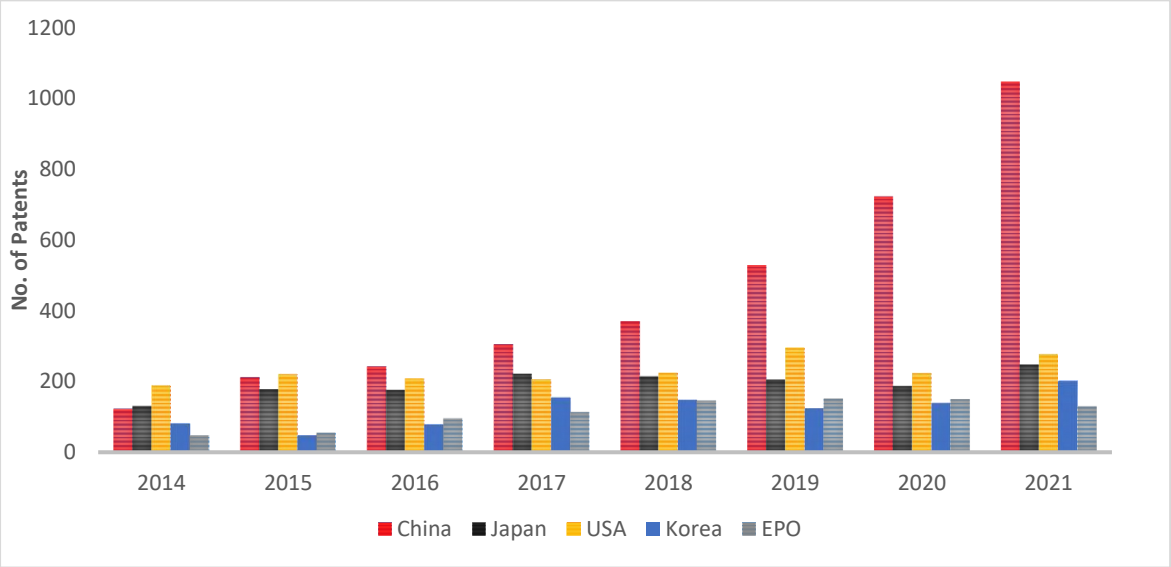
Figure 3.5.10: Number of hydrogen production patent applications published by the top 10 filers for the years 2014 to 2021.



3.5.3.2. Granted Patents

Figure 3.5.11 shows the total granted patents for hydrogen production from electrolysis across the top 5 patent offices.

Figure 3.5.11: Hydrogen production patents for 2014 to 2021.[8]



The granted patent data (Figure 3.5.11) shows a similar trend to the filing statistics (Figure 3.5.8) with China the dominant jurisdiction for filing hydrogen production patent applications

Figure 3.5.12 shows the top 10 assignees of granted hydrogen production patents for the top 5 offices over the period 2014 to 2021. The top filer is CEA.

Figure 3.5.13 shows the cumulative number of hydrogen production patents granted published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 3.5.12: Top ten filers of granted hydrogen production patents at the top 5 Patent Offices for 2014 to 2021.

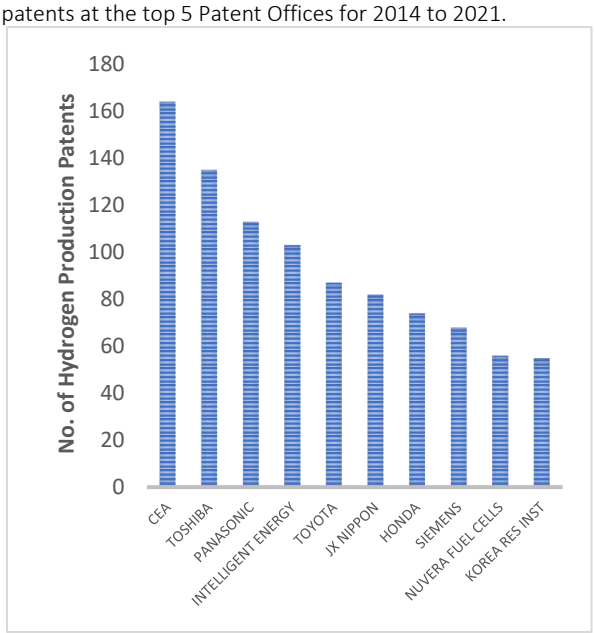
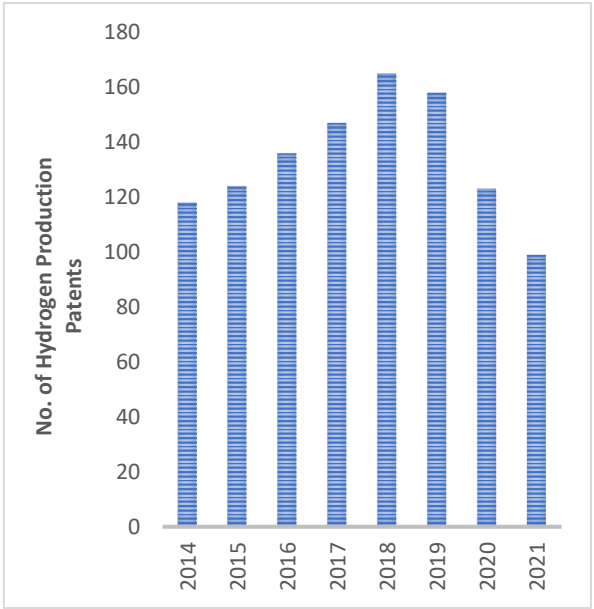


Figure 3.5.13: Number of hydrogen production patents granted by the top 10 filers for the years 2014 to 2021.



3.5.4. Summary

Despite the impact of Covid, the number of patent applications being filed in the area of hydrogen storage, hydrogen distribution and hydrogen production, at the top 5, offices appears to be increasing year-on-year, particularly in China, which is the most dominant jurisdiction for patent filings in this sector.

Similar results are also observed with the number of granted hydrogen production patents being granted at the top 5 offices.

Accordingly, it is clear that the area of hydrogen technology is becoming an increasingly important sector for filing patent applications and this may indicate an increasing focus on hydrogen as an important future fuel source.

4. Comparable Technologies

The above sections describe the progress in fuel cell technologies through the patent applications. In order to have a more complete picture and to be able to see the progress against other comparable technologies, in this section we assess the patent activity within the sector of battery accumulators and renewable energy sources.

4.1 Battery Accumulators

Figure 4.1.1 shows a comparison between the total number of patents published worldwide, the number of fuel cell patent applications and the number of battery patent applications (lithium batteries and lead-acid batteries) published worldwide between 2014 and 2020.

