Chapter 5
2021 Patent Report
July 2021

FUEL CELLS AND HYDROGEN
OBSERVATORY

Disclaimer

This report is based on data gathered as part of the Fuel Cells and Hydrogen Observatory for the period up to 31 December 2020. 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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The Fuel Cells and Hydrogen Observatory has been prepared for the FCH 2 JU under a public procurement contract.

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Executive summary

The Fuel Cells and Hydrogen Observatory is an ambitious project to collect available valuable sector information in a single go-to source and make 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 patents module of the FCHO presents a range of statistical patent data as an indicator of research and development activity in the sector and the change in that activity over time. https://www.fchobservatory.eu/observatory/patents
Scope:	Fuel cell, hydrogen deployment and comparable technology patent application data is presented on a global basis. This first report provides a snapshot of patent data in the period January 2014 – December 2020. The report will be updated periodically, providing an indication of trends in filing and grant statistics.
Key Findings:	Over the period, overall total patent filings for fuel cell technologies increased; The USA and China appear to be the most important jurisdictions for filing fuel cell patent applications whereas South East Asian automotive companies are the most prolific filers of patent applications; The numbers of patent applications filed for specific fuel cell chemistries appears to be in decline; Patent applications for mobile fuel cell technologies dominate the fuel cell deployment sector, far outpacing both stationary and portable fuel cells; Patent applications for hydrogen production dominate the hydrogen economy patent filings and hydrogen storage patent applications outpace those for hydrogen distribution; Comparable technology patent application data looks at patent filing and grant statistics for battery technologies.

1. Introduction

This Report covers the period 2014 to 2020 except where otherwise indicated.

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 deployment of hydrogen infrastructure is changing over time
- Patent activity in the area of batteries: showing the trends in patent filings and grant statistics of lithium batteries

Data was sourced in accordance with the methodologies described below.

1.1. Methodology

2014-2018 data was collected over the weekend of 22/23 February 2020 and was verified by a second data download the following weekend. 2019-2020 data was collected on 23 February 2021[1]. All data was subsequently re-validated.

Raw patent data was obtained from PatBase[2] by extraction using patent classification codes.

Although the latest data was extracted in February 2021, we are conscious that some results indicate a decline in 2020 filing statistics. This may be as a result of the data set being 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 2019.

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 to allow for the database to ensure compilation of the 2020 dataset. The 2020 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 WIPO Statistics Database
[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] http://web2.wipo.int/ipcpub/#viewmode=f&symbol=H01M0008000000&refresh=page

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 Cell	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
Lithium Batteries	H01M 10/052

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 2020, with the exception that when comparing the data to that published by WIPO it is presented for calendar years 2014 to 2019.

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
Audi AG	Germany	Automotive
Bosch GMBH	Germany	Engineering & Energy Technology
Commissariat Energie Atomique	France	Energy Research
Daimler AG	Germany/USA	Automotive
General Motors (GM) Global Tech Operations	USA	Automotive
Honda	Japan	Automotive
Hyundai	South Korea	Automotive
Intelligent Energy	UK	Fuel Cells
JX Nippon	Japan	Energy
Kia	South Korea	Automotive
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
Kyocera Corp	Japan	Electronics
LG (Including LG Chemical Ltd and LG Fuel Cell Systems)	South Korea (HQ), USA, UK	Electronics
NGK (including NGK Spark Plug Co and NGK Insulators)	Japan	Electronics
Nissan	Japan	Automotive
Panasonic	Japan	Electronics
Samsung	South Korea	Electronics
Toray Ind	Japan	Chemistry & Research
Toyota	Japan	Automotive
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 three cases: Bloom Energy Corp, Ford Motor Co and the French National Centre for Scientific Research (CNRS) take the place of Bosch GMBH, Daimler AG and Volkswagen. The sector in which these additional three companies operate can be found in Table 2.1.2. The remaining 17 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
Bloom Energy Corp	USA	Fuel Cells
Ford Motor Co	USA	Automotive
French National Centre for Scientific Research	France	Research

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 (orange line). 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).

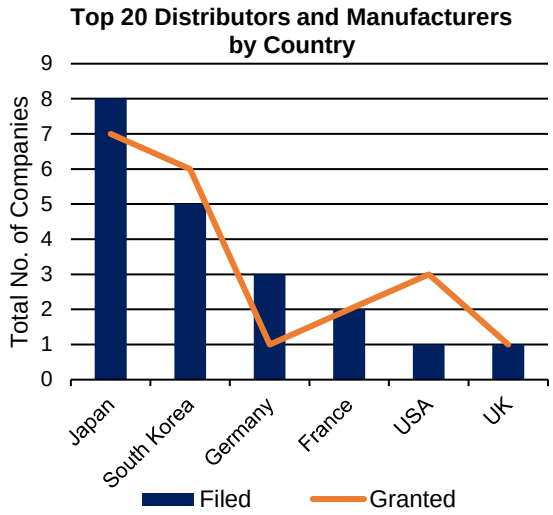


Figure 2.2.1. Top 20 fuel cell distributors and manufacturers by country.

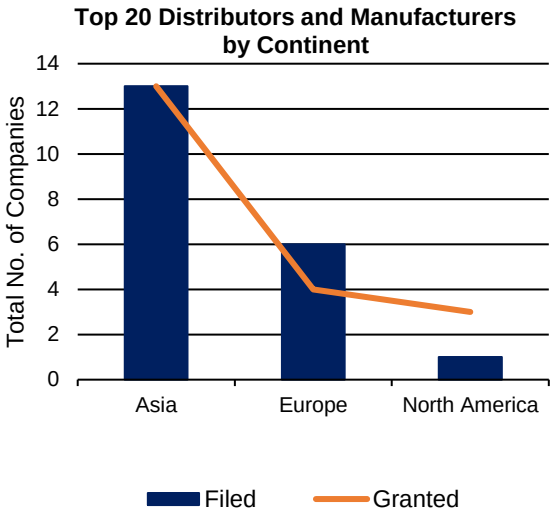


Figure 2.2.2. Global distribution of the Top 20 fuel cell manufacturers by continent.

Globally, 13 of the top 20 fuel cell companies of published applications 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 2019.

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).

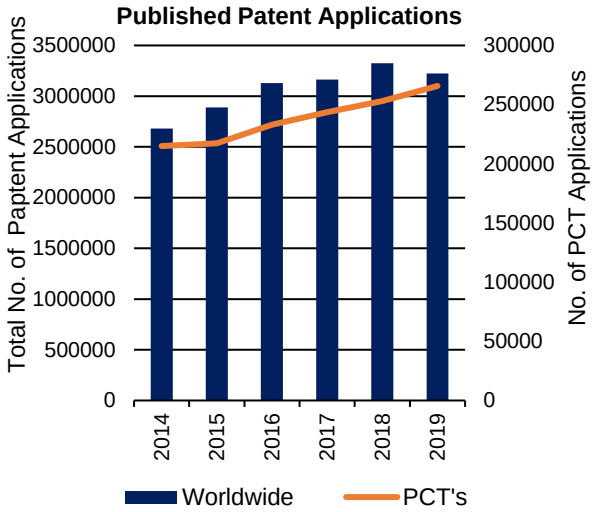


Figure 3.1.1. Published total patent applications vs. published PCT patent applications for 2014 to 2019.

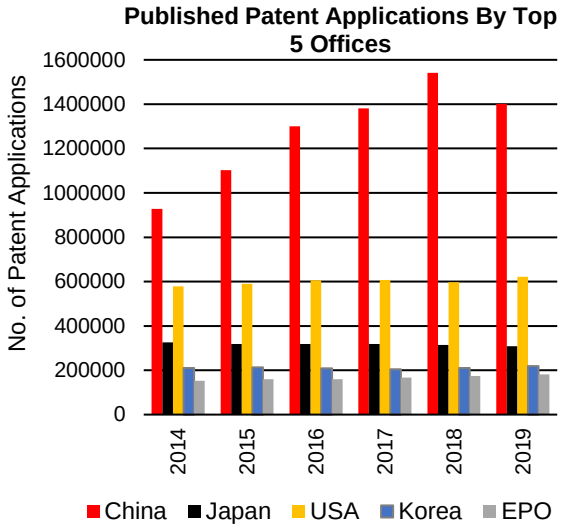


Figure 3.1.2. Published patent applications for the years 2014 to 2019.

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 in 2019, the total number of patent applications published worldwide shows a marginal decline.

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).

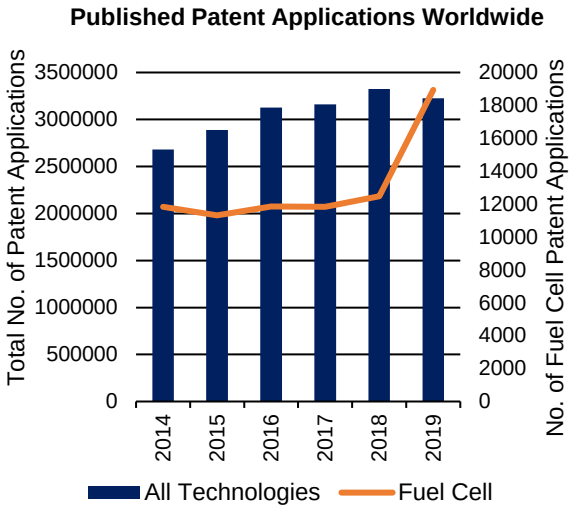


Figure 3.2.1. Published total patent applications vs. published fuel cell patent applications for 2014 to 2019.

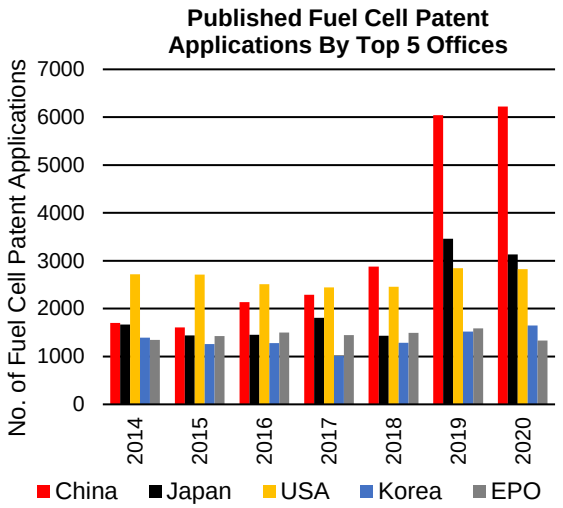


Figure 3.2.2. Published fuel cell patent applications for the Top 5 Patent Offices for 2014 to 2020.

The total number of patent filings are increasing annually at a greater rate than the total number of fuel cell patent filings for the period 2014 to 2018. Whilst the number of published fuel cell applications (orange line) appears fairly constant between 2014 and 2018, a large increase is observed between 2018 and 2019. This increase may be accounted for by the reclassification and addition of classifications within the search term (H01M8, Y02E60/50).

The publication data for fuel cell applications published at the Top 5 offices between 2014 and 2020 is shown in Figure 3.2.2. The overall number of fuel cell patents published at the top 5 offices between 2014 and 2018 is relatively constant year-on-year with the drops in some countries being mitigated by the rise in publications in China. As observed with the total number of fuel cell patent application filings (Figure 3.2.1; orange line), a large increase in the number of filings at the SIPO and JPO is observed between 2018 and 2019.

The number of fuel cell patents published annually around the world has remained in excess of 11000 since 2014. In 2019, the increase in the number of applications being published in the fuel cell space appears to be overtaking the overall increase in patent filings.

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.

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.

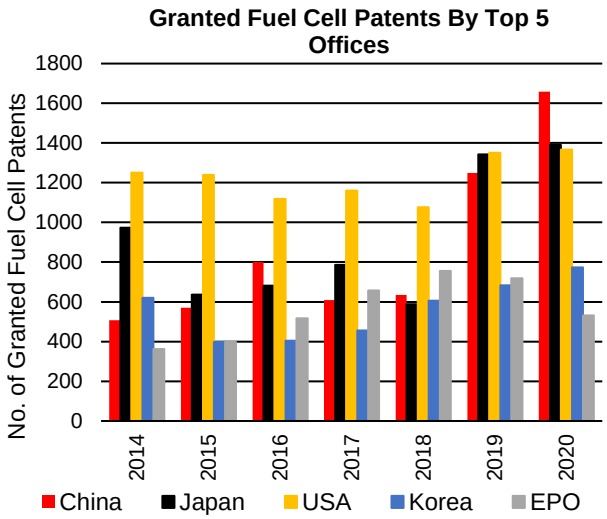


Figure 3.2.3. Granted fuel cell patents for the Top 5 Patent Offices for 2014 to 2020.

The number of fuel cell patents granted annually around the world has remained in excess of 3500 since 2014, with the top 5 offices accounting for over 86% of the total. Whilst the USPTO are the clear leaders in the publication of fuel cell patent applications over the period, the SIPO and the JPO have become increasingly more important territories for granting fuel cell patents since 2018. Businesses wishing to commercialise their fuel cell technology world-wide must continue to consider their patent position in these jurisdictions.

3.2.3. Assignee Data

Data presented below show 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 2020 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, followed by electronics companies.

3.2.3.1. Filing Statistics

The overall top 10 filers of published fuel cell patent applications for the years 2014 to 2020 are shown in Figure 3.2.4.

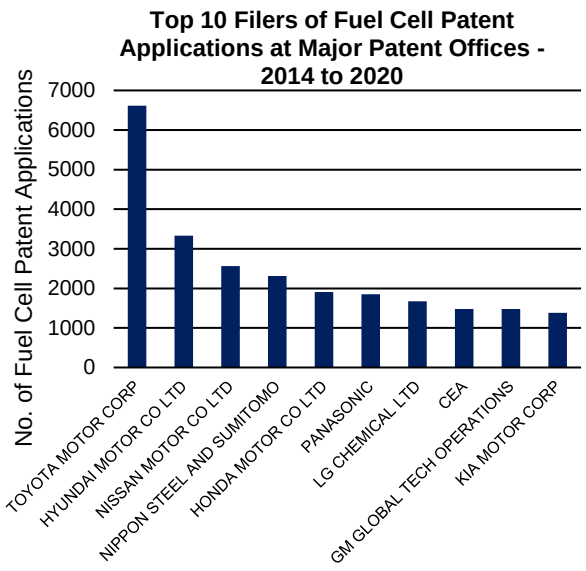


Figure 3.2.4. Top ten filers of published fuel cell patent applications at the Top 5 Patent Offices for 2014 to 2020.

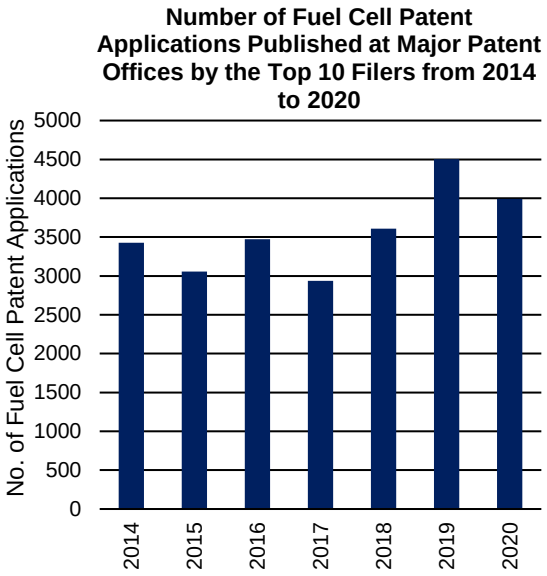


Figure 3.2.5. Number of patent applications published by top 10 filers for the years 2014 to 2020.

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

Toyota appears to be the dominant filer of fuel cell patent applications, with the number of filings accounting for 27% of the filings from the top 10. Toyota retains the position of top filer for each of the years 2014 to 2020. Second place is typically being taken by Hyundai or Nissan. 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 2020. 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 2020 are shown in Figure 3.2.6.

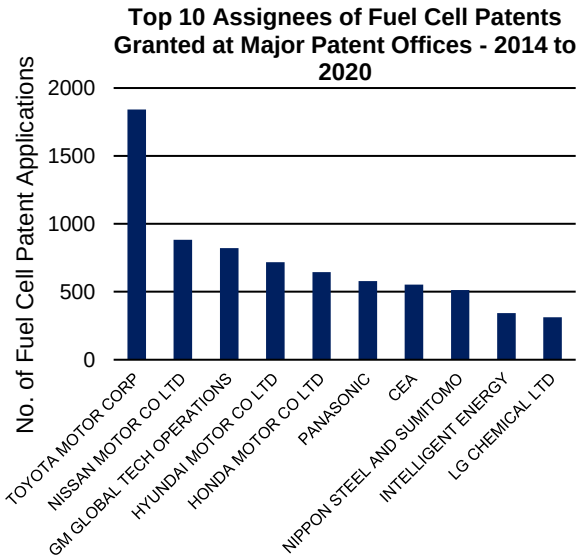


Figure 3.2.6. Top ten filers of granted fuel cell patents at the Top 5 Patent Offices for 2014 to 2020.

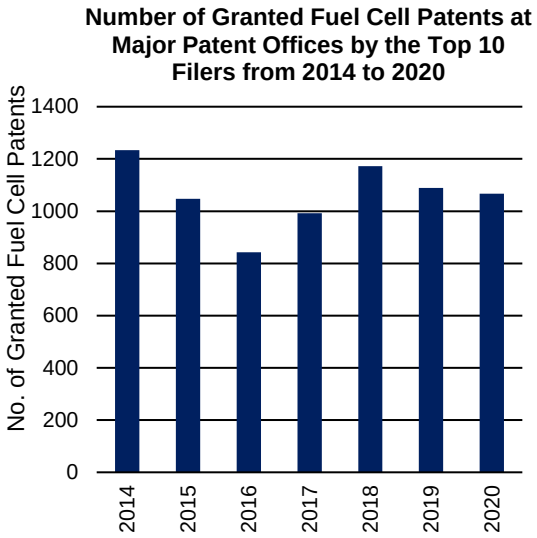


Figure 3.2.7. Number of patents granted by the top 10 filers for the years 2014 to 2020.

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 Intelligent Energy taking the place of Kia Motor Corp.

Toyota remains dominant, accounting for 26% of the granted fuel cell patents out of the top 10 filers.

Unsurprisingly, given the filing statistics, Toyota, Nissan, Hyundai, GM, Panasonic, CEA and Honda feature in the top 10 patentees annually. Toyota retains the position of top filer for each of the years 2014 to 2020.

Figure 3.2.7 shows the cumulative number of fuel cell patents granted by the top 10 filers from 2014 to 2020. The overall number of granted fuel cell patent applications of the top 10 filers fluctuates around 1000.

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 (orange line), for the years 2014 to 2020, 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 2020, 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 Japan are the leading university recipients of granted fuel cell patents for the period 2014 to 2020 (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.

