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Patent Analytics Hub

The Power of Innovation:
A patent analytics report on the Australian Battery Industry

June 2021

P TM D PBR

ISBN: 978-1-925245-50-9 (Online)

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SUMMARY

As a form of energy storage, battery technologies underpin Australia's national energy infrastructure and resilience. Analysing patent filings in battery technologies by Australian innovators provides information for decision-makers as we strengthen and consolidate our national capability.

This report identifies Australians who are actively working in different fields of battery development, both industrial and domestic, and outlines findings from analysis of patents filed between 2001 and 2018, including trends, innovators, filing destinations, commercial players and collaborators. The accompanying interactive visualisation allows users to 'drill down' into the data.

A highlight is the amount of international collaboration shown by Australian innovators in co-filed patents in battery technologies. This reflects global interest in Australian capability and presents opportunities for targeted investment in research and development in the energy-storage sector.

This patent analytics report on battery technologies identifies holdings of specific expertise and shows the potential for further specialisation and investment by Australia. Coupled with strong growth in the field this demonstrates Australian capability that can be leveraged for the benefit of the broader Australian economy.

- **206 patent** families were filed **in battery technologies** by Australians between 2001 and 2018
- **Patenting** activity relating to **batteries by Australians** has been **consistent** from 2001–17
- **Rechargeable battery technologies dominate** patent filings by Australians, with **over 60 per cent** of patent families (130) relating to this field
- The Commonwealth Scientific and Industrial Research Organisation **(CSIRO)** is the **top Australian** patent **filer**, with **35 patent** families **in battery technologies**
- The **United States**, **China**, **Europe** and **Japan** are Australia's **major foreign filing destinations** for patents in battery technologies
- **Australians specialise in lithium battery technologies**, with one-third of patent families (68) related to lithium batteries
- **70 battery technology patent families** (one-third) filed by Australians **are co-filed collaborations**
- Research in **electrode technologies** is also an **Australian strength**, with **over half of all battery-related filings** (111) directed to electrodes

INTRODUCTION

Energy storage is a vital part of the Australian economy, providing the critical link between energy production and consumption. Increasing energy storage enables the continued transition to renewables and emissions reduction in buildings, industry, and the electrification of transport.[1]

Batteries are one form of energy storage, alongside pumped hydro, thermal storage, hydrogen, and other technologies.

With bipartisan support for large-scale battery energy-storage facilities already established across the country,[2,3] Australia is well-placed to invest in developing and maintaining our national battery capability.

Australia has also been an early innovator in developing smart control systems that allow batteries to be charged and discharged in response to power system conditions and price signals through Australian companies such as Reposit, GreenSync, Redback, Selectronic and Evergeen.[1]

Improved energy storage provides benefits to both the power industry and its customers, including:

- Improved power quality and the reliable delivery of electricity to customers
- Improved stability and reliability of transmission and distribution systems
- Increased use of existing equipment, thereby deferring or eliminating costly upgrades
- Improved availability and increased market value of distributed generation sources
- Improved value of renewable energy generation
- Cost reductions through capacity and transmission payment deferral.[4]

In a 2018 report, the Australian Trade and Investment Commission (Austrade) set out the gaps in Australia's battery manufacturing capability:

> 'Australia requires the proprietary equipment, processes and technology to convert its raw materials into end-user lithium-ion batteries. Australia does not yet have the domestic capability to refine and manufacture coated spherical graphite from flaked graphite; polymer separator; and cell enclosure material; and copper and aluminium foils for electrodes and electrolyte.'[5]

Developing technology to store electrical energy so it can be available to meet demand whenever needed is critical to supporting Australia's industrial capability, as well as Australia's households.

This patent analytics report and its accompanying interactive visualisation[6] identifies Australian innovative capability in battery technology, as well as providing information on developments in technology that can be leveraged to build our national capability. This report analyses patent data, which relates to commercial uses, and does not review this field of academic research, in which Australians may be world-leaders.

This report is specifically directed to developments in battery technologies, including all possible batteries from the smallest domestic use to the largest industrial installations. This is because advances in battery technology in one area can be readily applied across different battery technologies. This report is limited to batteries: processes for mineral mining, extraction and recycling are not captured, although the technologies are intertwined.