All three data sets show an overall increase over the period with the battery patent application data showing the biggest increase over the period.

Figure 4.1.1: Comparison of total number of patent applications, number of fuel Cell patent publications and the number of battery patent publications for the years 2014 to 2020.

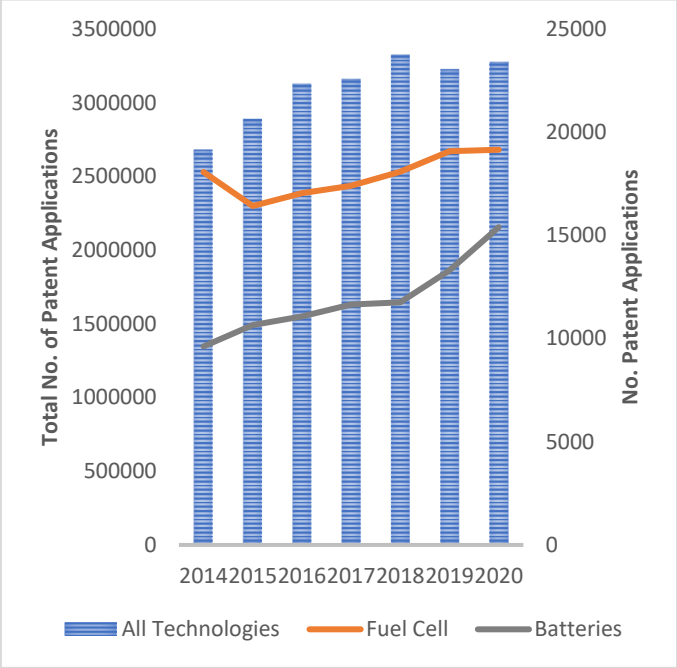
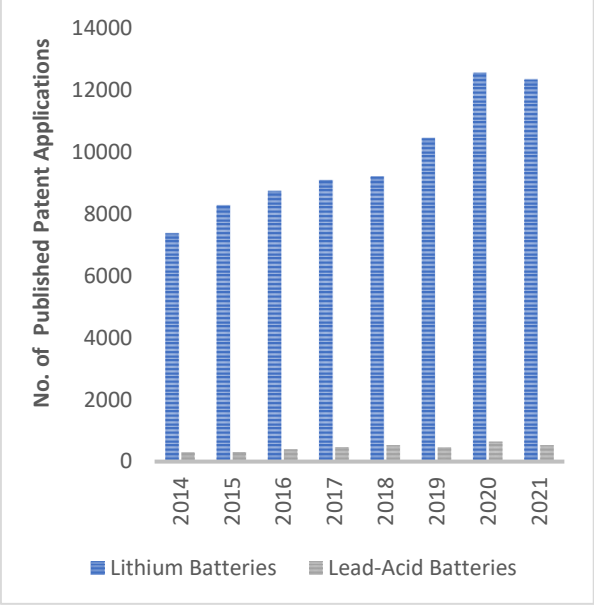


Table 4.1.1. List of classification codes searched for in battery accumulators.

Category	Classification Codes
Lead-Acid Batteries	HO1M10/06
Lithium Batteries	HO1M10/052

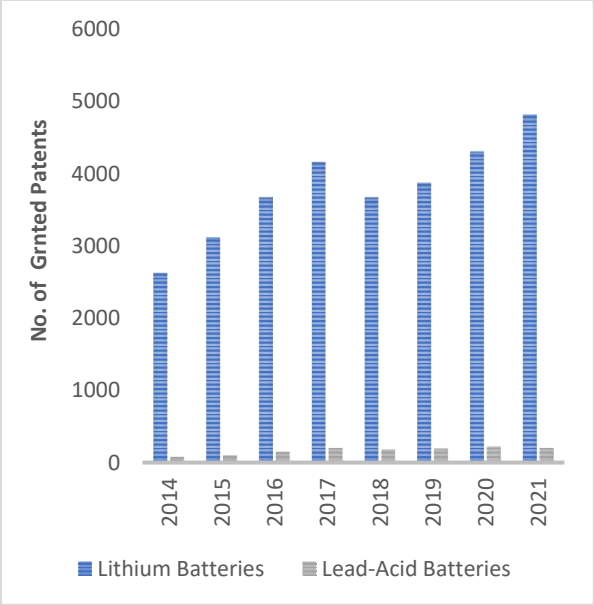
Figure 4.1.2 shows the total filings across the period at the top five offices for lithium battery patent applications in comparison to lead-acid battery patent applications. The data clearly shows that lithium batteries are the dominant field of endeavour and that the number of filings are increasing annually over the period.

Figure 4.1.2: Total patent applications at the top 5 offices for 2014 to 2021.[8]



The granted patent data (Figure 4.1.3) shows a similar trend to the filing statistics (Figure 4.1.2) with lithium batteries the dominant field of endeavour and the number of granted patents increasing annually over the period.

Figure 4.1.3: Total patents granted at the top 5 offices for 2014 to 2021.[8]



4.1.1. Lithium Batteries

The data presented below shows that China and the USA are the most important jurisdictions for organisations filing patent applications in the area of lithium batteries.

Also presented are the top 10 filers of patent applications for lithium batteries, for the period 2014 to 2021, for each of the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

4.1.1.1. Filing Statistics

Figure 4.1.4 shows the total patent filings for lithium batteries across the top 5 patent offices.

Figure 4.1.4: Lithium battery patent applications for 2014 to 2021.[8]