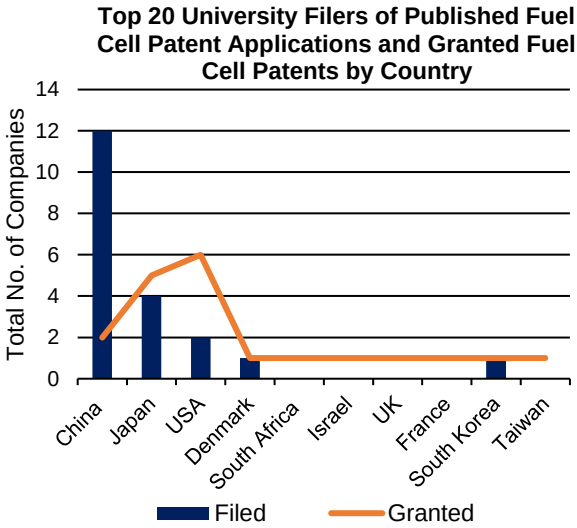


Figure 3.2.8. Top 20 university fuel cell applicants by country.

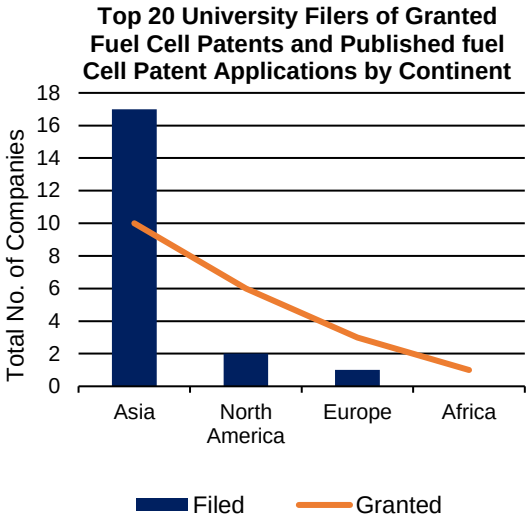


Figure 3.2.9. Distribution of the Top 20 university fuel cell patent applicants by continent.

Asia is the dominant continent in terms of the publication and grant of academic fuel cells patents. Globally, 85% of the top 20 university filers of fuel cell patent applications and 50% 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 2020). In each case the bars show the absolute number of patent applications or patents associated with each University.

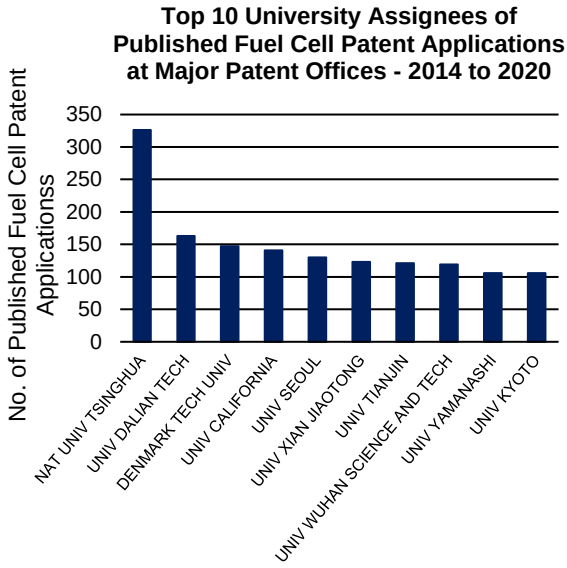


Figure 3.2.10. Top 10 university filers of fuel cell patent applications at the Top 5 Patent Offices for 2014 to 20120.

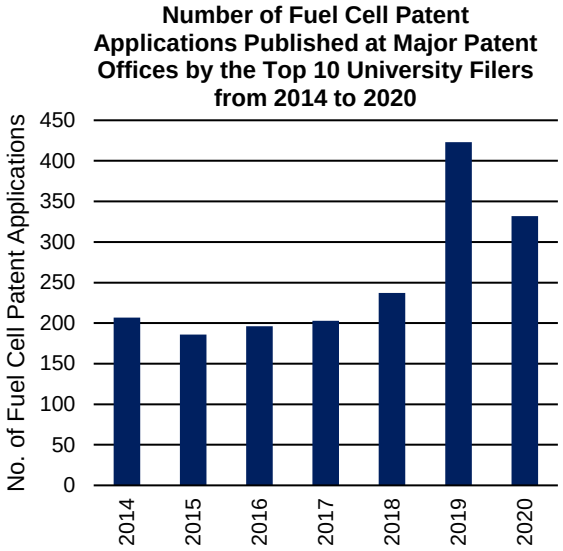


Figure 3.2.11. Number of patent applications published by top 10 university filers for the years 2014 to 2020.

The top 10 academic filers are dominated by Chinese universities.

The National University of Tsinghua is the leading university filer of fuel cell patent applications, filing 326 applications which accounts for 22% of the top 10 university filings.

The remaining 9 of the top 10 university filers of fuel cell patent applications each filed between 106 and 163 applications, each accounting for between 7 and 11% of the top 10 university filings.

The National University of Tsinghua appears to be, worldwide, the most dominant filer of fuel cell applications, featuring in the top two university filers annually from 2014 to 2020. However, there is a great variance in the number of filings reported with a low of 28 in 2016 and a high of 85 in 2019. These figures account for between 14 and 22% annually of the overall number of filings of the top 10 university fuel cell filers.

Figure 3.2.11 shows the cumulative number of fuel cell patent applications published by the top 10 university filers from 2014 to 2020.

The overall number of published fuel cell patent applications of the top 10 filers increased from 2015 to 2019. However, a notable decline in the number of fuel cell patent applications published by the top 10 universities was seen in 2020. 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.

3.2.4.3. Granted Fuel Cell Patents

The overall top 10 university filers of granted fuel cell patents for the years 2014 to 2020 is shown in Figure 3.2.12.

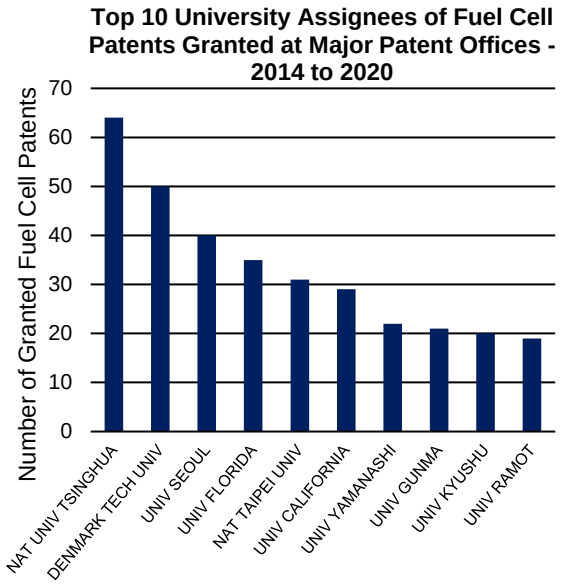


Figure 3.2.12. Top 10 university filers of granted fuel cell patents at the Top 5 Patent Offices for 2014 to 2020.

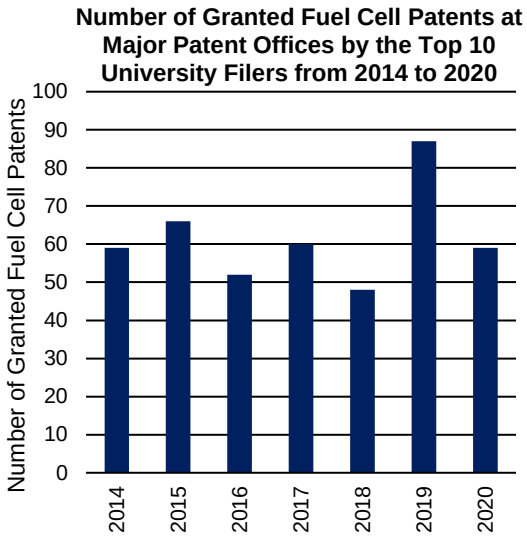


Figure 3.2.13. Number of patents granted to the top 10 university filers for the years 2014 to 2020.

The trend in patent statistics relating to the number of granted fuel cell patents of the top 10 university filers largely reflects that of the published patent applications, shown in Figure 3.2.10. The National University of Tsinghua remains in first and second place, with 4 of the top 10 universities also present in the top 10 university filers of granted fuel cell patents.

The National University of Tsinghua features in the top 3 university filers of granted fuel cell patents annually, except for 2019 when it featured in the top 9 university filers.

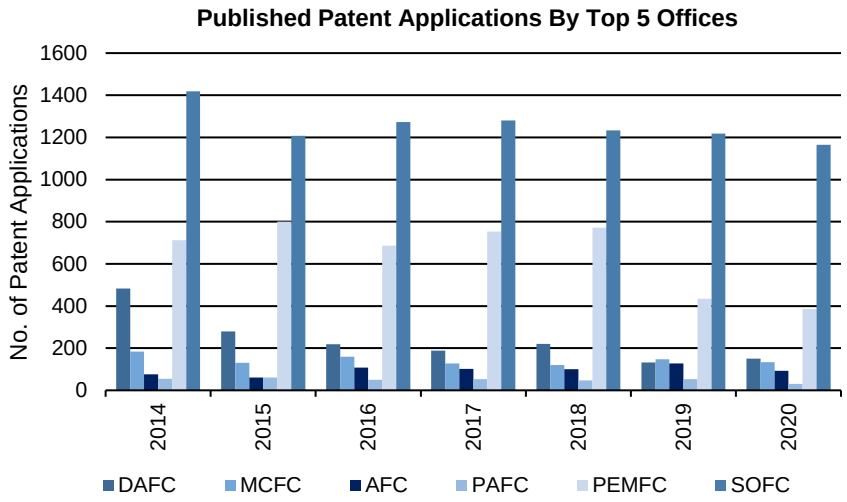
Figure 3.2.13 shows the cumulative number of fuel cell patents granted by the top 10 university filers from 2014 to 2020.

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 in 2019 and those reported in 2020, 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 shows the change in total filings across the period at the top five offices for each of the fuel cell types.



3.3.1. Total patent applications at the top five patent offices for 2014 to 2020.

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 a decrease 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 2020, at the top 5 offices.

The USPTO appears to be the office handling the most patent applications for specific chemistry. Whereas, the office handling the lowest number of patent applications appears to vary for the specific chemistries. The Chinese Patent Office (SIPO) is the second top filer for overall chemistries. This is in line with the overall fuel cell filings at the SIPO being in the top two annually between 2014 and 2020 (see Figure 3.2.2).

Also presented are the top 10 filers of patent applications for each of the individual fuel cell chemistries, for the years 2014 to 2020, 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.

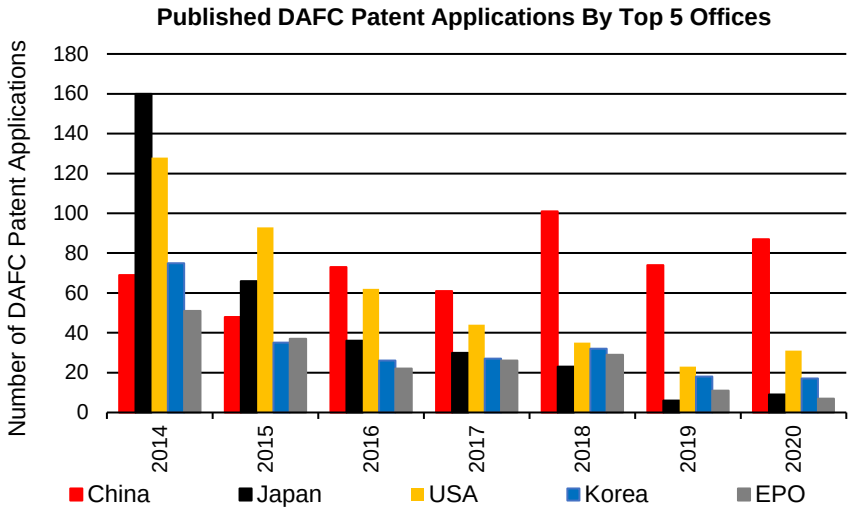


Figure 3.3.2. Direct alcohol fuel cell patent applications for 2014 to 2020.

The data shows that filings at the USPTO, JPO, 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 2018 and the second 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 (DMFCs), for the top 5 offices over the period 2014 to 2020. The top filers are dominated by Korean entities, with Samsung, LG and the Korean Research Institute being the top three filers of DAFC patent applications over the period.

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 2020. 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 2020.

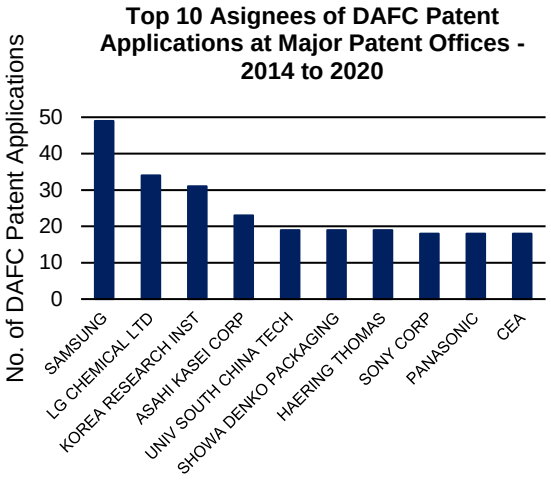


Figure 3.3.3. Top 10 filers of DAFC patent applications at the Top 5 Patent Offices for 2014 to 2020.

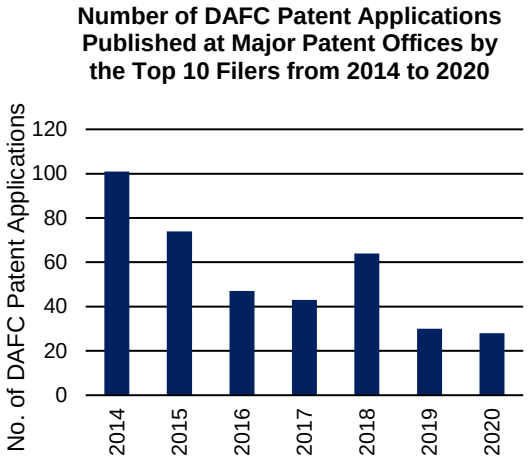
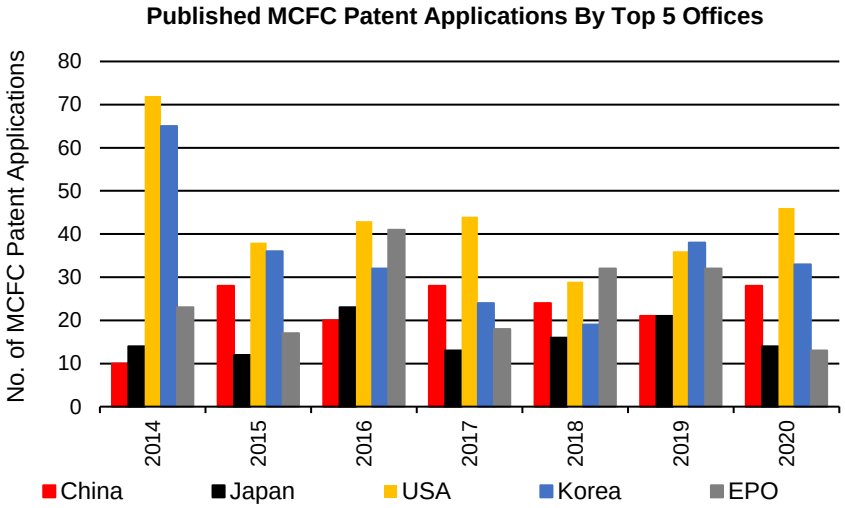


Figure 3.3.4. Number of DAFC patent applications published by the top 10 filers for the years 2014 to 2020.

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.



3.3.5. Molten Carbonate fuel cell patent applications for 2014 to 2020.

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 the USA and Korea has significantly waned over the following years, with marginal changes of -36% (USPTO) and -49% (KIPO) over the period. The EPO, SIPO and JPO show fluctuations in the number of patent filings over the period 2014 to 2020.

Figure 3.3.6 shows the top 10 assignees of MCFC patent applications for the top 5 offices over the period 2014 to 2020. The top filers are Exxon Mobil (USA) and Fuel Cell Energy Inc (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 2020. 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 2020 (Figure 3.3.7).

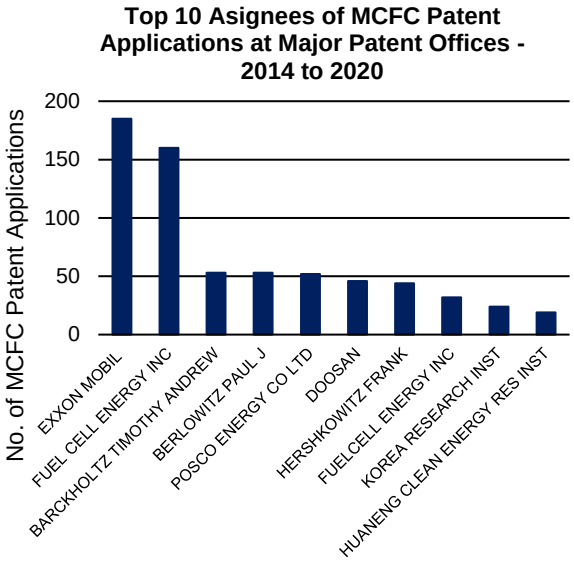


Figure 3.3.6. Top 10 filers of MCFC patent applications at the Top 5 Patent Offices for 2014 to 2020.

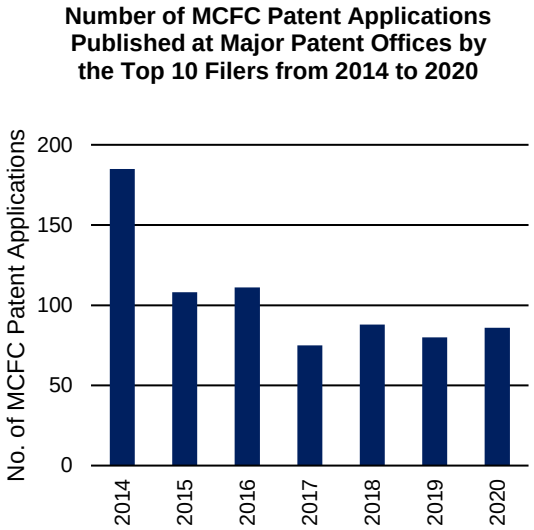
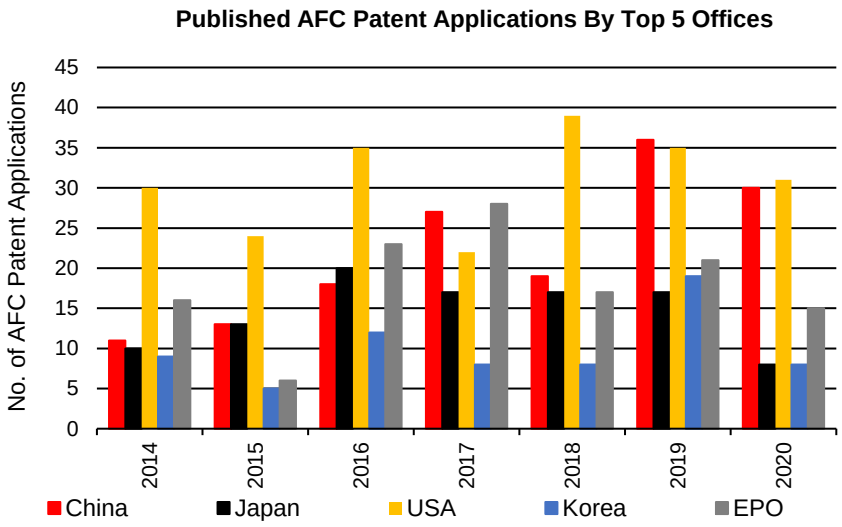


Figure 3.3.7. Number of MCFC patent applications published by the top 10 filers for the years 2014 to 2020.