Why patent data?

Patents can be used as indicators of innovative activity. By extracting and analysing data associated with patent documents, we can measure aspects of inventive activity such as scope, intensity, collaboration and impact. These metrics can be developed across technology sectors and by measures including individuals (inventors), institutions (applicants), countries and regions.

Patents are granted for devices, substances, methods or processes that are new, inventive and useful, giving exclusive commercial rights in exchange for full public disclosure of the invention. This means patents are a source of data on innovation trends in science and technology. More information about the patent system is given in

[1] Godfrey B, Dowling R, Forsyth M, Grafton RQ and Wyld I, (2017) The Role of Energy Storage in Australia's Future Energy Supply Mix. Report for the Australian Council of Learned Academies. https://acola.org/wp-content/uploads/2018/08/role-energy-storage-future-australia.pdf
[2] Clean Energy Council https://www.cleanenergycouncil.org.au/resources/technologies/energy-storage
[3] Smart Energy Council (2018) Australian Energy Storage Market Analysis - September 2018 https://www.smartenergy.org.au/sites/default/files/uploaded-content/field_f_content_file/australian_energy_storage_market_analysis_report_sep18_final.pdf
[4] Office of Electricity, United States Department of Energy, Energy Storage https://www.energy.gov/oe/activities/technology-development/energy-storage
[5] Australian Trade and Investment Commission (2018) The Lithium-Ion Battery Value Chain - New Economy Opportunities for Australia, page 43, Commonwealth of Australia, Canberra https://www.austrade.gov.au/ArticleDocuments/5572/Lithium-Ion%20Battery%20Value%20Chain%20report.pdf.aspx
[6] https://public.tableau.com/views/Batteriesanalysis/Batteries?%3Aembed=y&%3Atoolbar=no&%3Adisplay_count=no&%3AshowVizHome=no
[7] Intellectual Property Office (2014) Eight Great Technologies Energy Storage: A patent overview. IPO, Newport https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/359299/informatics-energy.pdf

Appendix A: Definitions.

Global technology trends across the broad field of energy storage were analysed using patent data from 2004 to 2013 by the United Kingdom Intellectual Property Office.[7] This report showed growing innovation and investment in energy storage. Applicants from China, Japan, the United States and South Korea dominated, with a combined total of 88 per cent of all patent filings. The relative specialisation analysis shows that Australia ranks sixth in the world with a particular focus on energy storage despite its relatively small share of applications. This demonstrates that Australia has a strong base on which to build its capability.

The authors and purpose of this report

This report provides a specific analysis of Australian capability in battery energy-storage technologies.

IP Australia is dedicated to building prosperity for Australia and ensuring that Australians benefit from great ideas. Using patent data analytics to provide evidence of innovation trends, we leverage our unique access to IP data, knowledge and expertise to deliver value to the broader community.

This report was prepared to support Australian research and investment in developing national battery energy-storage capability. In this patent analytics report we have analysed the development and uses of technology relating to batteries. Fuel cells are included in some of the patent data due to the similar technology involved, particularly the similarity to flow batteries, and with hybrid fuel cell batteries, and therefore that IP may overlap.