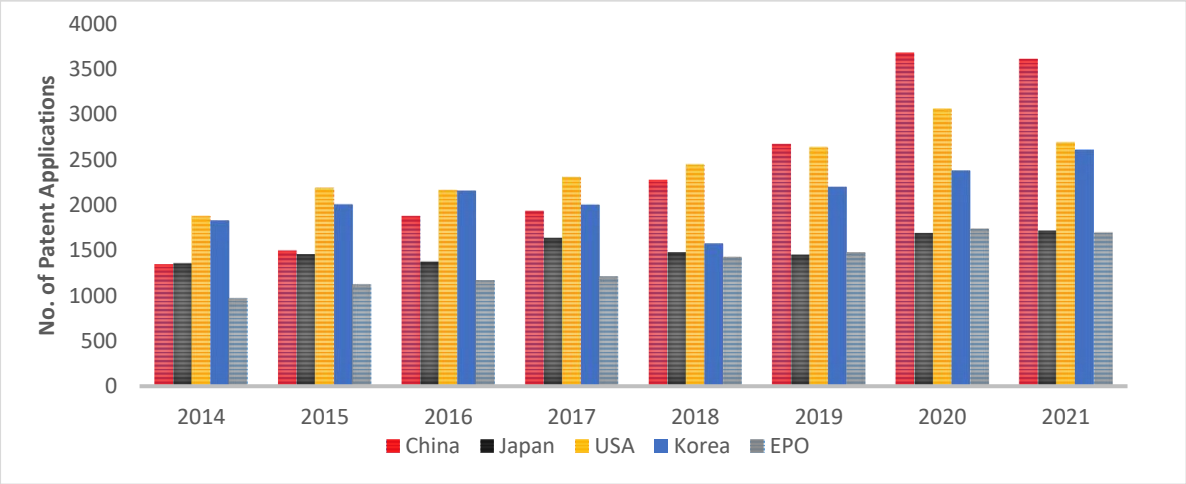


Figure 4.1.4 shows that China has become an increasingly important jurisdiction for lithium battery patent applications. Whilst Japan, Korea and the EPO show fluctuations in growth of the number of patent applications filed over the period.

Figure 4.1.5 shows the top 10 assignees of lithium battery patent applications for the top 5 offices over the period 2014 to 2021. The top filers are LG, Samsung and Toyota, with LG the dominant entity.

Figure 4.1.6 shows the cumulative number of lithium battery patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 4.1.5: Top ten filers of lithium battery patent applications at the top 5 Patent Offices for 2014 to 2021.

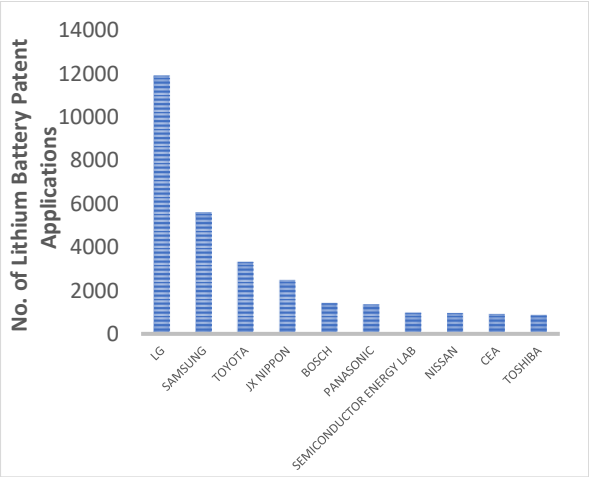
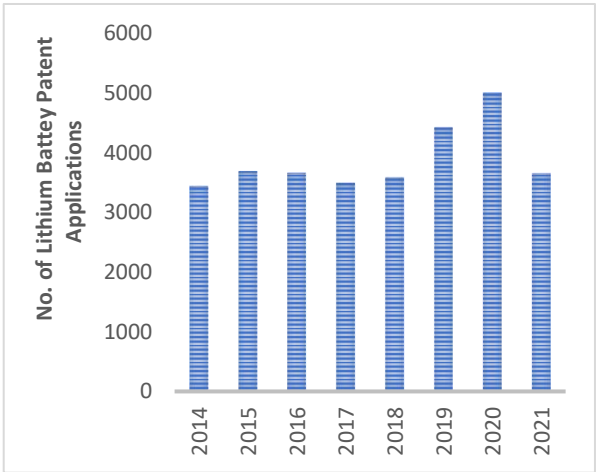


Figure 4.1.6: Number of lithium battery patent applications published by the top 10 filers for the years 2014 to 2021.



4.1.1.2. Granted Patents

Figure 4.1.7 shows the total number of granted lithium batteries across the top 5 patent offices.

Figure 4.1.7: Lithium battery patents for 2014 to 2021.[8]

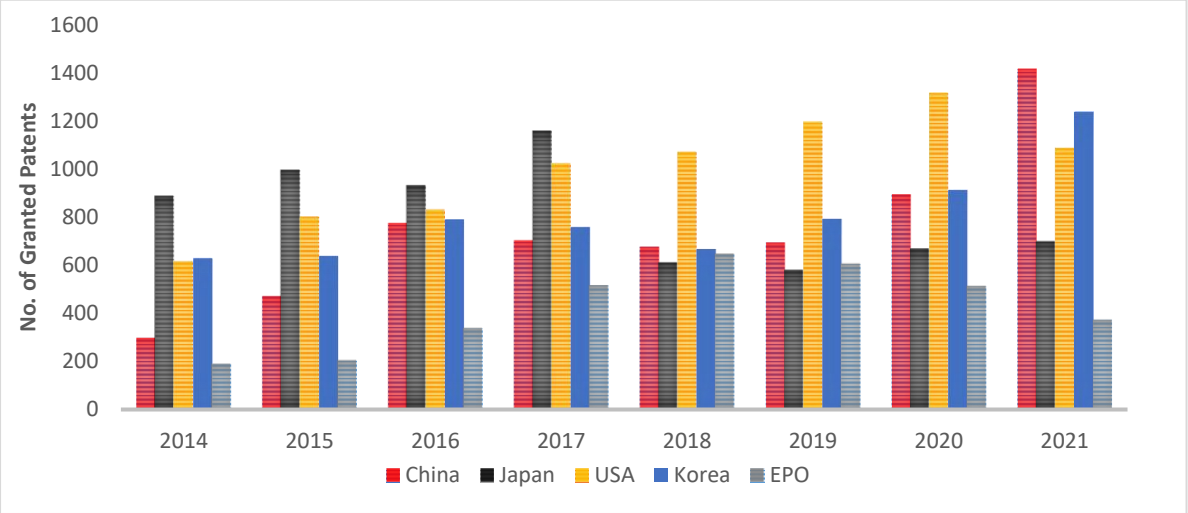


Figure 4.1.7 shows that in the period 2018 to 2020 the USA is the most important territory and that the EPO is the least important territory, of the top 5 offices, for granting lithium battery patents.

Figure 4.1.8 shows the top 10 assignees of granted lithium battery patents for the top 5 offices over the period 2014 to 2021. As observed with the number of lithium battery patent applications, the top assignees of granted lithium battery patents are LG, Samsung and Toyota.

Figure 4.1.9 shows the cumulative number of lithium battery patents granted at the top 5 offices by the top 10 assignees.

Figure 4.1.8: Top ten filers of granted lithium battery patents at the top 5 Patent Offices for 2014 to 2021.