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.



3.3.8. Alkaline fuel cell patent applications for 2014 to 2020.

All 5 offices show variations in the number of AFC patent applications published between 2014 and 2020. However, despite the fluctuation in the number of filings, the USPTO appears to be the most important filing jurisdiction 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 2020.

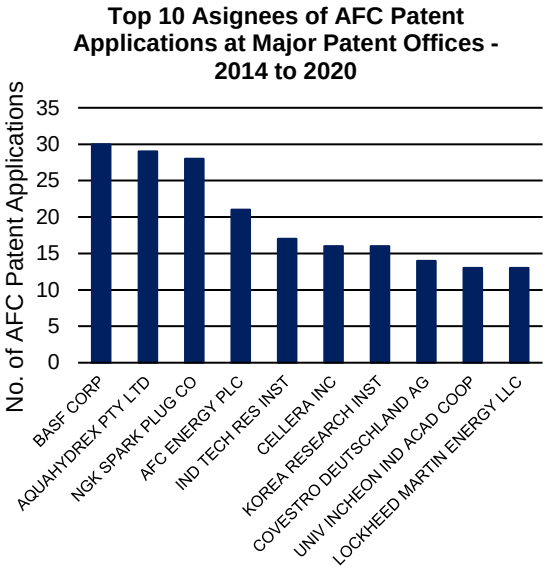


Figure 3.3.9. Top 10 filers of AFC patent applications at the Top 5 Patent Offices for 2014 to 2020.

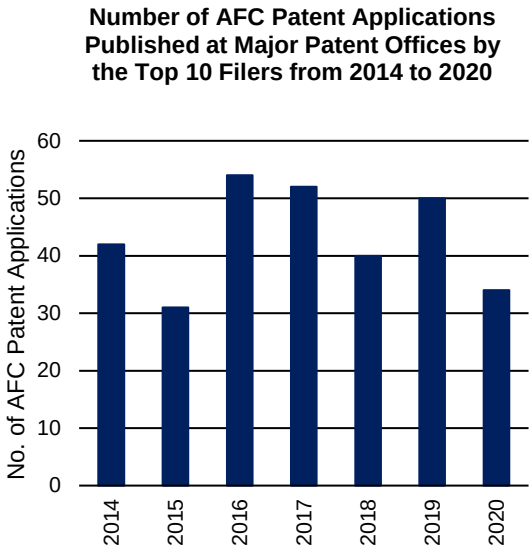
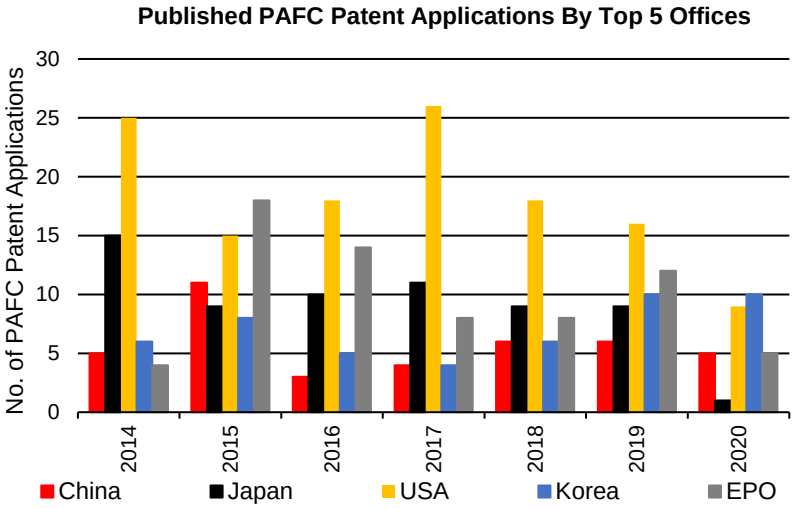


Figure 3.3.10. Number of AFC patent applications published by the top 10 filers for the years 2014 to 2020.

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.



3.3.11. Phosphoric acid fuel cell patent applications for 2014 to 2020.

All 5 offices show variations in the number of PAFC patent applications published between 2014 and 2020 by the top filers. Despite a marginal decrease of -36%, the USPTO again appears to be the most important filer over the period 2014 to 2019. However, filings at the KIPO increased significantly between 2017 and 2020, leading them to become the top filer of PAFC patent applications in 2020.

Figure 3.3.12 shows the top 10 assignees of PAFC patent applications for the top 5 offices over the period 2014 to 2020. 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 2020.

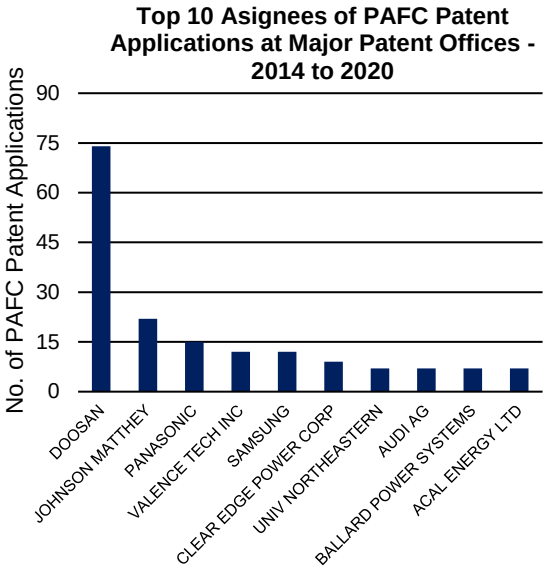


Figure 3.3.12. Top 10 filers of PAFC patent applications at the Top 5 Patent Offices for 2014 to 2020.

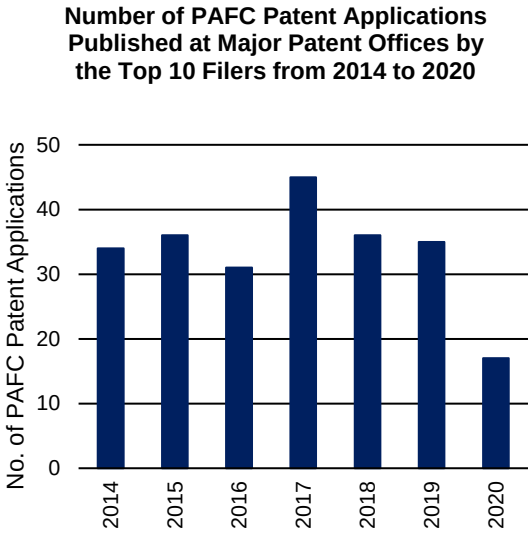
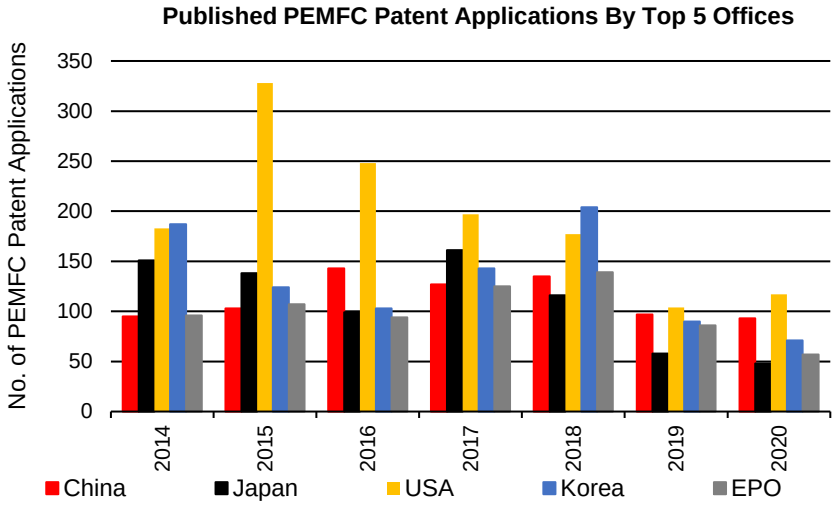


Figure 3.3.13. Number of PAFC patent applications published by the top 10 filers for the years 2014 to 2020.

3.3.5. Proton Exchange Membrane Fuel Cell

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



3.3.14. PEM fuel cell patent applications for 2014 to 2020.

All 5 offices show variations in the number of PEMFC patent applications published between 2014 and 2020. Notably, the data shows a temporary growth in filings at the USPTO between 2014 and 2015 followed by a substantial decline to show a marginal loss over the period of -36%.

Figure 3.3.15 shows the top 10 assignees of PEMFC patent applications for the top 5 offices over the period 2014 to 2020. Many of the top 10 filers come from the automotive sector, with the overall top filers consisting of Toyota (China, USA and Japan) and Hyundai (Korea).

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 2020.

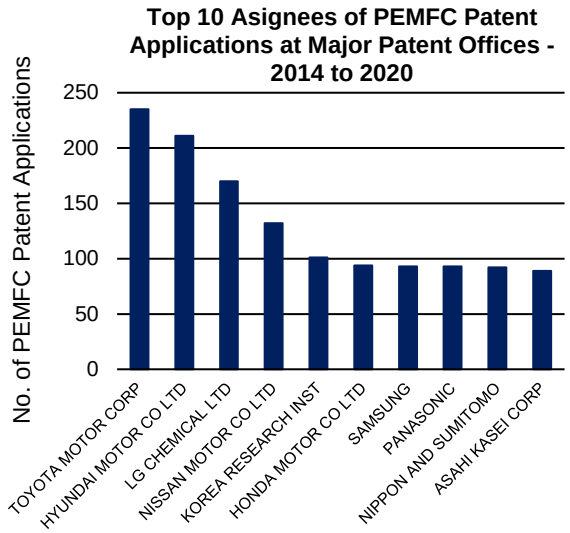


Figure 3.3.15. Top 10 filers of PEMFC patent applications at the Top 5 Patent Offices for 2014 to 2020.

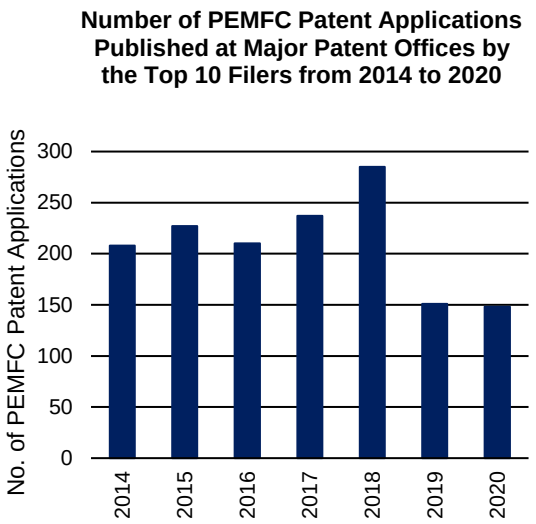
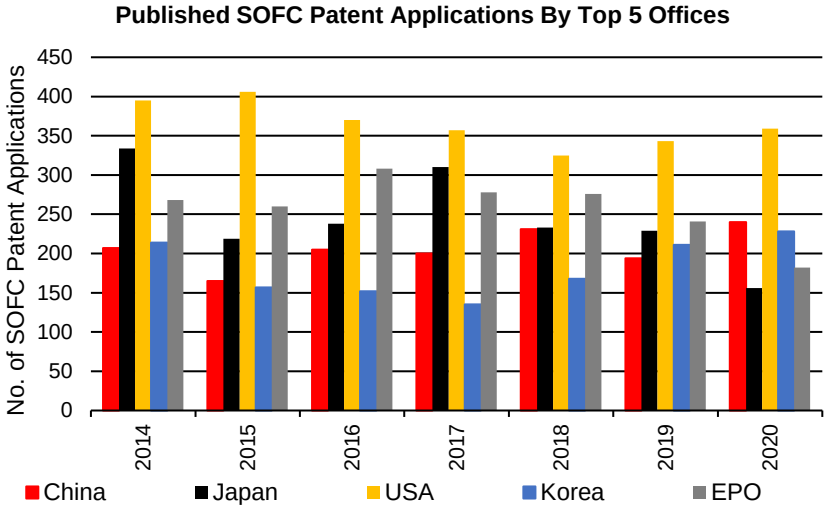


Figure 3.3.16. Number of PEMFC patent applications published by the top 10 filers for the years 2014 to 2020.

3.3.6. Solid Oxide Fuel Cells

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



3.3.17. Solid oxide fuel cell patent applications for 2014 to 2020.

All 5 offices show variations in the number of SOFC patent applications published between 2014 and 2020. However, the USPTO remains the most dominant filer of SOFC patent applications over the period.

Figure 3.3.18 shows the top 10 assignees of SOFC patent applications for the top 5 offices over the period 2014 to 2020. The top filers over the period are LG (Korea) and NGK (Japan).

Figure 3.3.19 shows the cumulative number of SOFC patent applications published at the top 5 offices by the top 10 filers from 2014 to 2020. An overall decrease in published SOFC patent applications by the top 10 filers is observed between 2014 and 2020 (Figure 3.3.19).

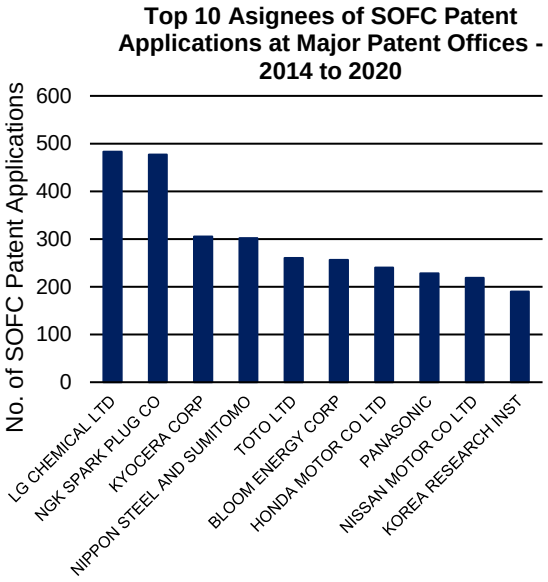


Figure 3.3.18. Top 10 filers of SOFC patent applications at the Top 5 Patent Offices for 2014 to 2020.

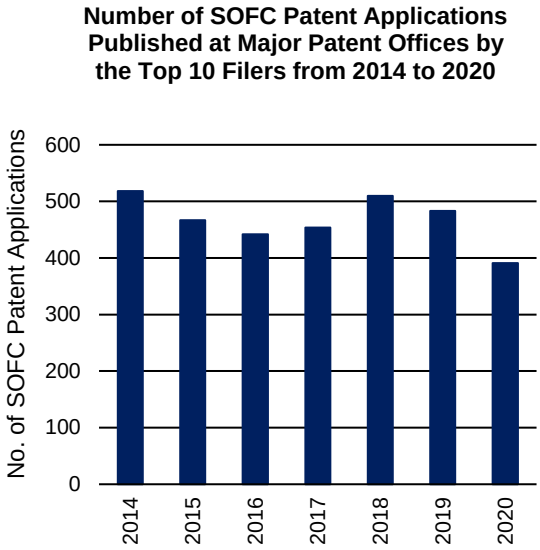
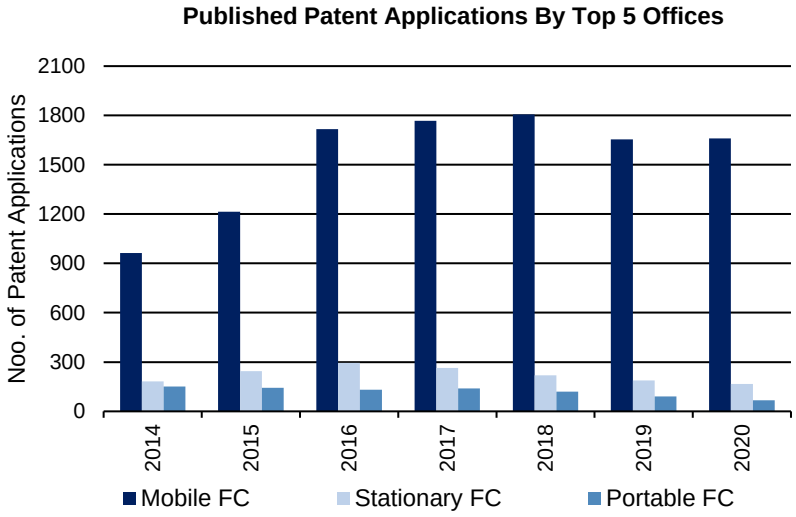


Figure 3.3.19. Number of SOFC patent applications published by the top 10 filers for the years 2014 to 2020.

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.



3.4.1. Total patent applications at the top five patent offices for 2014 to 2020.

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, for the years 2014 to 2020, at the top 5 offices.

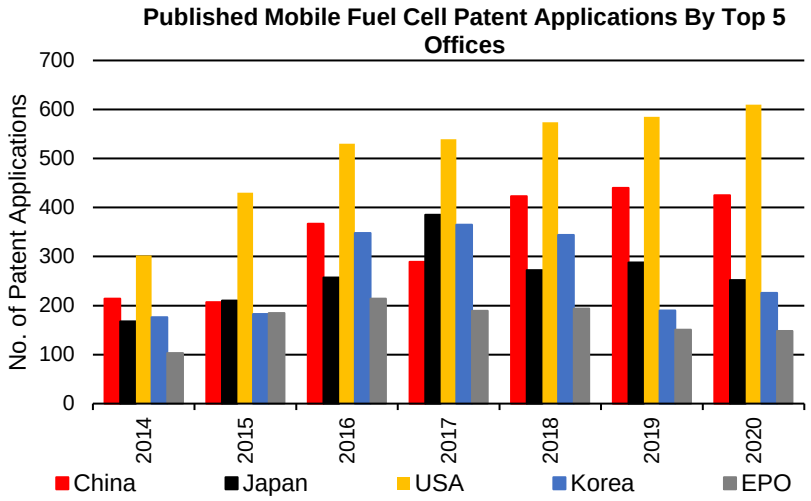
Consistently, the USPTO appears to be the office handling the most patent applications for fuel cell deployment.

Also presented are the top 10 filers of patent applications for mobile, stationary and portable fuel cell, for the years 2014 to 2020, 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, Hyundai and Nissan, Exxon Mobil and Intelligent Energy 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.



3.4.2. Mobile fuel cell patent applications for 2014 to 2020.

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.

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 2020. 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 2020. An overall increase in published mobile fuel cell patent applications by the top 10 filers is observed between 2014 and 2020 (Figure 3.4.4).

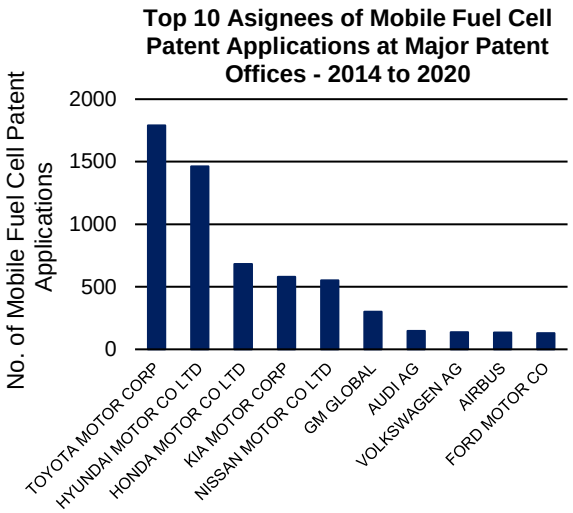


Figure 3.4.3. Top 10 filers of mobile fuel cell patent applications at Top 5 Patent Offices for 2014 to 2020.