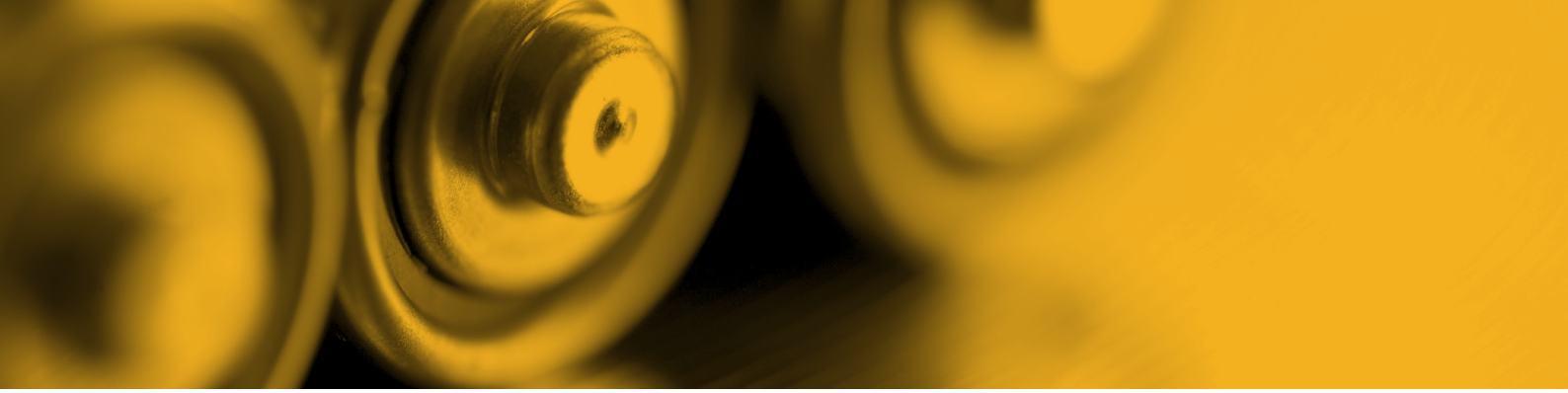
This report provides insight into Australian innovators in this field – based on patents filed – with potential connections for investment, research, development and commercialisation.

The interactive visualisation

The interactive visualisation accompanying this report can be accessed by a web URL.[8] As well as providing direct links to full details and content of each patent, the interactive visualisation allows users to quickly identify applicants in different technologies, and to review collaborators who are co-filing patents in specific technologies of choice.

The interactive visualisation allows users to select information on different types of batteries, battery parts and composition in any combination to identify the relevant patents and patent applicants. Users can also investigate selections of different applicants, countries of patent filing destinations and year.

[8] https://public.tableau.com/views/Batteriesanalysis/Batteries?%3Aembed=y&%3Atoolbar=no&%3Adisplay_count=no&%3AshowVizHome=no



PATENTING TREND OVERVIEW

As a basis for this analysis, we searched the PATSTAT database (2019 Autumn edition) for inventions relating to battery technologies filed by Australian applicants and/or inventors. The search[9] found 206 unique International Patent Documentation {INPADOC) patent families (see Appendix A: Definitions) relating to battery technologies filed worldwide by Australians[10] since 2001.

Patent filings

Analysing patent family filings across time indicates growth or decline in innovation. Additional in-depth analysis can help understand underlying factors and their correlation to these trends. Figure 1 shows the number of patent families by their earliest priority year and overall family patent status. More details on patent status are given in Appendix A: Definitions.

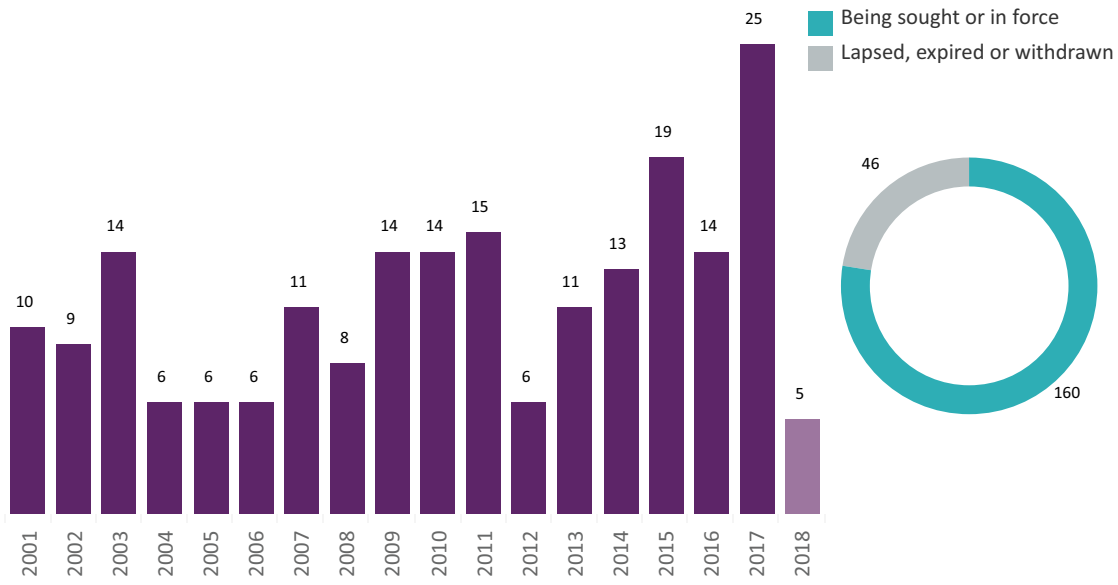
Australians have consistently been involved in battery patent filings since 2001, with no fewer than six filings in any year from 2001 to 2017. The dip in patent filings in 2018 reflects incomplete data due to a lag in publication of patents, indicated by a lighter colour.