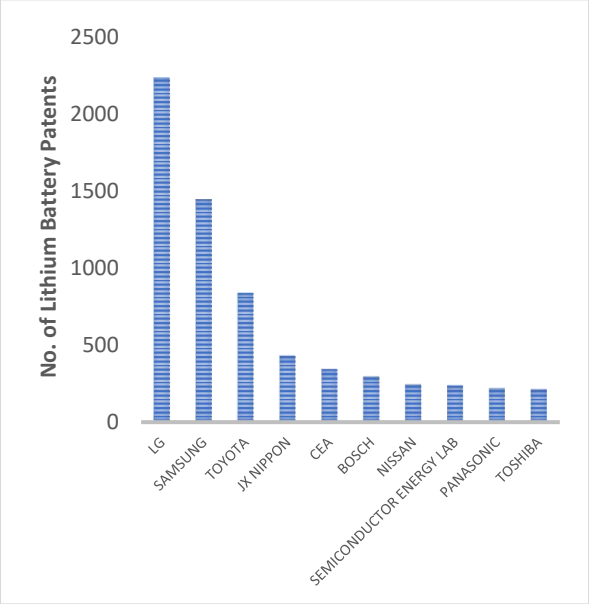
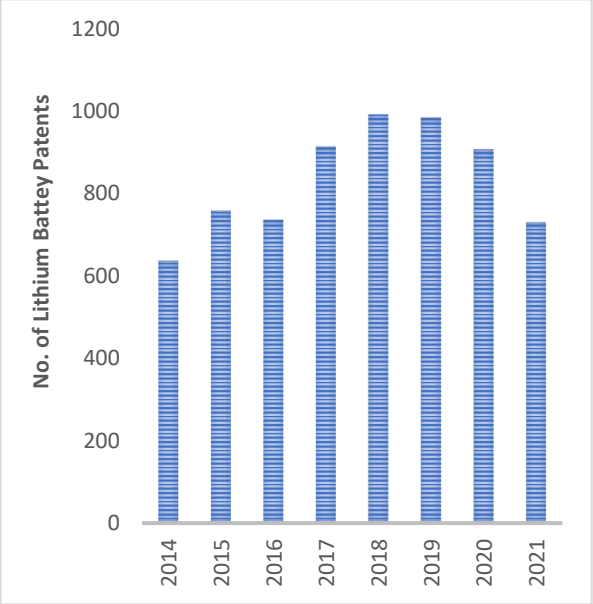


Figure 4.1.9: Number of lithium battery patents granted by the top 10 filers for the years 2014 to 2021.



4.1.2. Lead-Acid Batteries

The data presented below shows that China is the most important jurisdiction for organisations filing patent applications in the area of lead-acid batteries.

Also presented are the top 10 filers of patent applications for lead-acid batteries, for the period 2014 to 2021, for each of the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

4.1.2.1. Filing Statistics

Figure 4.1.10 shows the total patent filings for lead-acid batteries across the top 5 patent offices.

Figure 4.1.10: Lead-acid battery patent applications for 2014 to 2021.[8]

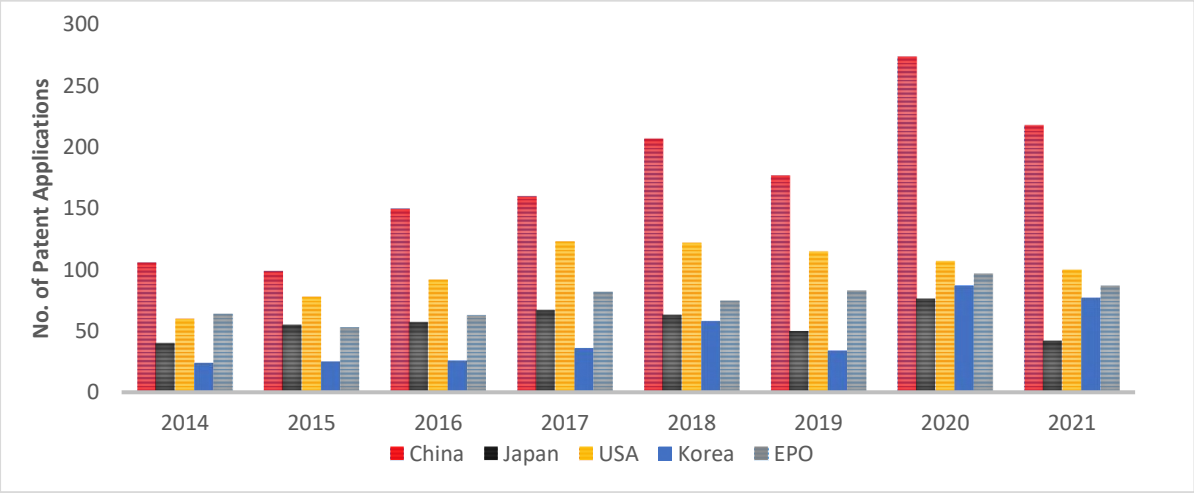


Figure 4.1.10 shows that China has become an increasingly important jurisdiction for lead-acid battery patent applications. Whilst the USA, Japan, Korea and the EPO show fluctuations in growth of the number of patent applications filed over the period.

Figure 4.1.11 shows the top 10 assignees of lead-acid battery patent applications for the top 5 offices over the period 2014 to 2021. The top three filers are GS Yuasa, Daramic and Johnson and Johnson.

Figure 4.1.12 shows the cumulative number of lead-acid battery patent applications published at the top 5 offices by the top 10 filers from 2014 to 2021.

Figure 4.1.11: Top ten filers of lead-acid battery patent applications at the top 5 Patent Offices for 2014 to 2021.

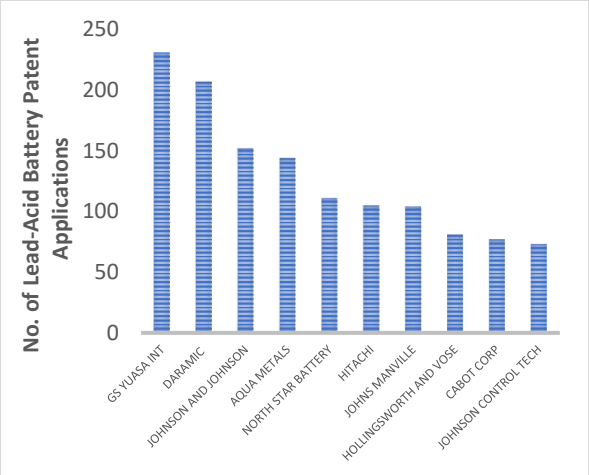
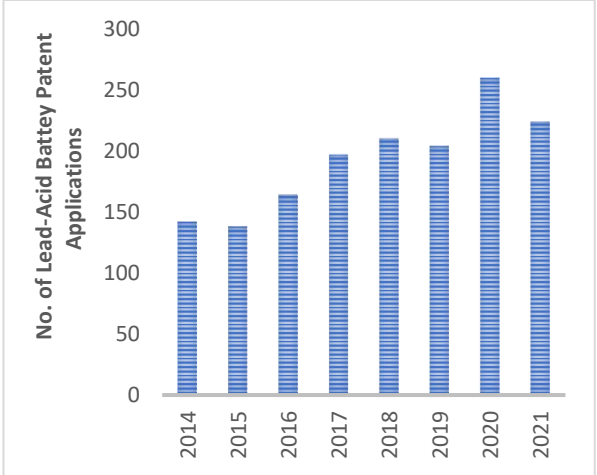


Figure 4.1.12: Number of lead-acid battery patent applications published by the top 10 filers for the years 2014 to 2021.