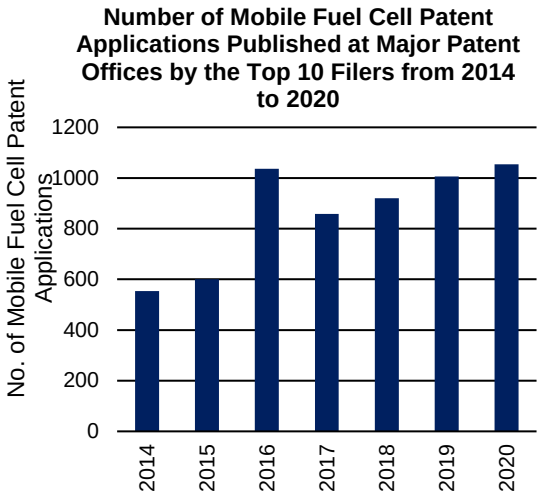
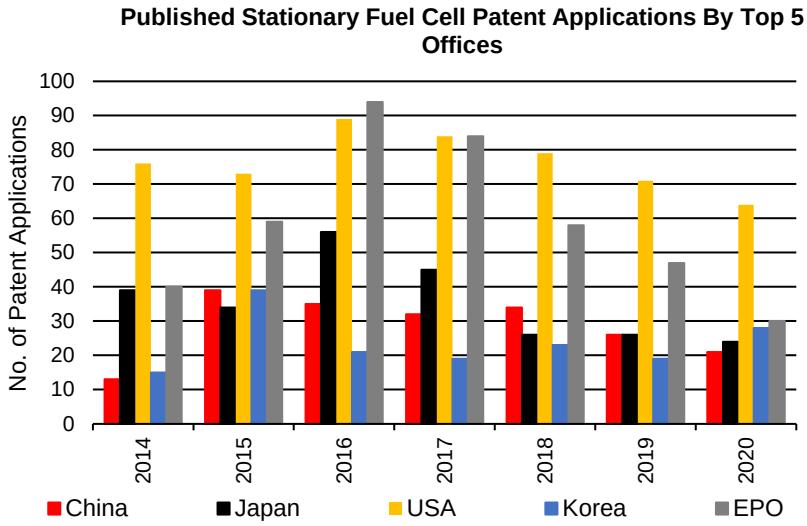


Figure 3.4.4 Number of mobile fuel cell patent applications published by the top 10 filers for the years 2014 to 2020.

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.



3.4.5. Stationary fuel cell patent applications for 2014 to 2020.

With the exception of 2016 and 2017, when the EPO were the top filer, 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 2020.

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 2020. 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 2020. An overall decrease in published stationary fuel cell patent applications by the top 10 filers is observed between 2014 and 2020 (Figure 3.4.7).

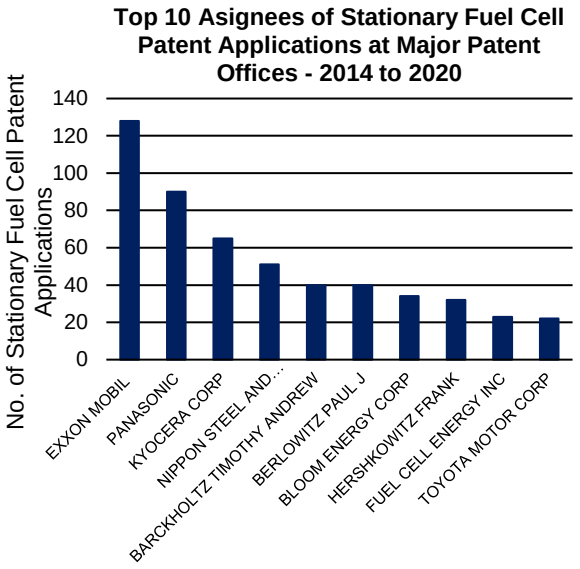


Figure 3.4.6. Top 10 filers of stationary fuel cell patent applications at Top 5 Patent Offices for 2014 to 2020.

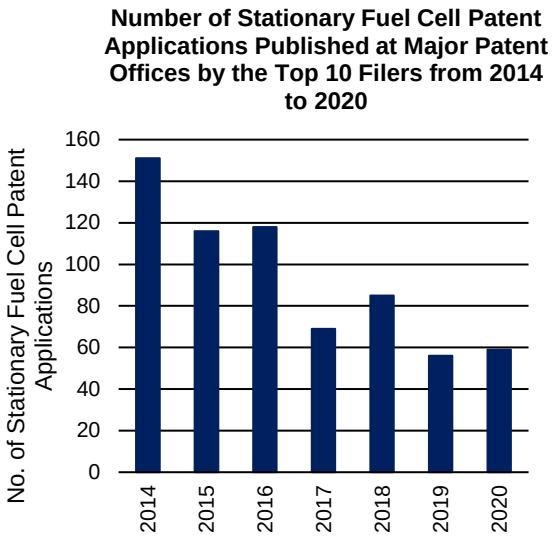
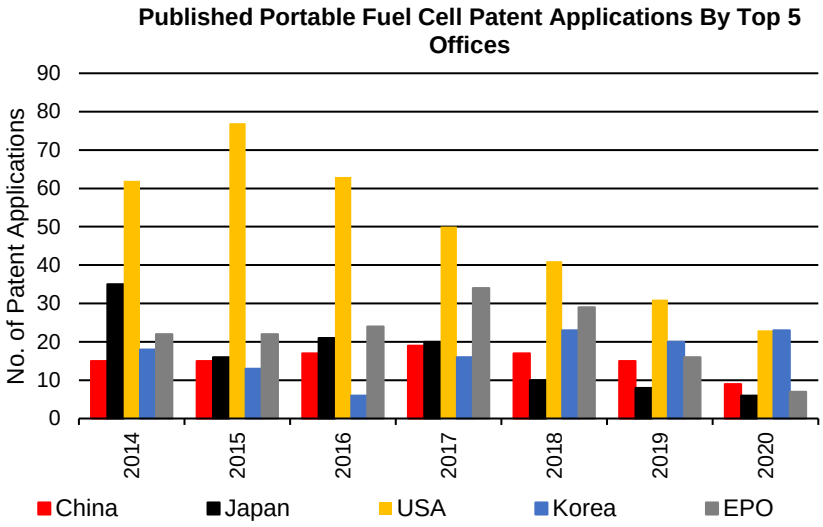


Figure 3.4.7 Number of stationary fuel cell patent applications published by the top 10 filers for the years 2014 to 2020.

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.



3.4.8. Portable fuel cell patent applications for 2014 to 2020.

The figures for patent filings at the USPTO show a marked decline over the period (-50%). Filings at the JPO appear to be trending downwardly whilst the remaining offices (EPO, KIPO and SIPO) show fluctuations between 2014 and 2020.

Figure 3.4.9 shows the top 10 assignees of portable fuel cell patent applications for the top 5 offices over the period 2014 to 2020. 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 2020. An overall decrease in published portable fuel cell patent applications by the top 10 filers is observed between 2014 and 2020 (Figure 3.4.10).

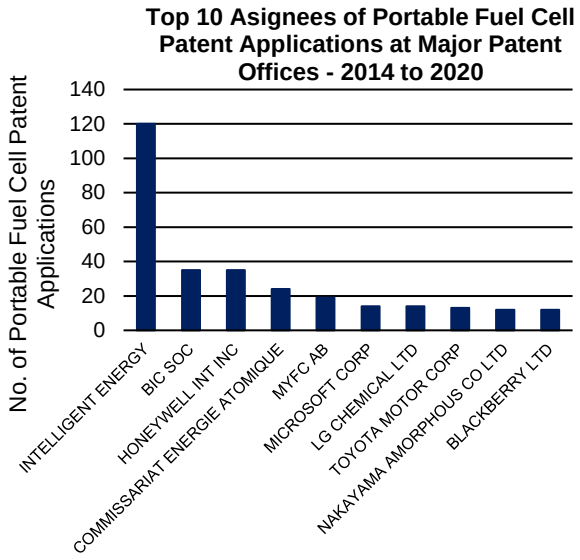


Figure 3.4.9. Top 10 filers of portable fuel cell patent applications at Top 5 Patent Offices for 2014 to 2020.

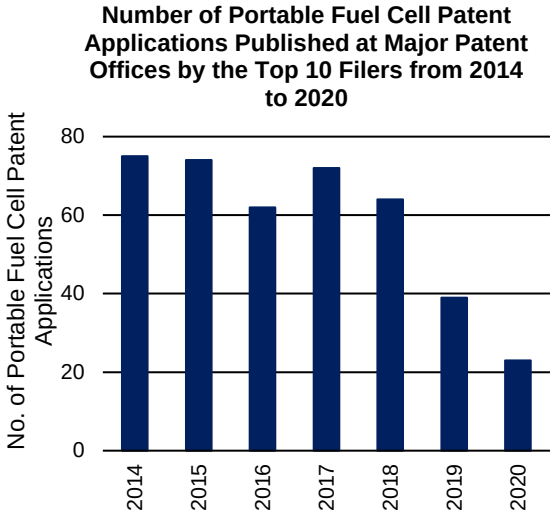
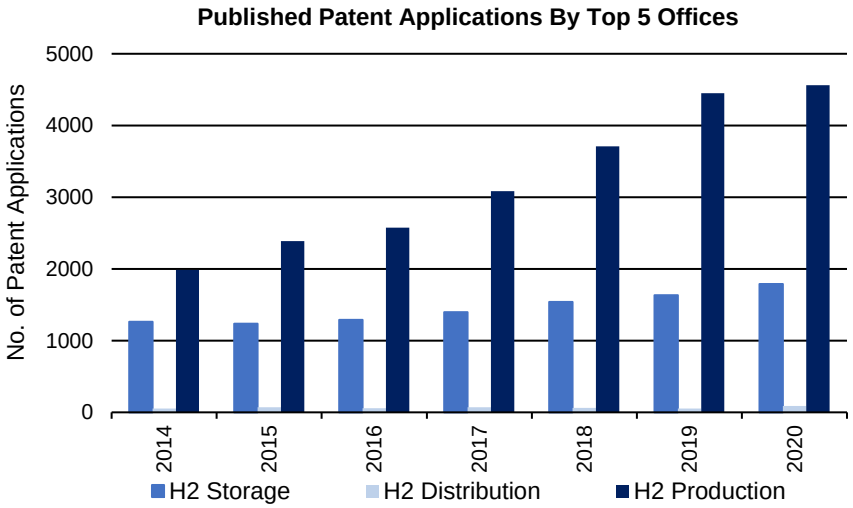


Figure 3.4.10 Number of portable fuel cell patent applications published by the top 10 filers for the years 2014 to 2020.

3.5. Hydrogen Transportation

The data presented below compares filing statistics according to hydrogen transportation, consisting of: 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, distribution and production.



3.5.1. Total patent applications at the top five patent offices for 2014 to 2020.

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

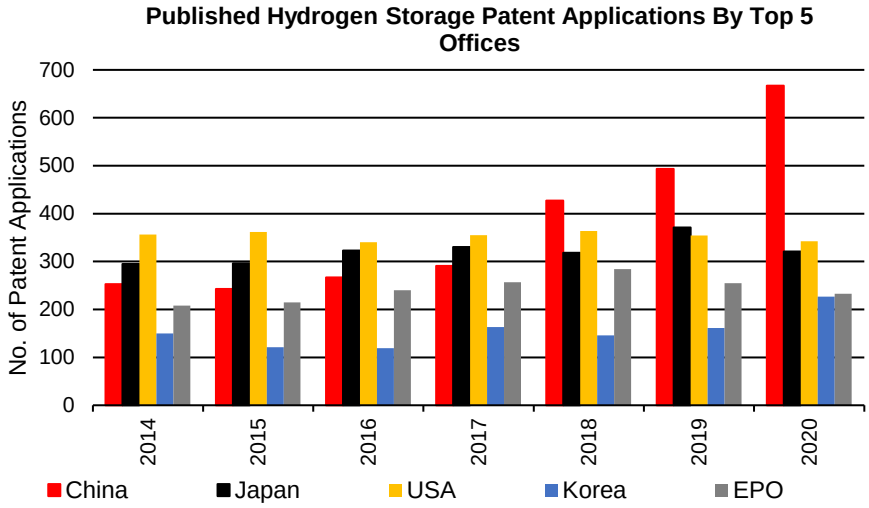
The following data presents the number of patent applications filed, according to hydrogen transportation, for the years 2014 to 2020, at the top 5 offices.

The data shows that China is the most important jurisdiction for businesses filing patent applications in these categories. In contrast, Korea does not appear to be an important jurisdiction for 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 2020, 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.



3.5.2. Hydrogen storage patent applications for 2014 to 2020.

Patent filings at the EPO, JPO, KIPO and SIPO appear to have been relatively flat between 2014 and 2020. In comparison, patent filings in China show a marked incline between 2017 and 2020.

Figure 3.5.3 shows the top 10 assignees of hydrogen storage patent applications for the top 5 offices over the period 2014 to 2020. 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 2020. A significant increase in the number of filings is observed between 2018 and 2019 (Figure 3.5.4).

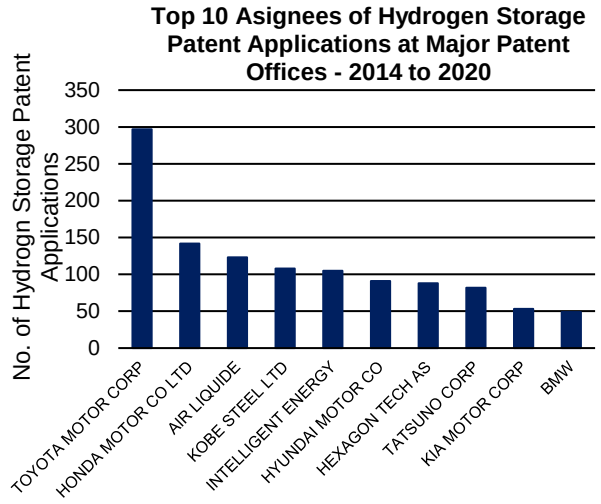


Figure 3.5.3. Top 10 filers of hydrogen storage patent applications at Top 5 Patent Offices for 2014 to 2020.

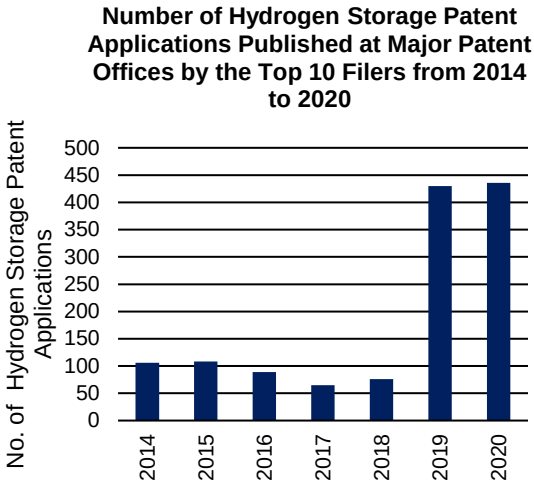
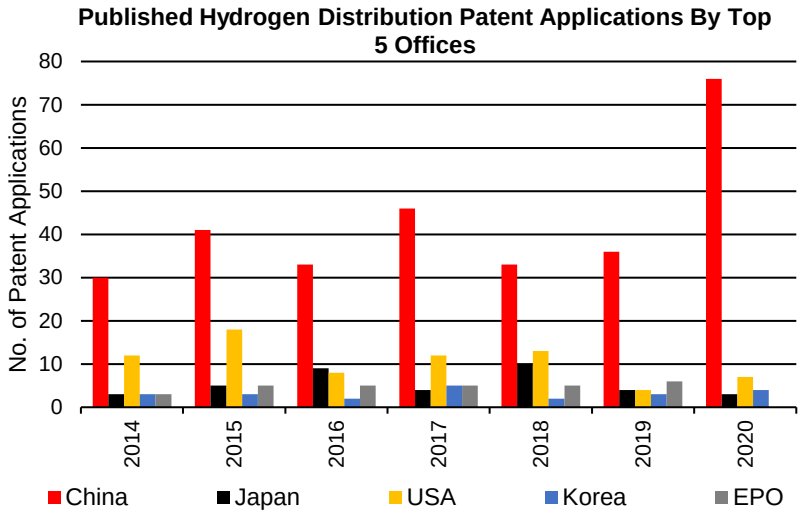


Figure 3.5.4. Number of hydrogen storage patent applications published by the top 10 filers for the years 2014 to 2020.

3.5.2. Hydrogen Distribution

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



3.5.5. Hydrogen distribution patent applications for 2014 to 2020.

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 2020. 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 2020.

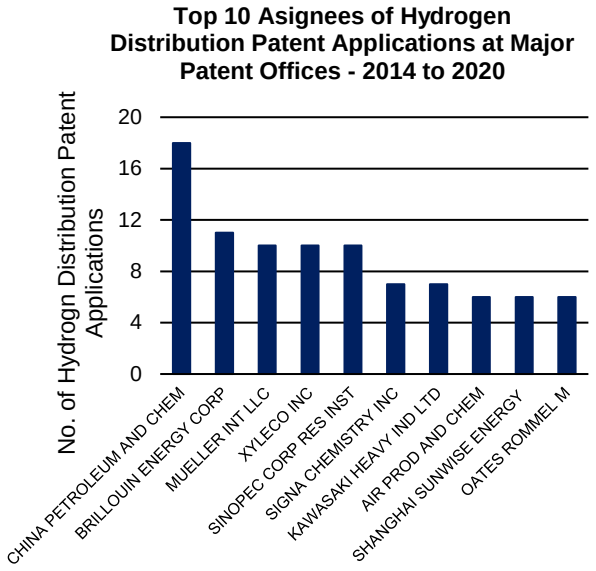


Figure 3.5.6. Top 10 filers of hydrogen distribution patent applications at Top 5 Patent Offices for 2014 to 2020.