Of the 206 patent families filed by Australians since 2001, 160 (78 per cent) are in an active state with patent protection being sought or in force, and 105 patent families have a patent application granted in at least one jurisdiction. The low levels of patent families that have lapsed, expired or been withdrawn may be reflective of both recent patenting activity in this technology area, and a high commercial interest in battery technologies.

The 206 patent families identified in this report relate specifically to developments in battery technologies, rather than the broader field of different uses of batteries.

Figure 1: Battery technology patent filings by Australians, by earliest priority year and patent status, 2001-18

Source: PATSTAT 2019 Autumn Edition



[9] The search used a combination of keywords, International Patent Classification (IPC) symbols and Cooperative Patent Classification (CPC) symbols. Detail of the search methodology is provided in Appendix B: Search strategy

[10] Who are Australians? In this analysis, a patent family is considered to have been filed by an Australian if any one of the patent applicants (generally companies, universities or research institutes) or inventors has listed an Australian address. This excludes patents filed outside Australia by inventors who may subsequently have relocated to Australia. More details are given at Appendix A: Definitions.

Top applicants filing patents in battery technologies

Figure 2 shows the top applicants filing patents across all battery technologies identified in this report. These are either Australian entities or are non-Australian entities that have filed patents listing an Australian applicant or inventor (such as the Furukawa Battery Company).

Information on the top seven entities with Australian applicants or inventors, who have each filed more than five patent families in battery technologies, and details of their patent co-filing collaborators are summarised on the following two pages (Table 1).

Figure 2: Battery technology patent filings by Australians, showing top applicants, 2001-18

Source: PATSTAT 2019 Autumn Edition

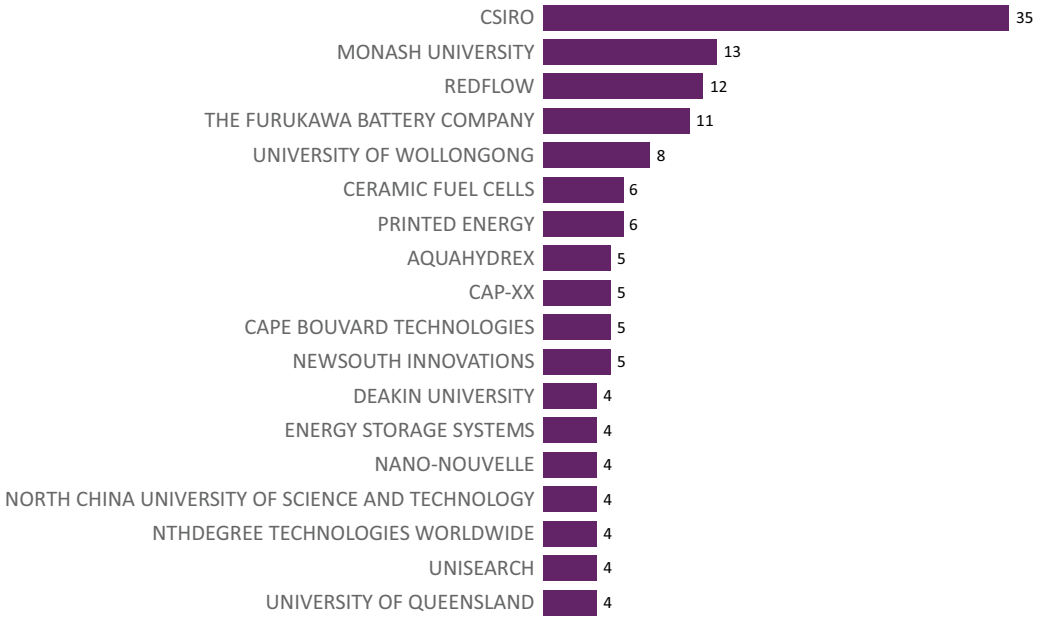


Table 1: Details of top patent applicants listing Australian applicants or inventors, in battery technologies, with co-filing collaborators