4.1.2.2. Granted Patents

Figure 4.1.13 shows the total number of granted lead-acid batteries across the top 5 patent offices.

Figure 4.1.13: Lead-acid battery patents for 2014 to 2021.[8]

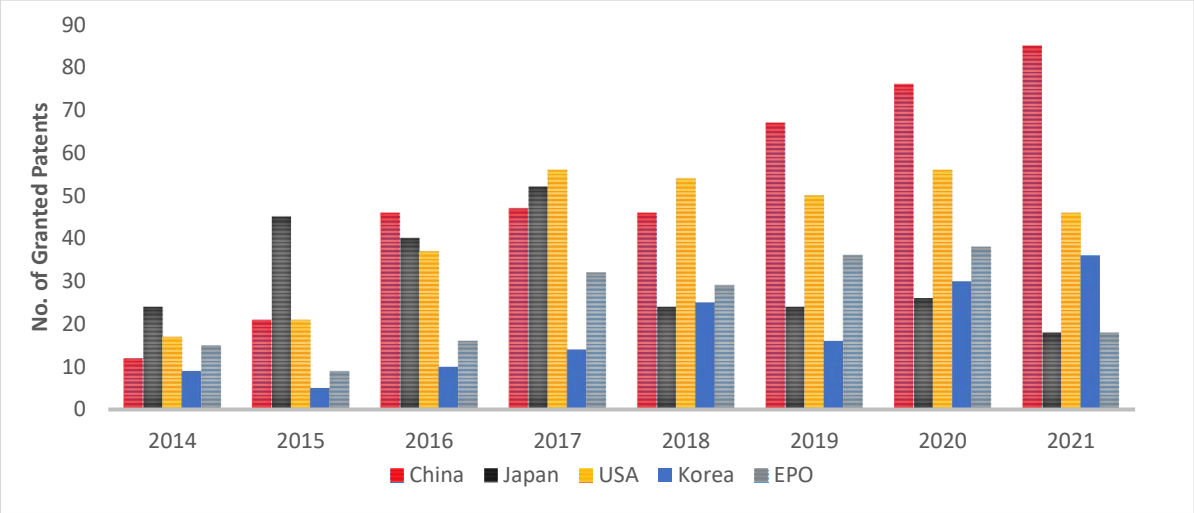


Figure 4.1.13 shows that in the period 2014 to 2021, China and the USA are the most important territories for granting lead-acid battery patents. Whilst the remaining offices (Japan, Korea and the EPO) show fluctuations in the number of patents granted over the period,.

Figure 4.1.14 shows the top 10 assignees of granted lead-acid battery patents for the top 5 offices over the period 2014 to 2021. As observed with the number of lead-acid battery patent applications, the top three assignees of granted lithium battery patents are GS Yuasa, Daramic and Johnson and Johnson.

Figure 4.1.15 shows the cumulative number of lead-acid battery patents granted at the top 5 offices by the top 10 assignees.

Figure 4.1.14: Top ten filers of granted lead-acid battery patents at the top 5 Patent Offices for 2014 to 2021.

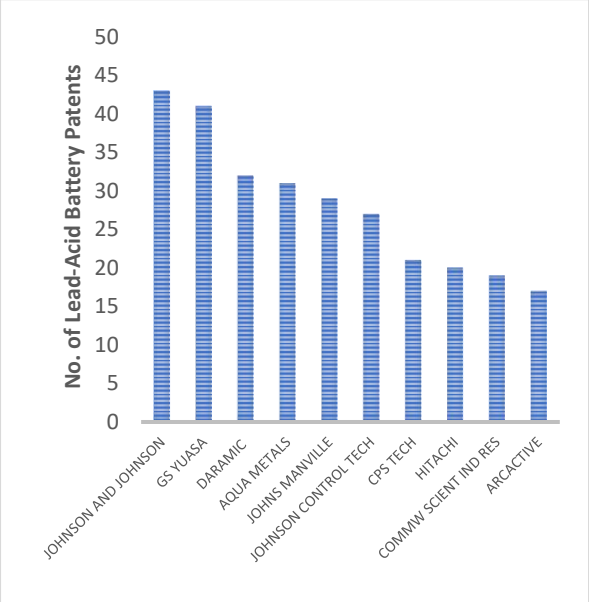
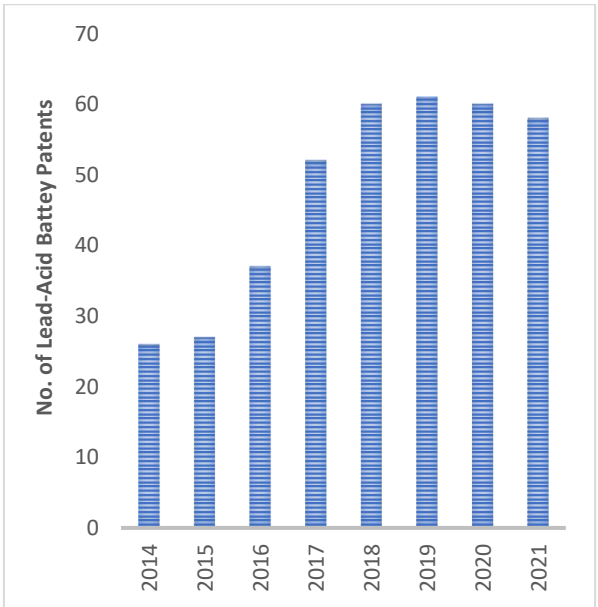


Figure 4.1.15: Number of lead-acid battery patents granted by the top 10 filers for the years 2014 to 2021.



4.2 Renewable Energy Sources

4.2.1. Filing Statistics

The number of renewable energy (solar, wind and geothermal energy) patent applications published annually around the world has remained in excess of 12000 since 2014. The data shows that solar energy is the standout renewable energy source. The USPTO and the Chinese office remain the most important territories for publishing alternative fuel patent applications, with those published at the Chinese office being the most significant.