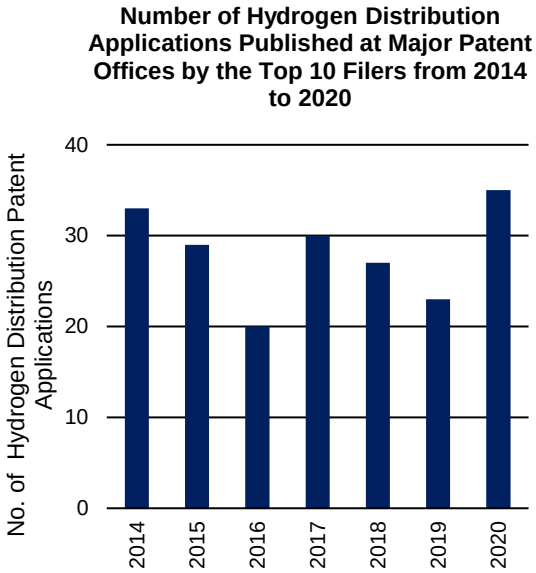
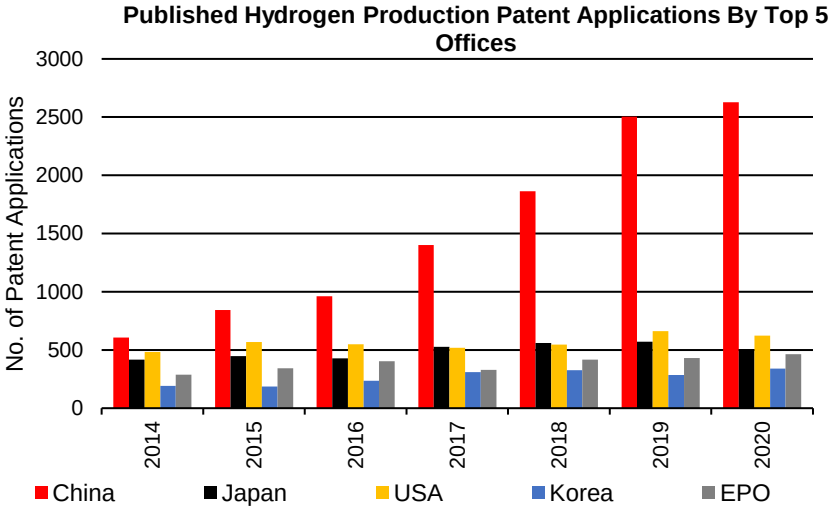


Figure 3.5.7. Number of hydrogen distribution patent applications published by the top 10 filers for the years 2014 to 2020.

3.5.3. Hydrogen Production Non-Carbon-Containing Sources including Electrolysis

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



3.5.8. Hydrogen production patent applications for 2014 to 2020.

Figure 3.5.8 shows that China is a very important jurisdiction for hydrogen production patent applications. 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 2020. The top filers are the CEA (France), Intelligent Energy (China, the USA and Europe) and Panasonic (Japan).

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 2020. As observed with the hydrogen storage patent applictions, a significant increase in the number of filings is observed between 2018 and 2019.

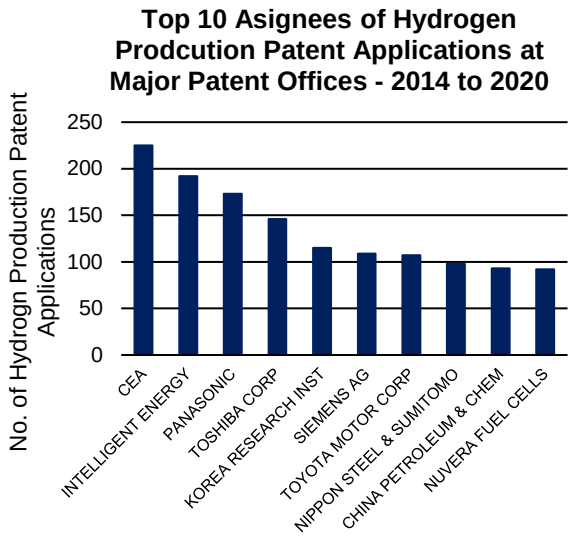


Figure 3.5.9. Top 10 filers of hydrogen production patent applications at Top 5 Patent Offices for 2014 to 2020.

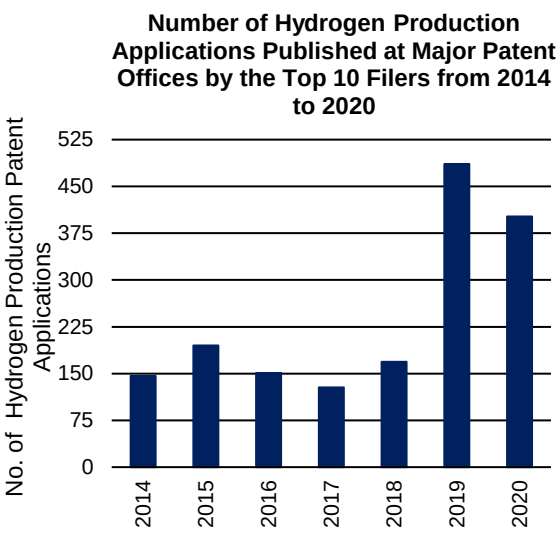


Figure 3.5.10. Number of hydrogen production patent applications published by the top 10 filers for the years 2014 to 2020.

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 alternative fuel sources.

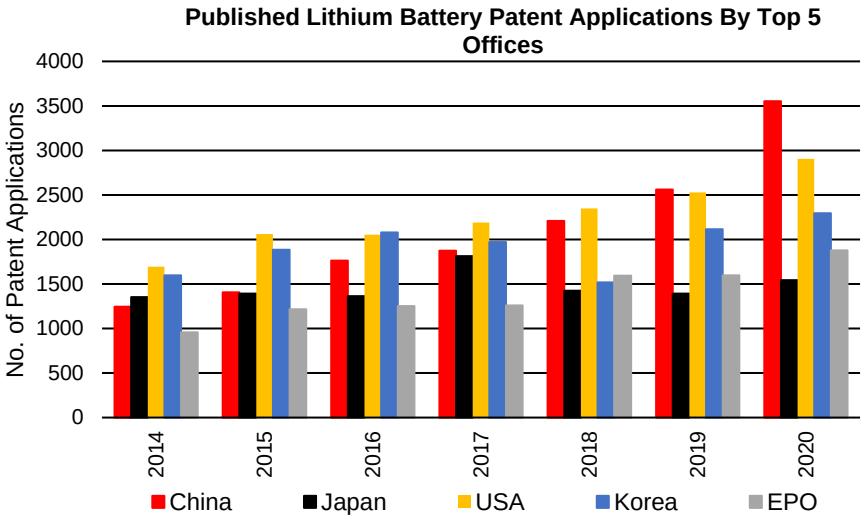
4.1. Lithium Batteries

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 years 2014 to 2020, 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. Filing Statistics

Figure 4.1.1 shows the total patent filings for lithium batteries across the top 5 patent offices.



4.1.1. Lithium battery patent applications for 2014 to 2020.

Figure 4.1.1 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, the overall trend in all jurisdictions is upwards, with growth in the number of patent applications filed being strongest in China and the USA.

Figure 4.1.2 shows the top 10 assignees of lithium battery patent applications for the top 5 offices over the period 2014 to 2020. The top filers are LG, Samsung and Toyota, with LG the dominant entity.

Figure 4.1.3 shows the cumulative number of lithium battery patent applications published at the top 5 offices by the top 10 filers from 2014 to 2020. An overall increase in the number of filings is observed between 2014 and 2020.

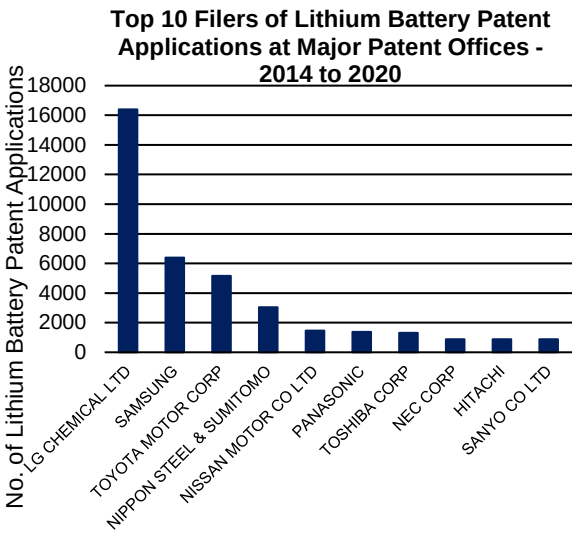


Figure 4.1.2. Top 10 filers of lithium battery patent applications at Top 5 Patent Offices for 2014 to 2020.

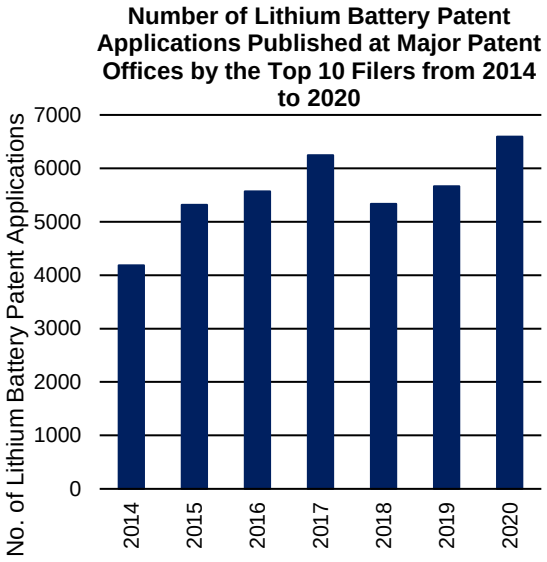
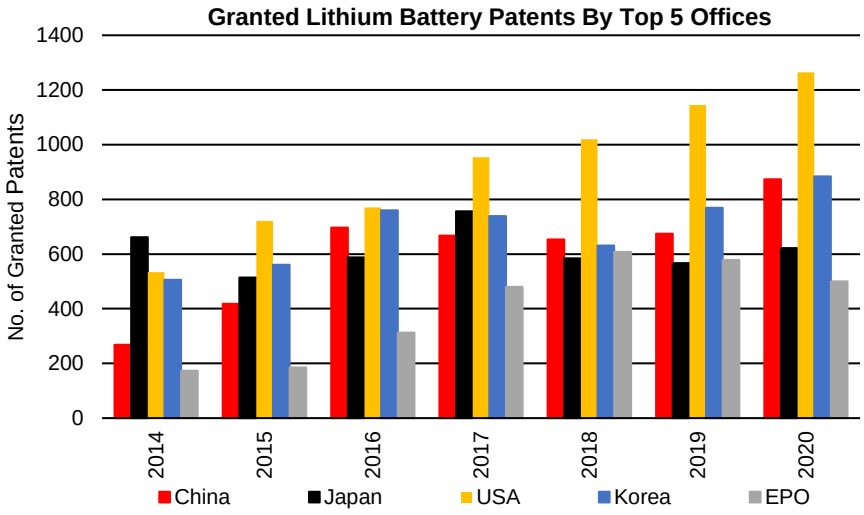


Figure 4.1.3. Number of lithium battery patent applications published by the top 10 filers for the years 2014 to 2020.

4.1.2. Granted Patents

Figure 4.1.4 shows the total number of granted lithium battery patents across the top 5 patent offices.



4.1.4. Granted lithium battery patents for 2014 to 2020.

Figure 4.1.4 shows that the USA is the most important territory for granting lithium battery patents and that the EPO is the least important territory, of the top 5 offices, for granting lithium battery patents.

Figure 4.1.5 shows the top 10 assignees of granted lithium battery patents for the top 5 offices over the period 2014 to 2020. As observed with the number of lithium battery patent applications, the top assignees of granted lithium battery patents are LG, Samsung and Toyota.

Figure 4.1.6 shows the cumulative number of lithium battery patents granted at the top 5 offices by the top 10 assignees. As observed with the cumulative number of lithium battery patent applications, the number of granted patents shows an overall increase between 2014 and 2020.

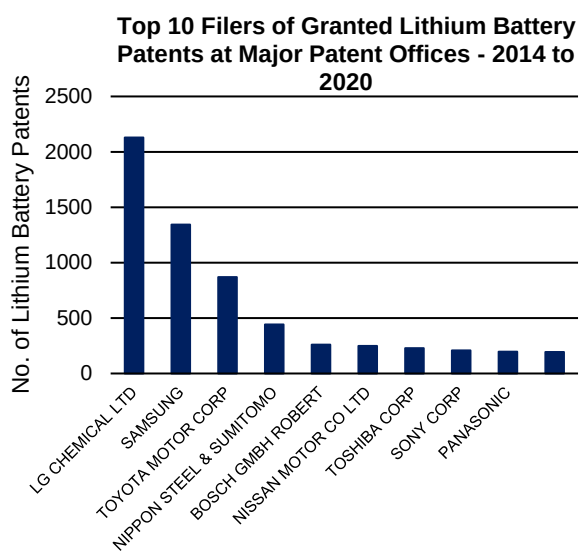


Figure 4.1.5. Top 10 filers of lithium battery patents granted at Top 5 Patent Offices for 2014 to 2020.

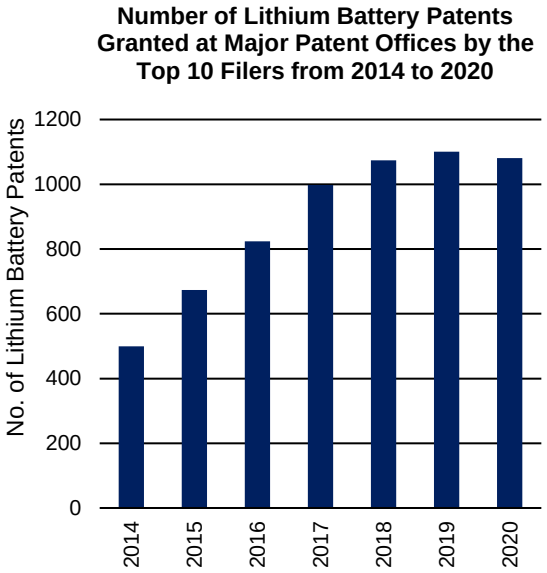


Figure 4.1.6. Number of lithium battery patents granted by the top 10 filers for the years 2014 to 2020.

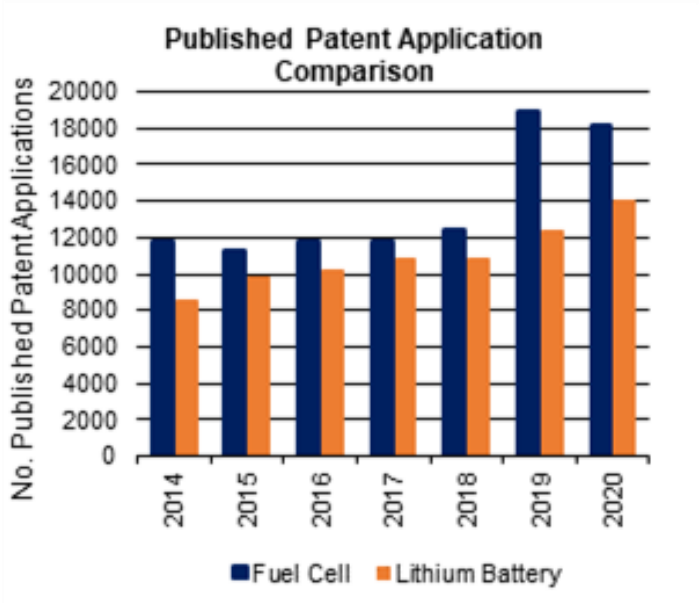


Figure 4.1.6. Comparison of total number of fuel cell patent publications and lithium battery patent publications for the years 2014 to 2020

The relative quanta of fuel cell patent application publications to lithium battery patent application publications is shown above. In both instances the absolute number of application sis increasing over the period, with the growth in lithium battery patent applications appearing to grow at a steady annual rate and the fuel cell patent applications showing a more varied growth. The filing statistics for following years will demonstrate how the trends continue.

4.2. Battery Accumulators

Figure 4.2.1 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 2019.

All three data sets show an overall increase over the period with the battery patent application data showing a similar trend to those of the total number of patent applications published worldwide.

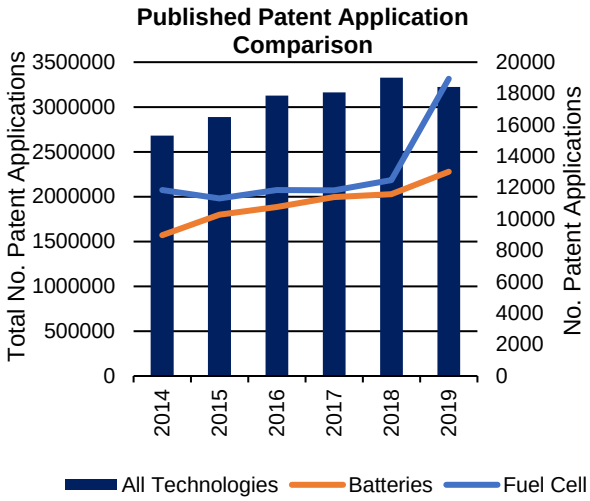
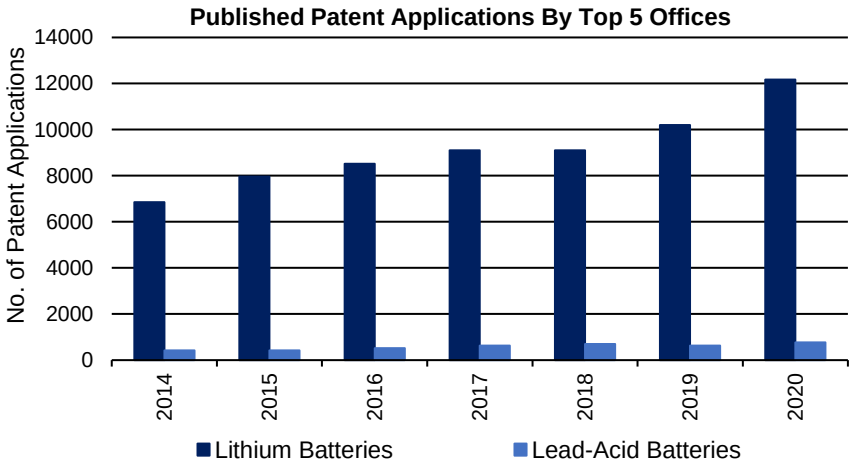


Figure 4.2.1. Top ten filers of hydrogen production patent applications at the Top 5 Patent Offices for 2020.

Table 4.2.1. List of classification codes searched for in battery accumulators.

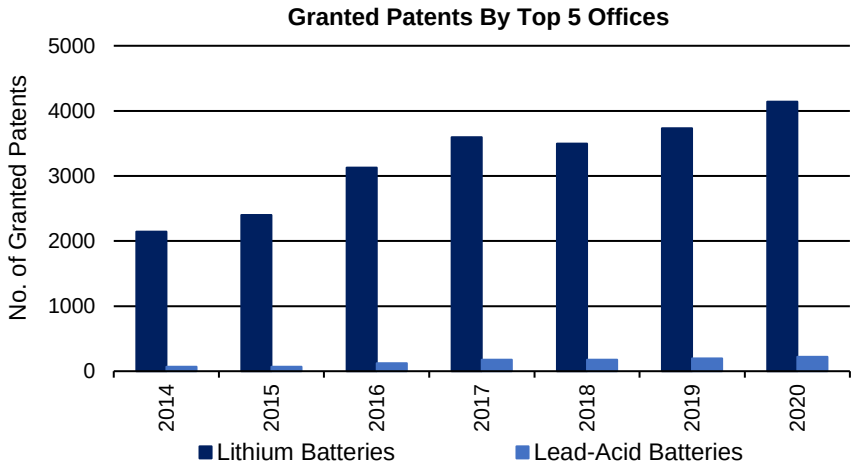
Category	Classification Codes
Lithium Batteries	HO1M10/052
Lead-Acid Batteries	HO1M10/06

Figure 4.2.2 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.



4.2.2. Total patent applications at the top five patent offices for 2014 to 2020.

The granted patent data (Figure 4.2.3) shows a similar trend to the filing statistics (Figure 4.2.2) with lithium batteries the dominant field of endeavour and the number of granted patents increasing annually over the period.