Applicant	Applicant description	Co-filing collaborators
CSIRO	CSIRO has been developing battery energy-storage solutions for more than 20 years.[11] CSIRO is Australia's largest public research organisation, with 5500 employees and funding of about $830 million in 2018-19.[12]	• The Furukawa Battery Company • Monash University • International Lead Zinc Research Company • University of Melbourne • University of Texas System
Monash University	Monash University is a leading Australian university with over 80 000 students.[13] Researchers at Monash have developed lithium-sulphur batteries with lower environmental impacts than current lithium-ion technologies, with a team including researchers from CSIRO and the Fraunhofer Institute for Material and Beam Technology.[14]	• CSIRO • Aquahydrex • Deakin University • Toyota Motor Engineering and Manufacturing North America • Waseda University
Redflow	Redflow Limited is a publicly listed Australian company founded in 2005 that produces zinc-bromine flow batteries. These flow batteries are designed for long term residential and commercial energy storage with a high-cycle rate, and can be used with solar panels to create mini grids.[15]	

[11] CSIRO https://www.csiro.au/en/Research/EF/Areas/Grids-and-storage/Energy-storage
[12] CSIRO Annual Report 2018-19 https://www.csiro.au/en/About/Our-impact/Reporting-our-impact/Annual-reports/18-19-annual-report
[13] Monash University https://www.monash.edu/about/who/glance
[14] Monash University https://www.monash.edu/news/articles/supercharging-tomorrow-australia-first-to-test-new-lithium-batteries Note: Fraunhofer Institute for Material and Beam Technology was not identified as a co-filing collaborator with Monash University in the patent applications in this report.
[15] Redflow https://redflow.com/about-us/

Applicant	Applicant description	Co-filing collaborators
The Furukawa Battery Company	The Furukawa Battery Company has headquarters in Yokohama, Japan. They manufacture lead-acid and alkaline storage batteries, power supply systems and related items.[16] Furukawa worked with CSIRO on the development of the UltraBattery.[17]	• CSIRO
University of Wollongong	The University of Wollongong has a dedicated Institute for Superconducting & Electronic Materials,[18] which has developed both sodium-ion and room temperature sodium-sulphur battery technology.[19] A trial of their sodium-ion batteries was commissioned in 2018 by Sydney Water.[20]	• North China University of Science and Technology • Aquahydrex • SMR Automotive Australia • SMR Patents • University of South Australia
Ceramic Fuel Cells	Ceramic Fuel Cells was an Australian company, formed by CSIRO and a consortium of leading energy companies in 1992. Ceramic Fuel Cells focused on developing fuel cell technology to create electricity from gas[21] filing patents identified here through their similarity in functional use to battery technologies. Following voluntary administration in 2015,[22] the company was delisted from the Australian Securities Exchange in early 2018.[23]	
Printed Energy	Printed Energy is an Australian company founded in 2016 with a research team in Arizona.[24] They collaborate with the University of Queensland, the University of New South Wales and other partners to develop manufacturing techniques for printing batteries and photovoltaics. Printed Energy received a $2 million Cooperative Research Centres Project grant in 2017.[25]	• Nthdegree Technologies Worldwide

Patent destination

Applicants must file patent applications in each country or patent jurisdiction where they wish to have enforceable patent protection. Reasons for seeking patent protection include the country being a target for commercialisation, further research or manufacturing.

Figure 3 shows the number of patent families filed by Australians in different jurisdictions. Patent Cooperation Treaty (PCT) applications have been excluded from this figure because these do not represent an enforceable right in any jurisdiction.

This information shows that Australian innovators in battery technologies are exporting their technical knowledge worldwide, with a focus on export to the United States and China that is equal to their filing in the Australian market.

This also aligns with the 2018 Austrade report finding that Australia lacks the proprietary equipment, processes and technology to convert its raw materials into end-user batteries,[26] and represents an opportunity for investment and growth in Australian capability in battery technology.