Table 4.2.1. List of classification codes searched for renewable energy sources.

Category	Classification Codes
Solar	E04D1/30, E04D13/18, F24J2/00, F24J2/02, F24J2/04, F24J2/05, F24J2/06, F24J2/07, F24J2/08, F24J2/10, F24J2/12, F24J2/13, F24J2/14, F24J2/15, F24J2/16, F24J2/18, F24J2/23, F24J2/24, F24J2/36, F24J2/38, F24J2/42, F24J2/46, F03G6/06, G02B5/10, H01L31/052, H01L31/04, H01L31/042, H01L31/18, G02F1/136, G05F1/67, H01L25/00, H01L31/00, H01L31/048, H01L33/00, H02J7/35, H02N6/00
Wind	F03D1/00, F03D3/00, F03D5/00, F03D7/00, F03D9/00, F03D11/00, B60L8/00
Geothermal	F24J3/08, F03G4/00, F03G7/05

Figure 4.2.1 shows worldwide patent statistics for the annual publication of patents in the area of Renewable energy sources.

Figure 4.2.1: Published renewable energy patent applications for 2014 to 2021.

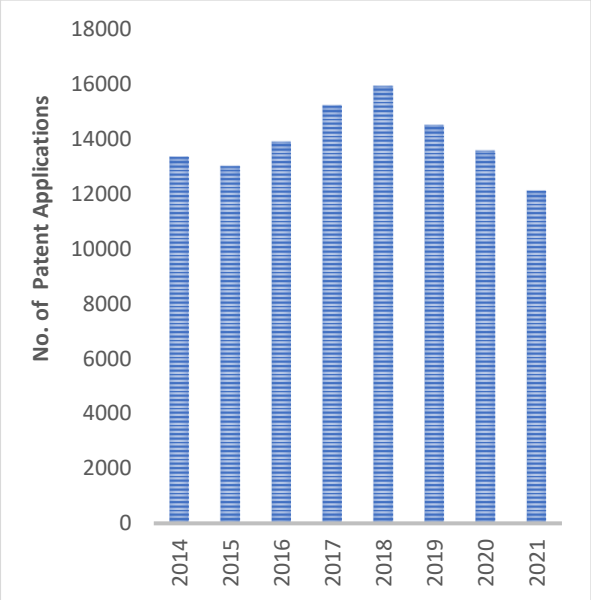


Figure 4.2.2: Published total patent applications vs. published renewable energy patent applications for the years 2014 to 2020.

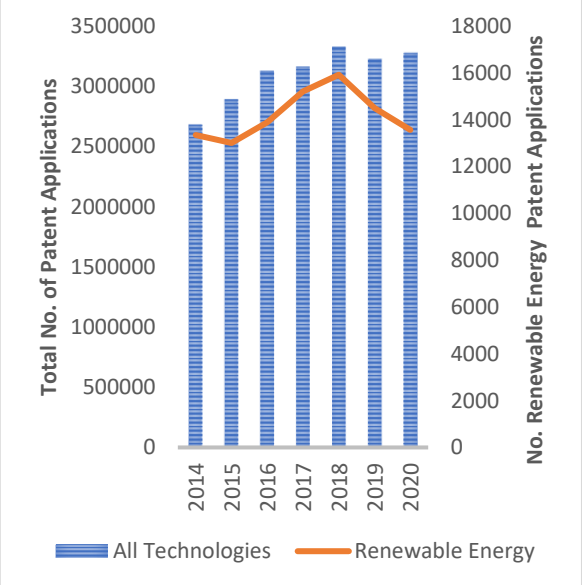


Figure 4.2.2 shows a comparison between the number of published renewable energy patent applications (orange line) and the total number of published patent applications (blue bars) between 2014 and 2020.

Figure 4.2.3 shows a comparison between the number of published renewable energy patent applications and the number of published fuel cell patent applications.

Figure 4.2.3: Published fuel cell patent applications vs. published renewable energy patent applications for the years 2014 to 2021.

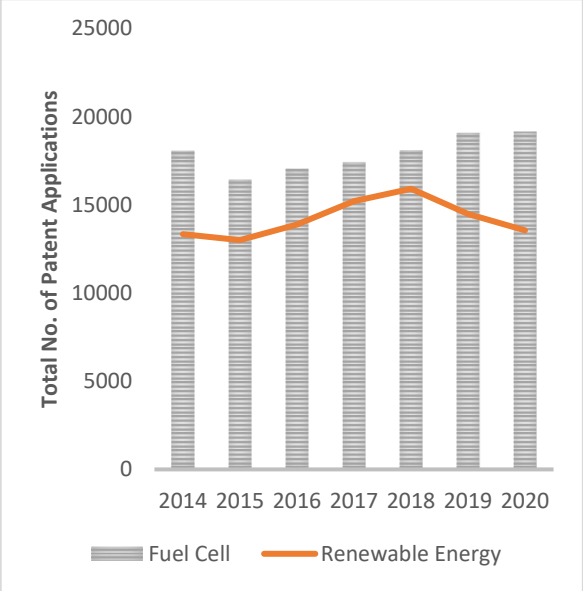


Figure 4.2.4: Published renewable energy patent applications by fuel source for the years 2014 to 2021.