4.2.3. Total patents granted at the top five patent offices for 2014 to 2020.

4.2.1. Lithium Batteries

The data presented below shows the top 10 university filers of patent applications (Figures 4.2.4 to 4.2.10) and granted patents (Figures 4.2.11 to 4.2.17) in the area of lithium batteries recorded annually from 2014 to 2020 at the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

LG, Samsung and Toyota are in the top three assignees annually (for the period 2014 to 2020) for both published lithium battery application and granted lithium battery patents.

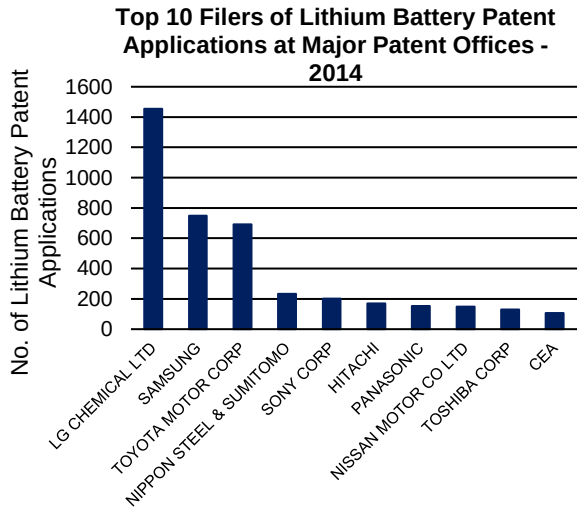


Figure 4.2.4. Top 10 filers of lithium battery patent applications at the Top 5 Patent Offices for 2014.

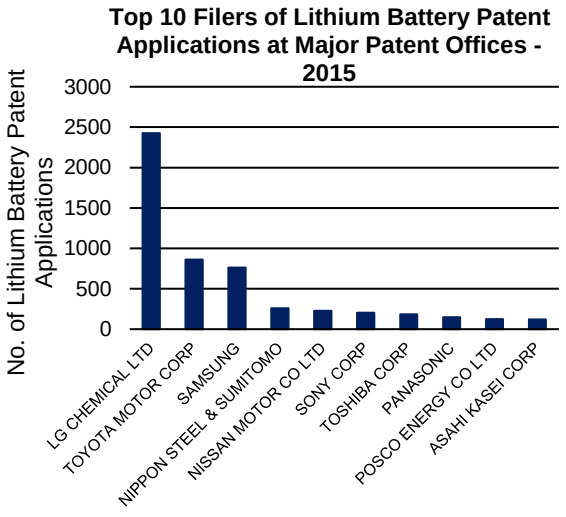


Figure 4.2.5. Top 10 filers of lithium battery patent applications at the Top 5 Offices for 2015.

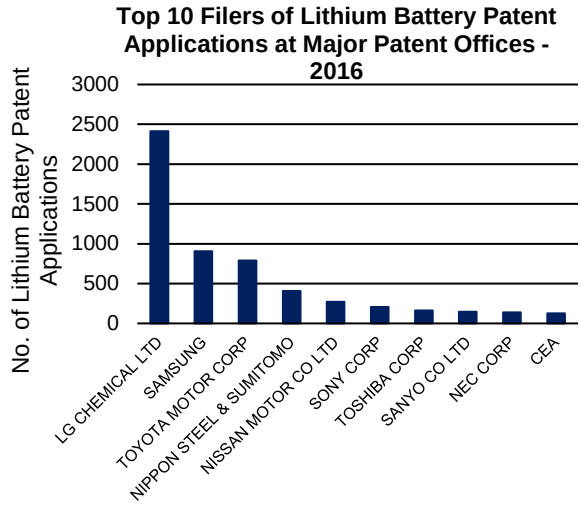


Figure 4.2.6. Top 10 filers of lithium battery patent applications at the Top 5 Patent Offices for 2016.

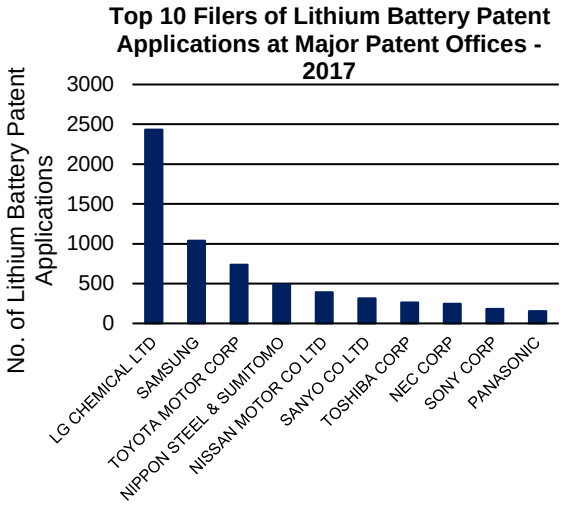


Figure 4.2.7. Top 10 filers of lithium battery patent applications at the Top 5 Offices for 2017.

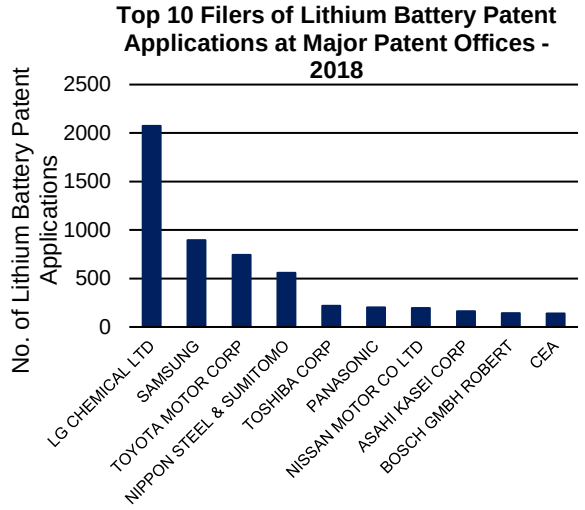


Figure 4.2.8. Top 10 filers of lithium battery patent applications at the Top 5 Patent Offices for 2018.

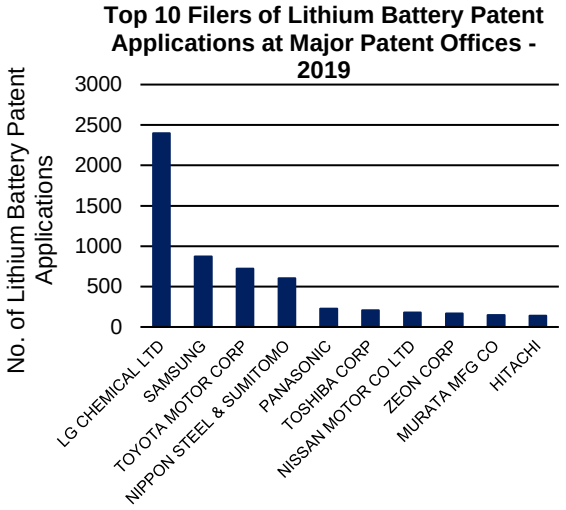
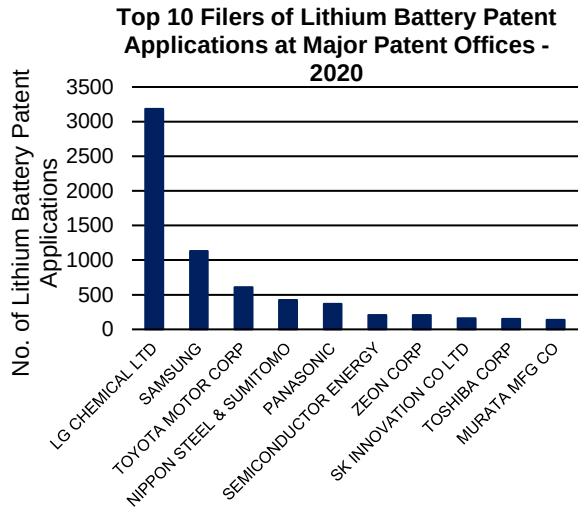


Figure 4.2.9. Top 10 filers of lithium battery patent applications at the Top 5 Offices for 2019.



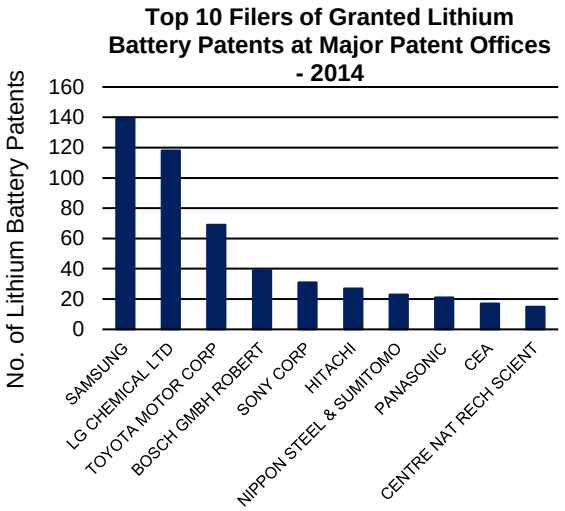


Figure 4.2.10. Top 10 filers of lithium battery patent at the Top 5 Patent Offices for 2020.

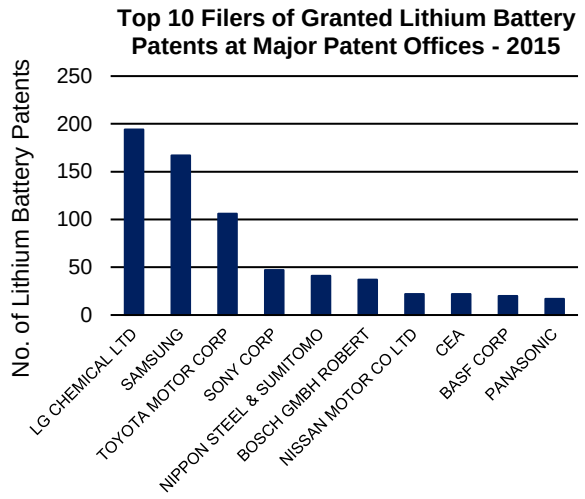


Figure 4.2.11. Top 10 filers of lithium battery patents applications at the Top 5 Offices for 2014.

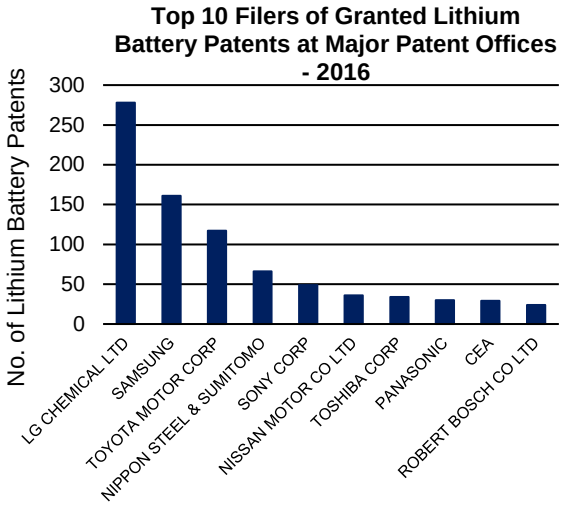
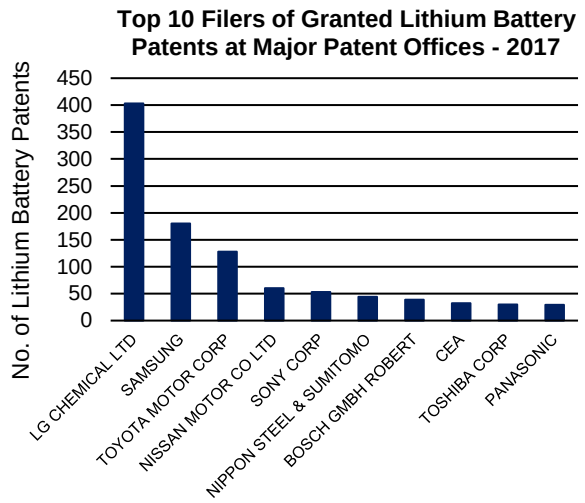


Figure 4.2.12. Top 10 filers of lithium battery patents at the Top 5 Patent Offices for 2015.

Figure 4.2.13. Top 10 filers of lithium battery patents at the Top 5 Offices for 2015.



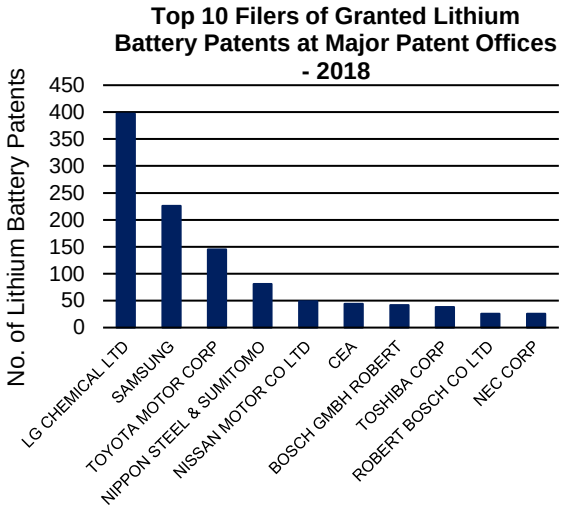


Figure 4.2.14. Top 10 filers of lithium battery patents at the Top 5 Patent Offices for 2017.

Figure 4.2.15. Top 10 filers of lithium battery patents at the Top 5 Offices for 2018.

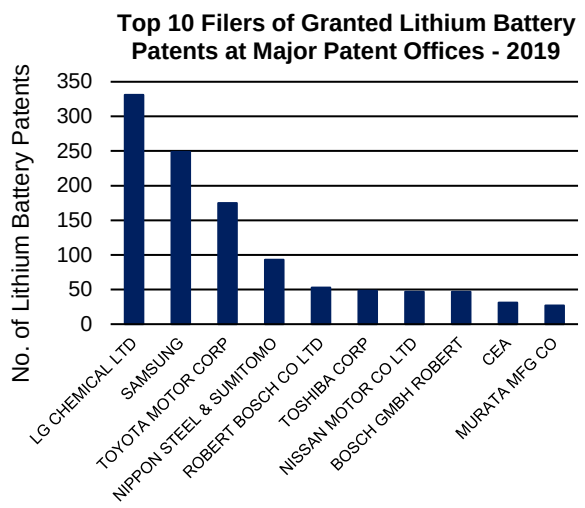


Figure 4.2.16. Top 10 filers of lithium battery patents at the Top 5 Patent Offices for 2019.

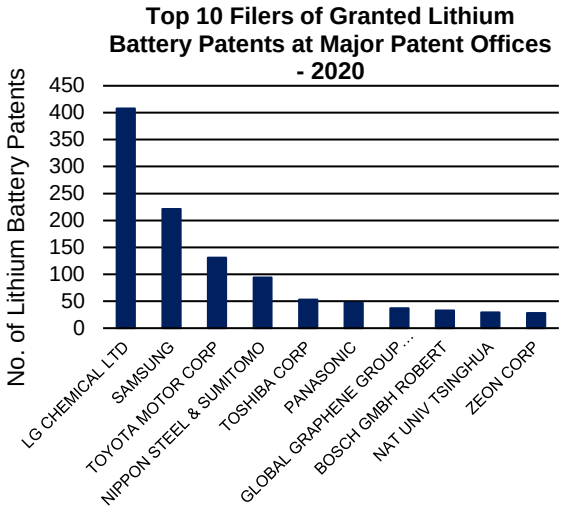
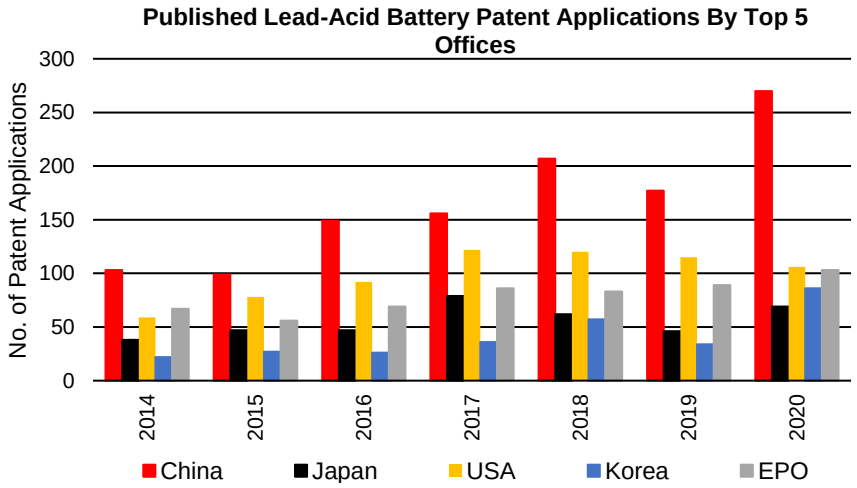


Figure 4.2.17. Top 10 filers of lithium battery patents at the Top 5 Offices for 2020.

4.2.2. Lead Acid Batteries

4.2.2.1. Filing Statistics

Figure 4.2.18 shows the total patent filings for lead-acid batteries across the top 5 patent offices.



4.2.18. Lead-acid battery patent applications for 2014 to 2020.

Figure 4.2.18 shows that China has become an increasingly important jurisdiction for filing lead-acid battery patent applications. Whilst Japan, Korea, the USA and the EPO show fluctuations in the number of patent applications filed in this area, the overall number of patent applications filed at the top 5 offices between 2014 and 2020 appears to be increasing.

Figure 4.2.19 shows the top 10 assignees of lead-acid battery patent applications for the top 5 offices over the period 2014 to 2020. The top five filers are GS Yuasa, Daramic, Hitachi, Johnson and Johnson and Panasonic.

Figure 4.2.20 shows the cumulative number of lead-acid battery patent applications published at the top 5 offices by the top 10 filers from 2014 to 2020. The data shows an increase in lead-acid battery patent application filings between 2014 and 2017, a decrease between 2017 and 2019 and a sharp increase between 2019 and 2020, leading to an overall increase in filings over the period.

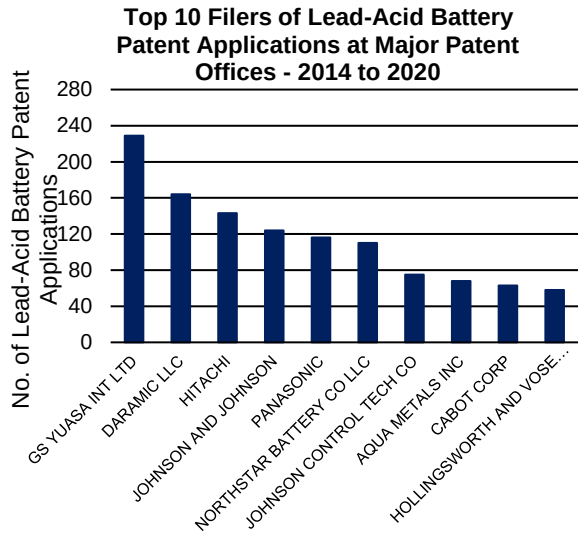


Figure 4.2.19. Top 10 filers of lead-acid battery patent applications at Top 5 Patent Offices for 2014 to 2020.