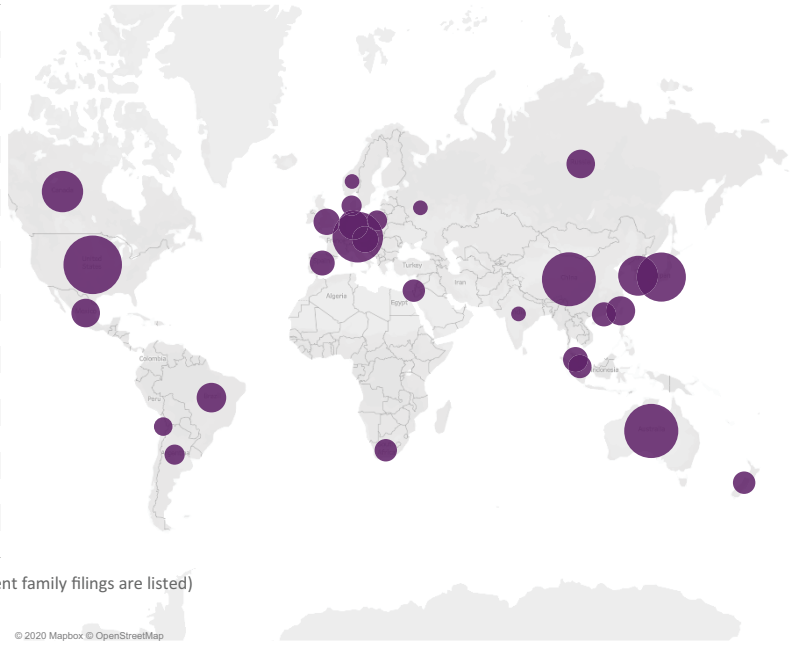
[16] The Furukawa Battery Company https://corp.furukawadenchi.co.jp/en/company/profile.html
[17] CSIRO https://www.csiro.au/en/Research/EF/Areas/Grids-and-storage/Energy-storage
[18] University of Wollongong https://www.uow.edu.au/research-and-innovation/our-research/research-institutes-and-facilities/australian-institute-for-innovative-materials/isem/
[19] PV Magazine, Marija Maisch https://www.pv-magazine-australia.com/2019/11/19/australian-researchers-achieve-breakthrough-for-sodium-sulfur-batteries/
[20] PV Magazine, Marija Maisch https://www.pv-magazine-australia.com/2018/10/26/sodium-ion-batteries-get-commercial-rollout-as-li-ion-alternative/
[21] CSIRO https://csiropedia.csiro.au/ceramic-fuel-cells/
[22] Australian Financial Review, Angela Macdonald-Smith https://www.afr.com/companies/ceramic-fuel-cells-falls-into-administration-20150302-13snjl
[23] Australian Securities Exchange https://www.asx.com.au/asx/statistics/announcements.do?by=asxCode&asxCode=CFU&timeframe=Y&year=2015
[24] Printed Energy https://www.printedenergy.com.au/#news
[25] The Office of the Hon Arthur Sinodinos, Minister of Industry, Innovation and Science (2017) https://www.minister.industry.gov.au/ministers/sinodinos/media-releases/australia-leading-charge-developing-ground-breaking-battery
[26] Australian Trade and Investment Commission (2018) The Lithium-Ion Battery Value Chain - New Economy Opportunities for Australia, Commonwealth of Australia, Canberra https://www.austrade.gov.au/ArticleDocuments/5572/Lithium-Ion%20Battery%20Value%20Chain%20report.pdf.aspx

Figure 3: Battery technology patent filings by Australians, by patent destination, 2001-18

Source: PATSTAT 2019 Autumn Edition

United States of America	131
Australia	106
China	105
European Patent Office (EPO)	88
Japan	81
Canada	49
Republic of Korea	44
Brazil	16
Germany	16
Taiwan	15
Mexico	14
Russian Federation	14
Austria	10
United Kingdom	10
Malaysia	8
Spain	8
Hong Kong	7
Singapore	6
Israel	5
New Zealand	5
South Africa	5

(Note: only jurisdictions with 5 or more patent family filings are listed)