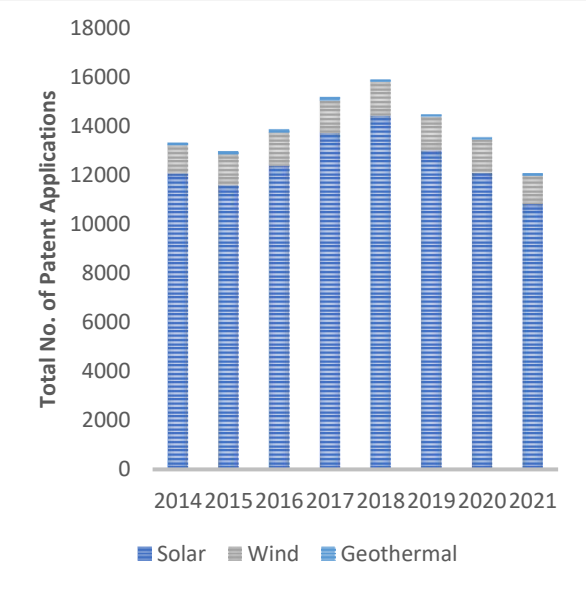
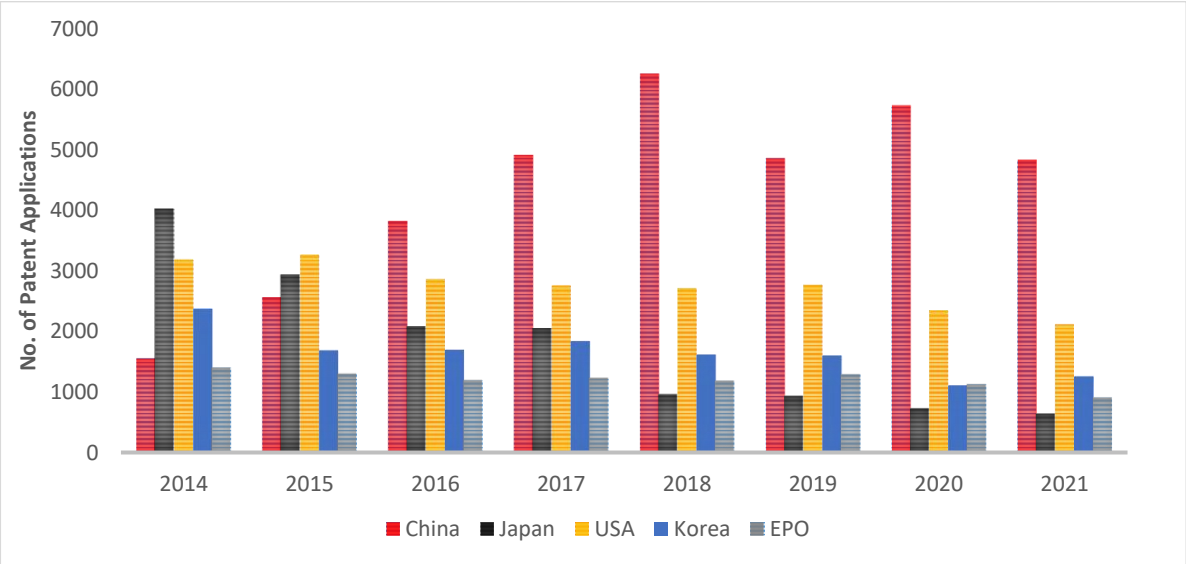


Figure 4.2.4 shows the overall number of published renewable energy patent applications according to the type of renewable energy source. The majority of the published renewable energy patent applications are in the field of solar energy.

Figure 4.2.5 shows the overall number of published renewable energy patent applications according to the geographical split of the top 5 patent offices.

The data reflects a similar trend to that of the overall number of renewable energy patent applications published worldwide (Figure 4.2.1).

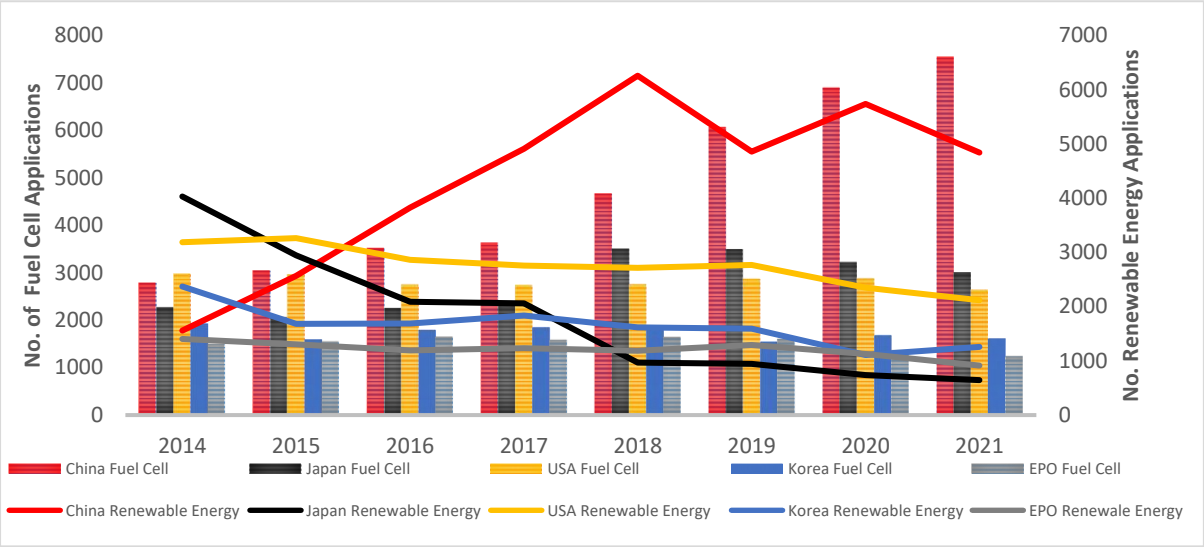
Figure 4.2.5: Published renewable energy fuel patent applications at the top 5 offices for the years 2014 to 2021.[8]



The Chinese Patent Office and the USPTO have become clear leaders in the publication of renewable energy patent applications over the period. The number of filings in Europe appears to be fairly stable.

Figure 4.2.6 shows the number of published renewable energy patent applications in comparison to the number of published fuel cell patent applications, according to the geographical split of the top 5 patent offices.

Figure 4.2.6: Published fuel Cell patent applications vs. Published renewable energy patent applications at the top 5 offices for the years 2014 to 2021.[8]



The number of alternate fuel cell patent applications being published in each of the top 5 offices appears to show a similar trend to the number of publications of fuel cell patent applications. Most notably, the data shows a significant increase in the number of renewable energy patent applications published at the Chinese office over the period. In comparison to the Chinese office, the trend at the remaining 4 major patent offices, although showing fluctuations, remain relatively stable in terms of publication numbers.

4.2.2. Granted Renewable Energy Patents

The data shows fluctuations in the number of granted renewable energy patents between 2014 and 2021. The USPTO and the SIPO remain the most important territories for granting alternate fuel patents.

Businesses wishing to commercialise their alternate fuel technology world-wide must continue to consider their patent position in the USA and China.

Figure 4.2.7 shows the annual number of granted renewable energy patents for the top 5 offices.