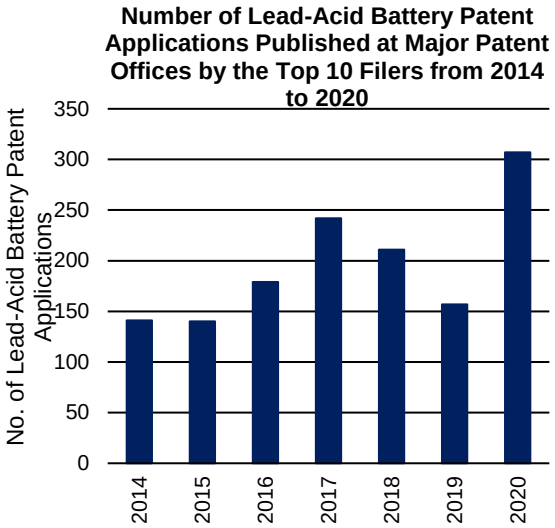


Figure 4.2.20. Number of lead-acid battery patent applications published by the top 10 filers for the years 2014 to 2020.

The data presented below shows the top 10 university filers of patent applications (Figures 4.2.21 to 4.2.27) in the area of lead-acid batteries recorded annually from 2014 to 2020 at the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

Whilst the top filers appear to vary over the period, the number of applications filed within the field of lead-acid batteries remains relatively low, in comparison to the number of lithium battery applications and granted patents.

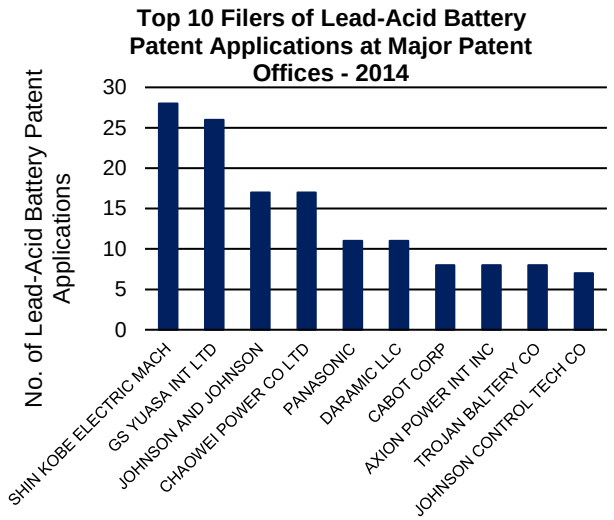


Figure 4.2.21. Top 10 filers of lead-acid battery patent applications at the Top 5 Patent Offices for 2014.

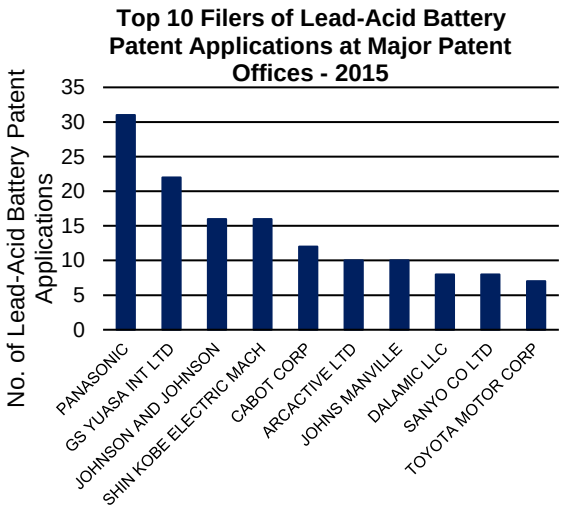


Figure 4.2.22. Top 10 filers of lead-acid battery patent applications at the Top 5 Offices for 2015.

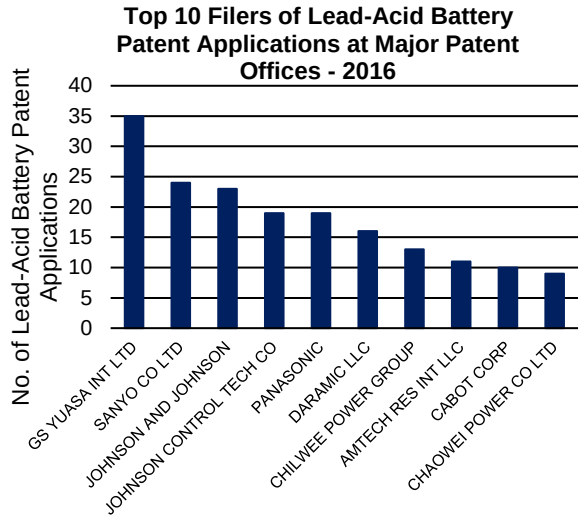


Figure 4.2.23. Top 10 filers of lead-acid battery patent applications at the Top 5 Patent Offices for 2016.

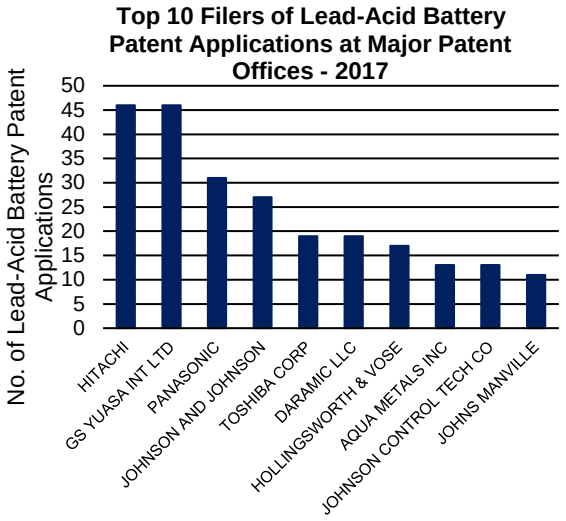


Figure 4.2.24. Top 10 filers of lead-acid battery patent applications at the Top 5 Offices for 2017.

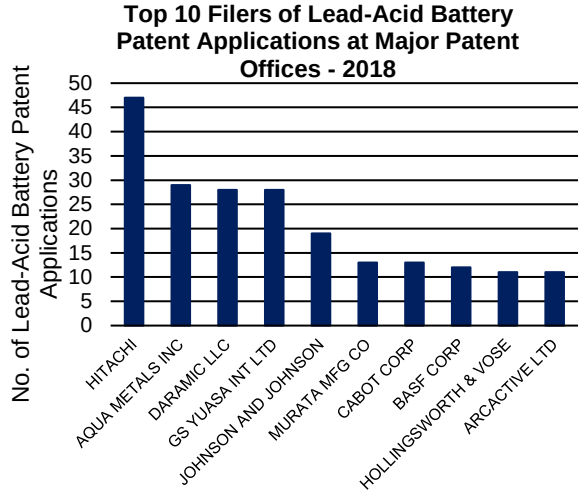


Figure 4.2.25. Top 10 filers of lead-acid battery patent applications at the Top 5 Patent Offices for 2018.

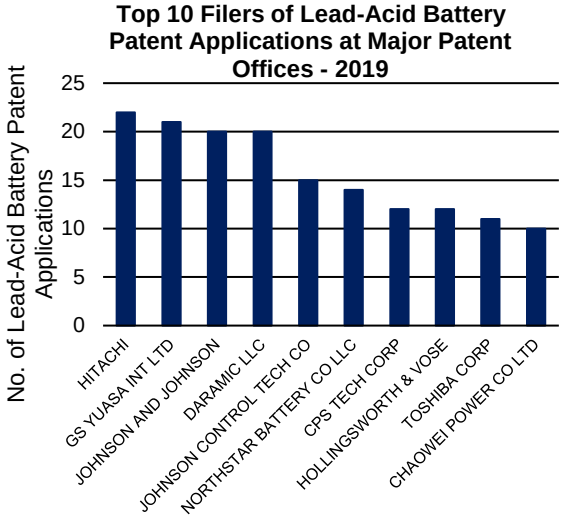


Figure 4.2.26. Top 10 filers of lead-acid battery patent applications at the Top 5 Offices for 2019.

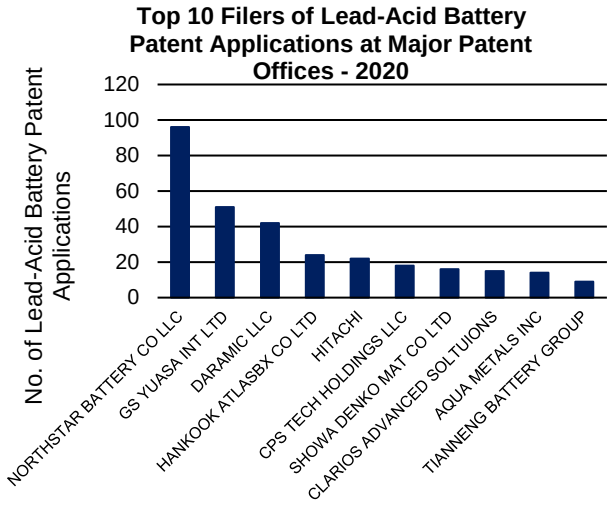
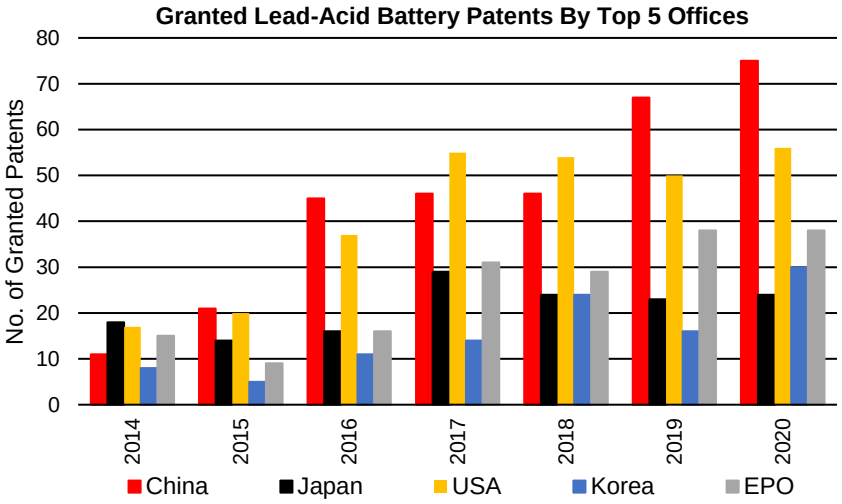


Figure 4.2.27. Top 10 filers of lead-acid battery patent applications at the Top 5 Patent Offices for 2020.

4.2.2.2. Granted Patents

Figure 4.2.28 shows the total number of granted lead-acid battery patents across the top 5 patent offices.



4.2.28. Granted lead-acid battery patents for 2014 to 2020.

Figure 4.2.28 shows that since 2016, China and the USA are the important jurisdictions in terms of the absolute number of patents granted in the area of lead-acid batteries. Whilst the remaining offices (Japan, Korea and the EPO) show fluctuations in the number of patents granted over the period, the overall trajectory appears to be increasing.

Figure 4.2.29 shows the top 10 assignees of granted lead-acid battery patents for the top 5 offices over the period 2014 to 2020. The top filers are GS Yuasa, Johnson Control Tech Co and Hitachi.

Figure 4.2.30 shows the cumulative number of lead-acid battery patents granted at the top 5 offices by the top 10. As observed with the cumulative number of published lead-acid battery applications, an increase in granted lead-acid battery patents is observed between 2014 and 2017. However, a more gradual decrease is observed between 2017 and 2019.

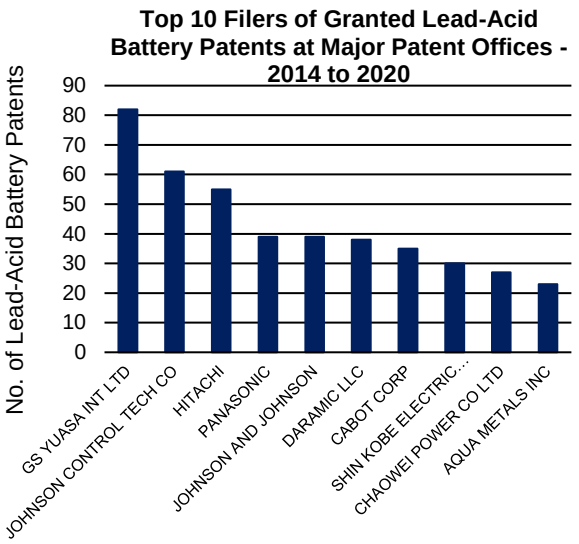


Figure 4.2.29. Top 10 filers of lead-acid battery patents granted at Top 5 Patent Offices for 2014 to 2020.

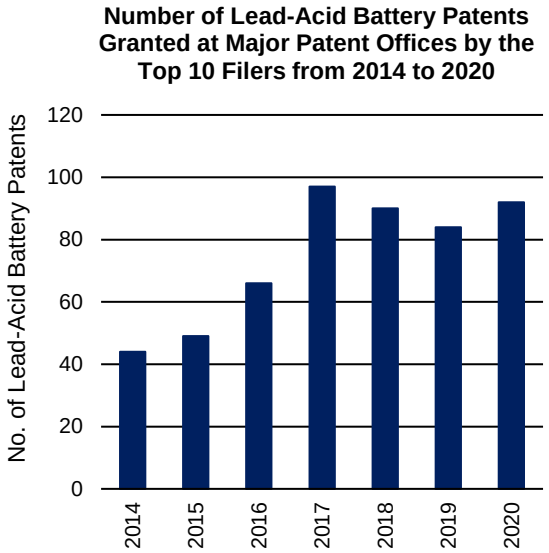


Figure 4.2.30. Number of lead-acid battery patents granted by the top 10 filers for the years 2014 to 2020.

The data presented below shows the top 10 university filers of granted patents (Figures 4.2.31 to 4.2.37) in the area of lead-acid batteries recorded annually from 2014 to 2020 at the top 5 patent offices. In each case the bars show the absolute number of patent applications associated with a particular entity.

Whilst the top filers appear to vary over the period, the number of patents granted within the field of lead-acid batteries remains relatively low, in comparison to the number of lithium battery applications and granted patents.

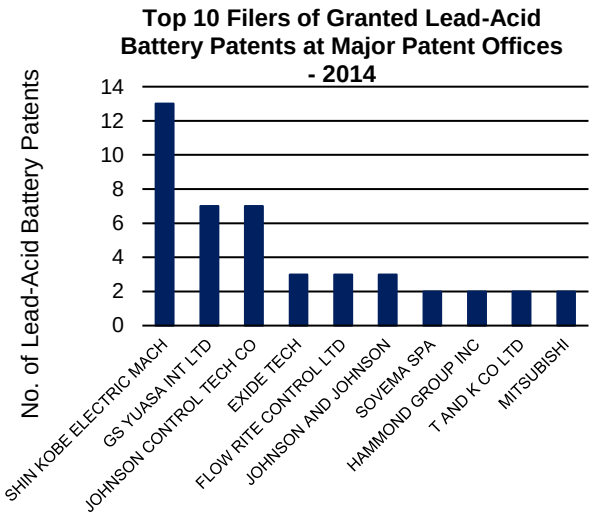


Figure 4.2.31. Top 10 filers of lead-acid battery patents at the Top 5 Offices for 2014.

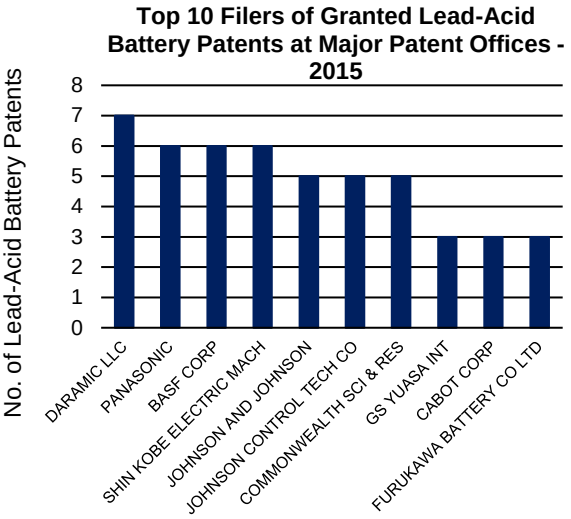


Figure 4.2.32. Top 10 filers of lead-acid battery patents at the Top 5 Patent Offices for 2015.

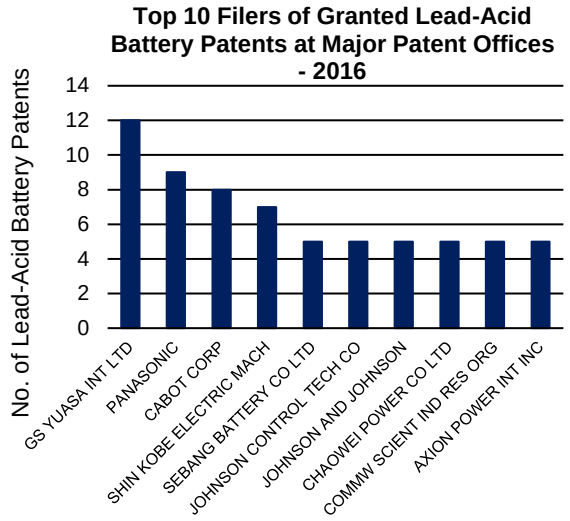


Figure 4.2.33. Top 10 filers of lead-acid battery patents at the Top 5 Offices for 2016.

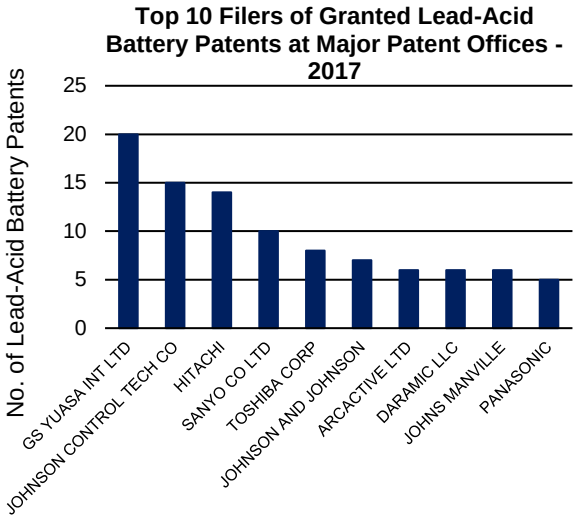


Figure 4.2.34. Top 10 filers of lead-acid battery patents at the Top 5 Patent Offices for 2017.

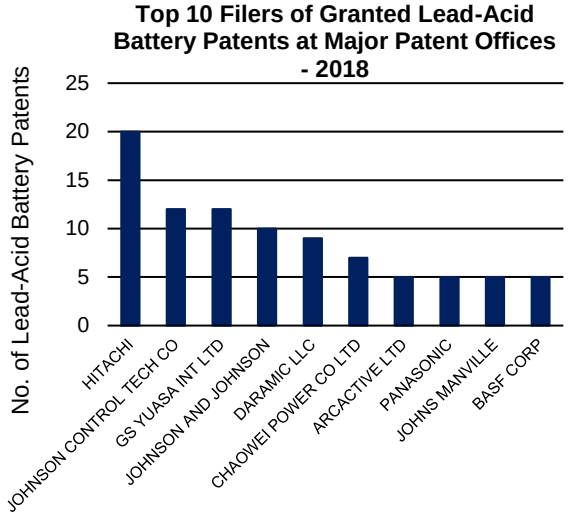


Figure 4.2.35. Top 10 filers of lead-acid battery patents at the Top 5 Offices for 2018.