Technology overview

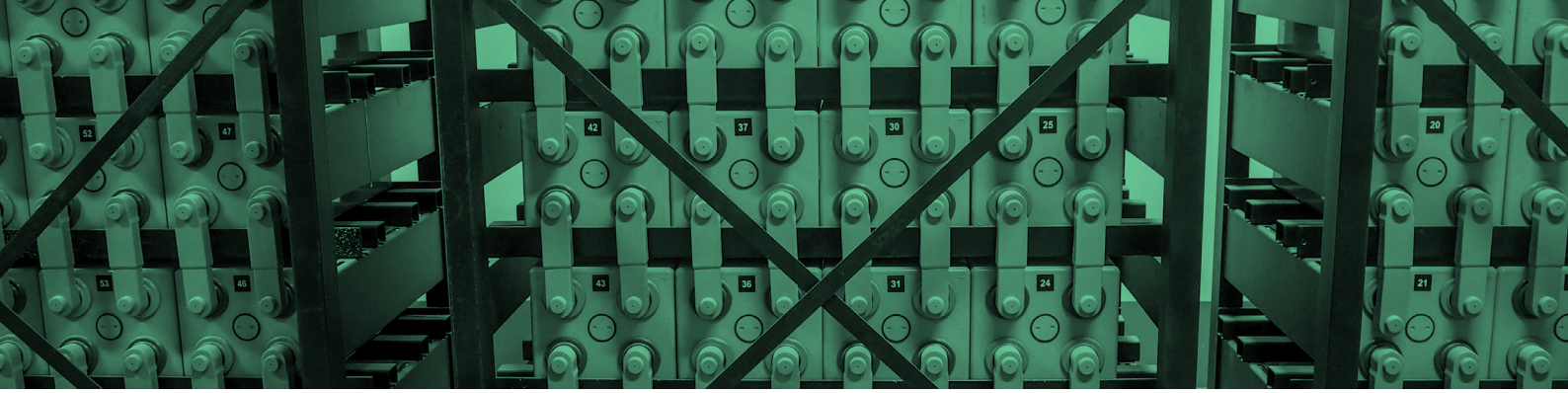
Analysing the technical content of patents can provide insights into specific technologies. These insights highlight areas of commercial interest and can be used to inform investment, research and commercialisation strategies.

In battery technologies, we have considered these developments in terms of three separate functional categories: battery type, battery parts and battery composition. This categorisation gives an idea of relative investment and the degree of focus on applications of these technologies.

All the 206 patents identified in this analysis have been categorised within each of the three technology divisions, as summarised below (Table 2). Each of the divisions is discussed in greater detail in the following sections.

Table 2: Battery technology patent filings by Australians, by technology division, 2001-18

Functional category	Subcategories	Number of patent families filed by Australians
Battery type	Rechargeable	130
	Regenerative fuel cell (e.g. 'flow battery')	11
	Hybrid (fuel cell / battery)	7
	Primary (non-rechargeable)	1
	General	57
Battery parts	Non-active parts (e.g. casings)	49
	Electrodes	111
	Cell chemistry / other	46
Battery composition	Lithium	68
	Non-lithium	138



BATTERY TYPES

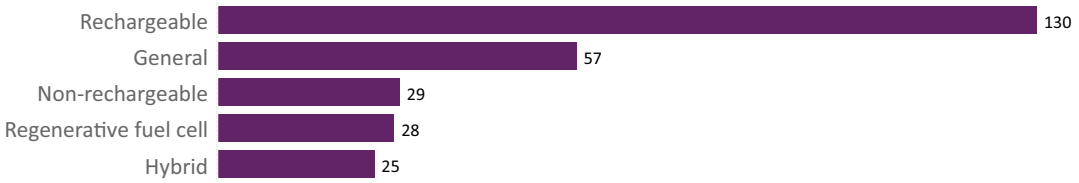
There are 149 patent families filed by Australians that describe specific battery types, with 57 patent families that describe general battery technologies that can be applied to different battery types.

Because patents can be classified as containing more than one technology, we have analysed the battery types (Figures 4-8) in a non-hierarchical system allowing overlap in technology classifications for each patent. This means that each patent can belong to multiple technology classifications, and the number of patent families in these figures will add up to be more than the total of 149 listed above.