Figure 4.2.7: Granted renewable energy patent applications at the top 5 offices for the years 2014 to 2021.[8]

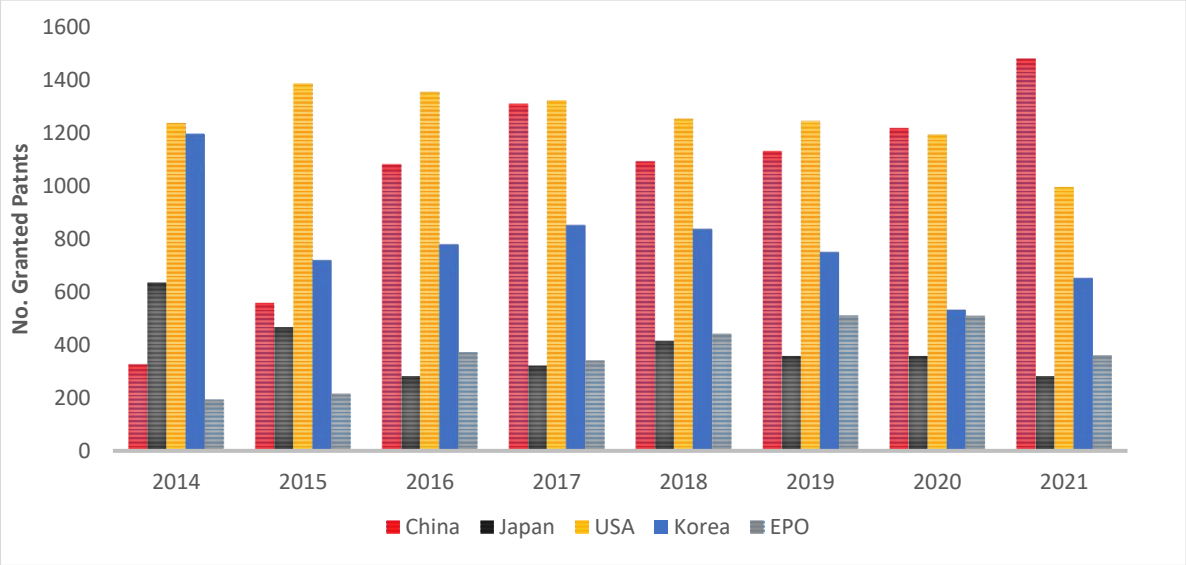
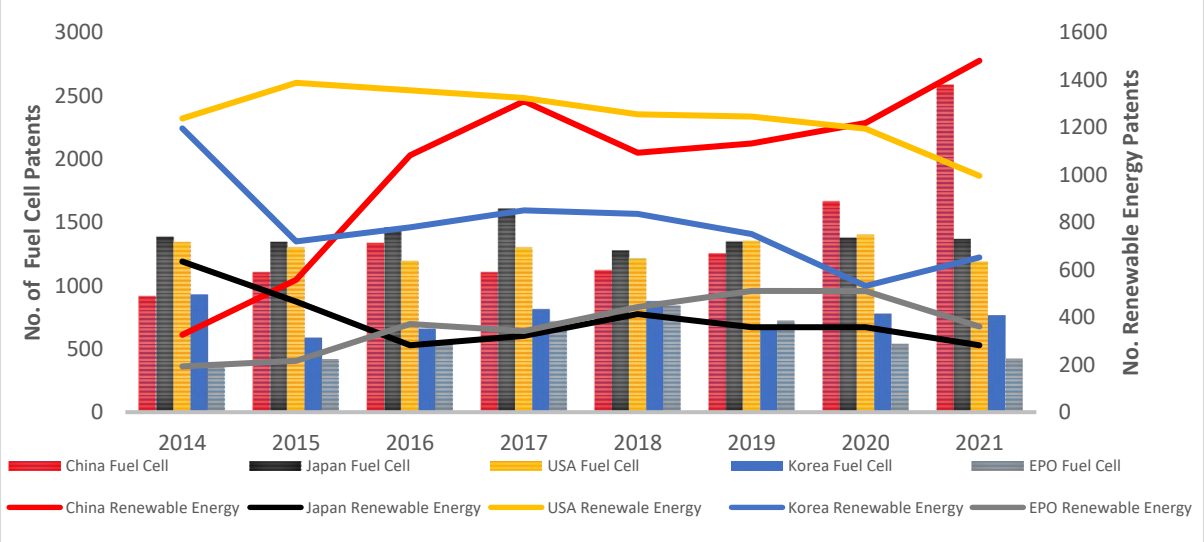


Figure 4.3.8 shows a comparison between the annual number of granted renewable energy patents and the number of granted fuel cell patents for the top 5 offices.[8]



5. Conclusions

Fuel cells offer an interesting prospect in times where there is drive towards use of climate friendly energy technologies. When assessing the state of the industry it is important to consider many of the contributing factors. This report looks at trends in patent activity for businesses and research and academic organisations.

It is clear that there are many companies currently manufacturing and distributing fuel cells. Our report focuses on world's largest patent offices which account for approximately 75% of global patent filings of the major businesses involved in filing patent applications in the fuel cell space the leaders in terms of numbers appear to be based in Asia, more specifically, in Japan and South Korea and are dominated by the large automotive companies.

From the patent analysis, China appears to be by far the most dominant country for academic filings of fuel cell patents and the USPTO and the Chinese patent office remain the most important territories for publishing fuel cell patents.

Whilst the absolute number of applications is robust, the mix of those patent applications appears to be changing with decreasing amounts of patent applications being filed for inventions which are categorised in specific fuel cell types.

Decreases in the number of filings for the most recent years may be as a result of the data sets being incomplete or it may be attributed to the impact of COVID-19.

Fuel cells for vehicles remain one of the most high-profile applications of fuel cells, with a large majority of the top ranked companies coming from the automotive sector.

From this report it is clear that research and development in the global fuel cell industry is fairly stable, despite the impact of Covid-19. Whilst the filing statistics are dominated by a few large players the patent filings are relatively diverse with many businesses actively filing patent applications.

6. Contributors

6.1 About the Authors

On behalf of the FCHO this Report has been compiled by Dr Chris Moore, and Dr Louise Slope. Data extraction and validation was performed by data scientists Sam Thrippleton and Gleb Kolpakov.

Chris is a partner and patent attorney at HGF.
Chris has a PhD in chemistry and represents clients in the chemical and engineering fields.
Chris is ranked as an IP Star (MIP) and as one of the world's leading patent attorneys (IAM Patent 1000).
Chris co-authored a previous report about patent filings in the fuel cell space.

Louise is a trainee patent attorney at HGF.
Louise has a PhD in chemistry and acts for clients in the chemical fields.

6.2 About HGF

HGF is a leading firm of Intellectual Property Specialists. HGF has its headquarters in the United Kingdom and has 22 offices throughout Europe.

HGF is one of the largest intellectual property firms in Europe with over 200 attorneys spanning patent, trade mark and IP solicitor disciplines.

HGF was recognised as one of the leading patent firms in Europe 2021 by The Financial Times and many attorneys are recognised as being leaders in their fields.

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