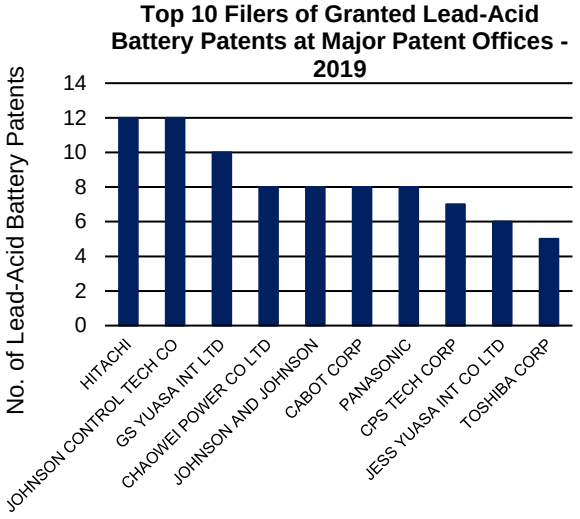


Figure 4.2.36. Top 10 filers of lead-acid battery patents at the Top 5 Patent Offices for 2019.

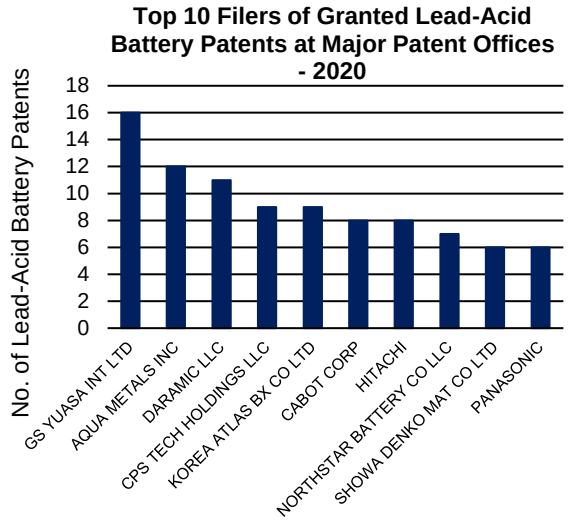


Figure 4.2.37. Top 10 filers of lead-acid battery patents at the Top 5 Offices for 2020.

4.3. Alternative Fuel Sources

4.3.1. Filing Statistics

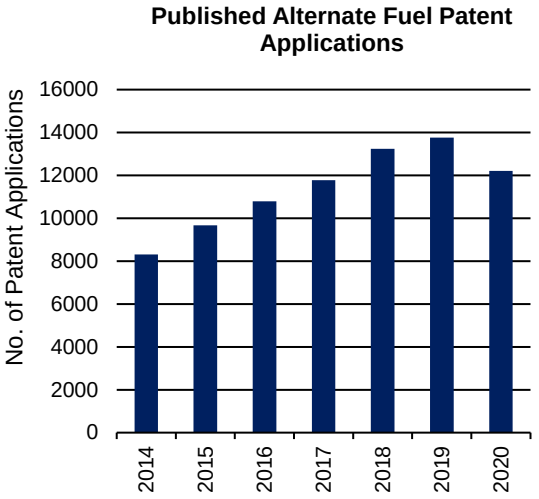
The number of alternative fuel (solar, wind and geothermal energy) patent applications published annually around the world has remained in excess of 8000 since 2014. The data shows an increasing trajectory in the number of published alternative fuel patent applications, with solar energy being the standout alternative. The USPTO and the Chinese office remain the most important territories for publishing alternative fuel patent applications, with the rise in those published at the Chinese office being the most significant.

If the current trend continues, the number of alternative fuel patent applications will likely outstrip the number of fuel cell patent applications in the near future.

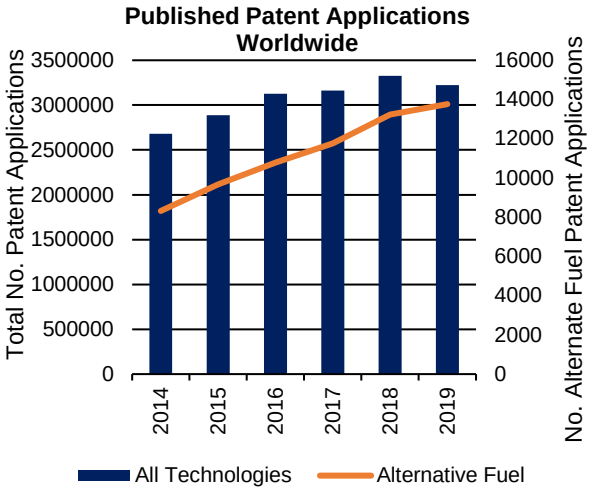
Table 4.3.1. List of classification codes searched for in alternative fuel sources.

Category	Classification Codes
Solar	E04D 1/30, E04D 13/18, F24J 2/00, F24J 2/02, F24J 2/04, F24J 2/05, F24J 2/06, F24J 2/07, F24J 2/08, F24J 2/10, F24J 2/12, F24J 2/13, F24J 2/14, F24J 2/15, F24J 2/16, F24J 2/18, F24J 2/23, F24J 2/24, F24J 2/36, F24J 2/38, F24J 2/42, F24J 2/46, F03G 6/06, G02B 5/10, H01L 31/052, H01L 31/04, H01L 31/042, H01L 31/18, G02F 1/136, G05F 1/67, H01L 25/00, H01L 31/00, H01L 31/048, H01L 33/00, H02J 7/35, H02N 6/00
Wind	F03D 1/00, F03D 3/00, F03D 5/00, F03D 7/00, F03D 9/00, F03D 11/00, B60L 8/00
Geothermal	F24J 3/08, F03G 4/00, F03G 7/05

Figure 4.3.1 shows worldwide patent statistics for the annual publication of patents in the area of alternative fuel sources.



4.3.1. Published alternative fuel patent applications for 2014 to 2020.



4.3.2. Published total patent applications vs. published alternative fuel patent applications for 2014 to 2019.

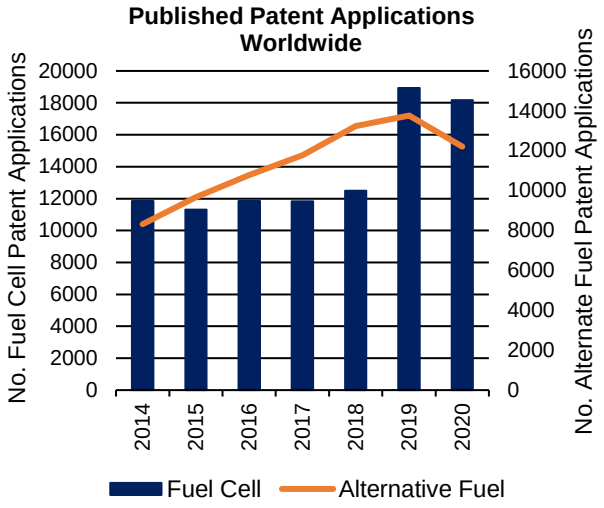
The data shows an increase in the number of alternative fuel patent applications being published between 2014 and 2019. A drop off in publication number is observed between 2019 and 2020[8].

Figure 4.3.2 shows a comparison between the number of published alternative fuel patent applications and the total number of published patent applications between 2014 and 2019.

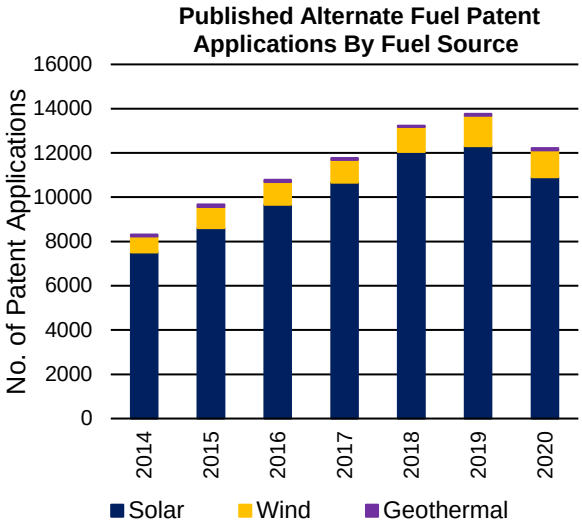
Both total patent applications (blue bars) and alternate fuel patent applications (orange line) show an incline in annual publication numbers between 2014 and 2019.
The marginal growth of +65% recorded between 2014 and 2019 for the publication of alternative fuel patent applications (orange line), is more than three times the growth reported for the total number of published patent applications (blue bars), with a marginal growth of +20%.
This clearly shows that patent applications relating to alternative fuels are an increasingly important component of the overall patent filing picture and that an increasing amount of research activity is be undertaken in these fields as compared to technology in general.
Figure 4.3.3 shows a comparison between the number of published alternative fuel patent applications and the number of published fuel cell patent applications.

Whilst an overall increase in publication number is observed between 2014 and 2018 for both the number of fuel cell patent applications (blue bars, LH scale) and alternative fuel patent applications (orange line, RH scale), the number of alternative fuel patent applications seems to be growing at a much higher rate with the number of fuel cell patent applications being relatively flat. However, a sharp increase in the number of fuel cell patent applications is observed between 2018 and 2019.

[8] As previously explained, the numbers presented for 2020 may be subject to change and may therefore not be a true representation of the filing statistics for that year.



4.3.3. Published fuel cell patent applications vs. published alternative fuel patent applications for 2014 to 2020.

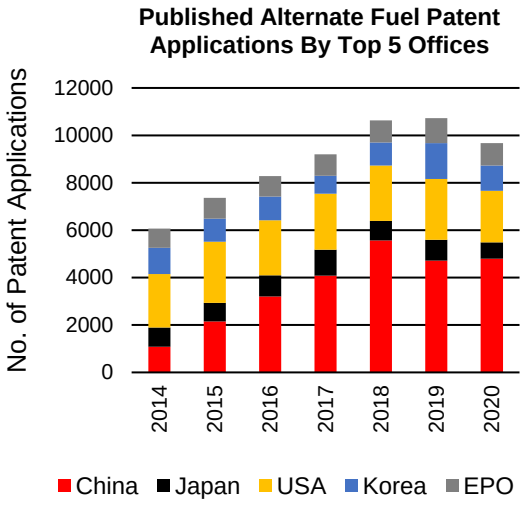


4.3.4. Published alternative fuel patent applications by fuel source for 2014 to 2020.

Figure 4.3.4 shows the overall number of published alternative fuel patent applications according to the alternative fuel source.

Over 89% of the published alternative fuel patent applications are in the field of solar energy, with the remaining 11% relating to the areas of wind (10%) and geothermal (1%) energy.

Figure 4.3.5 shows the overall number of published alternative fuel patent applications according to the geographical split of the top 5 patent offices.
The data reflects that of the overall number of alternative fuel patent applications published worldwide (Figure 4.3.1).

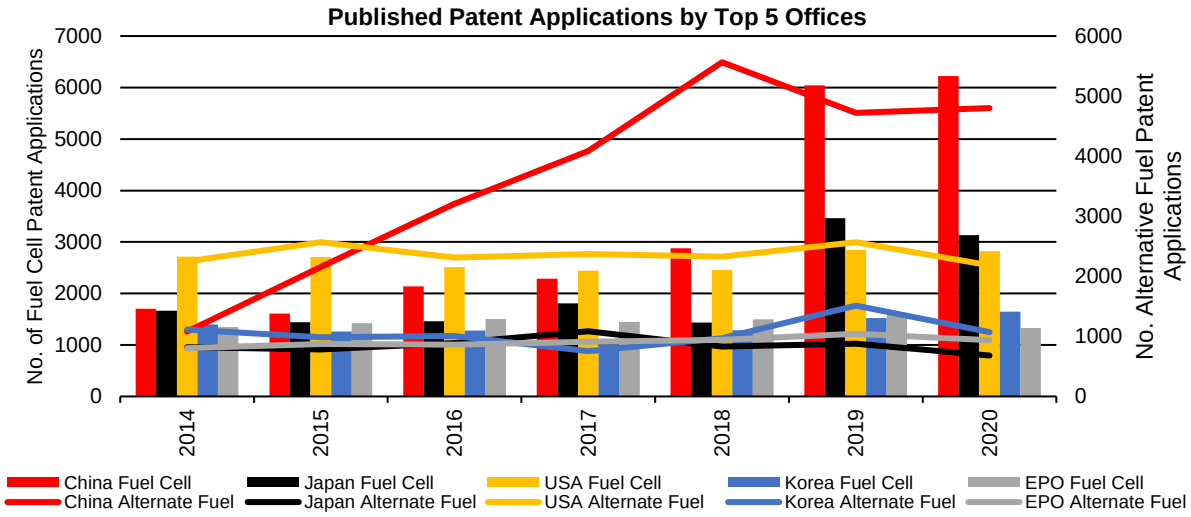


4.3.5. Published alternative fuel patent applications at the Top 5 Patent Offices for 2014 to 2020.

The data shows a marked incline in the number of alternative fuel patent applications published at the top 5 patent offices between 2014 and 2019.

The Chinese office and the USPTO are clear leaders in the publication of alternative fuel patent applications, with the Chinese office overtaking the USPTO in terms of absolute numbers in 2016. The number of filings in Europe appears to be fairly stable.

Figure 4.3.6 shows the number of published alternative fuel patent applications in comparison to the number of published fuel cell patent applications, according to the geographical split of the top 5 patent offices.



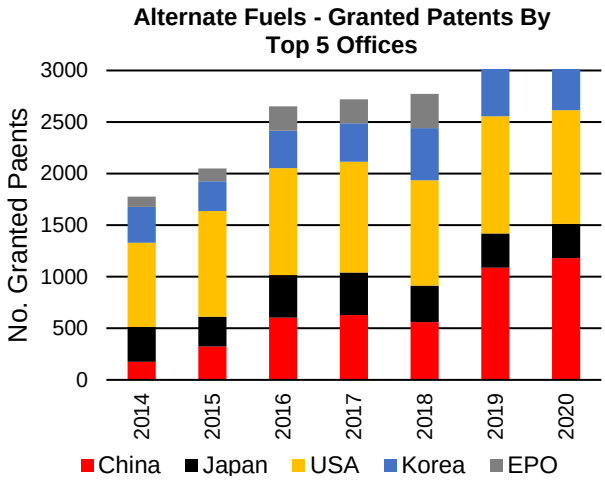
4.3.6. Published fuel cell patent applications vs. published alternative fuel patent applications at the Top 5 Patent Offices for 2014 to 2020.

The number of alternate fuel cell patent applications being published in each of the top 5 offices appears to reflect the same trend observed with the publication of fuel cell patent applications. Most notably, the data shows a significant increase in the number of alternative fuel patent applications published at the Chinese office. 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.

4.3.2. Granted Alternative Fuel Patents

The number of alternative fuel cell patents granted annually, in the top 5 offices, has remained in excess of 1700 since 2014. The data shows a marked increase in the number of granted alternative fuel patents between 2014 and 2016 which is then followed by a period of stability before a further between 2018 and 2019. The USPTO remains the single most important territory 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.

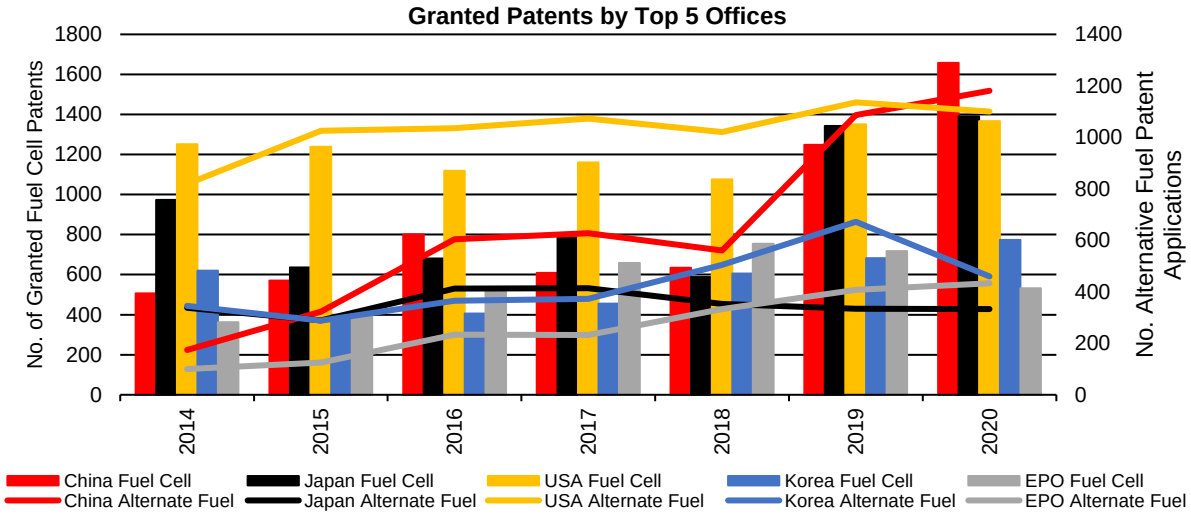
Figure 4.3.7 shows the annual number of granted alternative fuel patents for the top 5 offices.



4.3.7. Granted alternate fuel patents for the Top 5 Patent Offices for 2014 to 2020.

With the exception of Japan, each of the top 5 offices has observed an increased marginal growth in the number of granted alternate fuel patents between 2014 and 2020, with those of the Chinese office and the EPO being the most significant (579% and 333% respectively). However, it is the USPTO that remains by far the most significant authority for granting patents in the area of alternative fuels.

Figure 4.3.8 shows a comparison between the annual number of granted alternative fuel patents and the number of granted fuel cell patents for the top 5 offices. The trend in the number of granted alternative fuel parents appear to mirror those of the granted fuel cell patents.



4.3.8. Granted fuel cell patents vs. granted alternative fuel patents at the Top 5 Patent Offices for 2014 to 2020.

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.
China appears to be by far the most dominant country for academic filings of fuel cell patents.
From the patent analysis, it appears that patent activity within the sector of fuel cells is in flux. The number of fuel cell patent applications published annually around the world has remained in excess of 11,000 since 2014 and the overall trajectory appears to be increasing.

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.

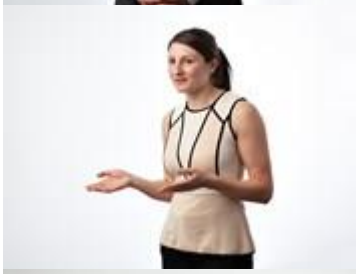
Fuel cells for vehicles remain one of the most high-profile applications of fuel cells, with a large majority of the top ranked companies coming from the automotive sector.
Within the hydrogen sector the number of hydrogen production patent applications are greater than those of both hydrogen storage and hydrogen distribution. This indicates that research and innovation in this area is continuing to develop, albeit at a slower rate than heretofore.
Within the comparable technology sector of batteries, there is shown an overall increasing trajectory in terms of the total numbers of patent applications being filed and those being granted.
From this report it is clear that research and development in the global fuel cell industry is fairly stable, and if anything, increasing. 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 Sam Thrippleton.

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.

Sam is a data scientist at HGF.
Sam has an MSc in data science and has a vast experience in the manipulation and analysis of large data sets.

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 2019 by The Financial Times and many attorneys are recognised as being leaders in their fields.

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