Figure 4 shows the distribution of patents according to their technology classification. A focus on rechargeable batteries is seen in patent filings by Australians.

Figure 4: Battery technology patent filings by Australians, by battery type, 2001-18

Source: PATSTAT 2019 Autumn Edition



Next, we classified each of the 206 patent families non-hierarchically into the battery types: rechargeable, regenerative fuel cell, hybrid and non-rechargeable, to determine the Australians who have filed the most patents in each category. In the analysis below, a patent family is counted once for each relevant category.

Rechargeable batteries

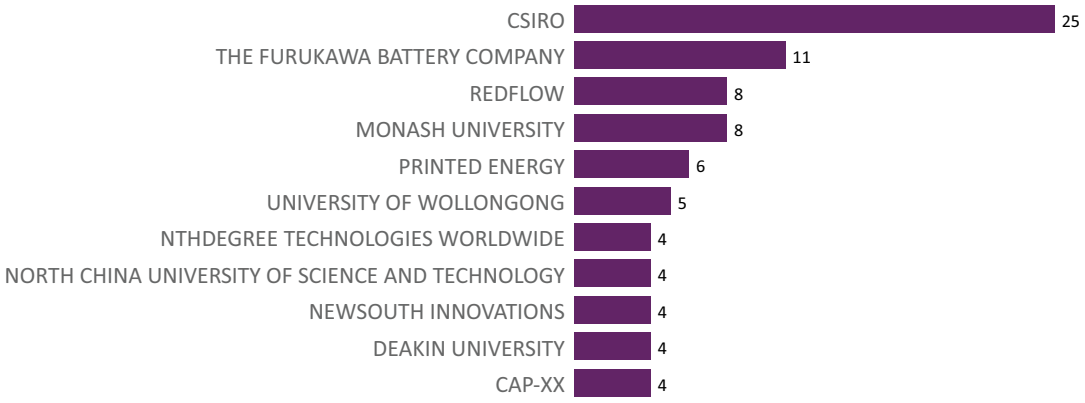
Figure 5 shows the top patent filers of rechargeable ('secondary') batteries. CSIRO is the top Australian filer of rechargeable battery technologies, with their collaboration with the Furukawa Battery Company on development and commercialisation of their UltraBattery responsible for nearly one-third of CSIRO's battery technology patents.

The top five applicants in rechargeable batteries 'CSIRO', 'the Furukawa Battery Co', 'Redflow', 'Monash University' and 'Printed Energy' are also listed above in the overall top filers summary (Table 1).

An example of a patent on rechargeable battery technology is AU20100287342 'Lead-acid battery and method for manufacturing a composite negative capacitor plate for use in a lead-acid battery', filed by CSIRO in collaboration with the Furukawa Battery Company. This patent relates to a composite capacitor plate formed from at least two types of carbon material for use in a lead-acid battery, designed to improve both the manufacturing efficiency and the change/discharge behaviour of the battery.

Figure 5: Rechargeable battery patent filings by Australians, by applicant, 2001-18

Source: PATSTAT 2019 Autumn Edition



Regenerative fuel cells

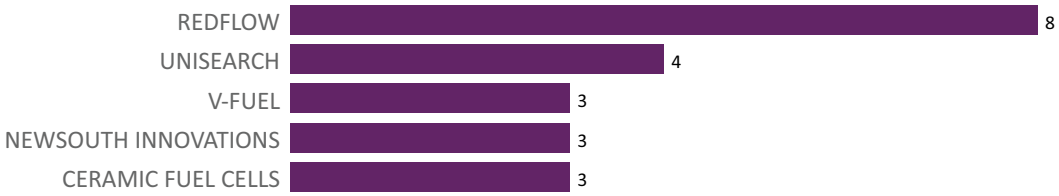
Figure 6 shows the Australians who have filed patents related to regenerative fuel cells.

Fuel cells perform redox reactions on liquid or gas fuel moving through the electrodes. Fuel cells that can be run in reverse to regenerate the inputs are known as regenerative fuel cells. Regenerative fuel cells can run in a closed system and thus operate similar to a rechargeable battery. The top applicant, Redflow, is an Australian company that specialises in 'flow batteries',[27] which are a subcategory of regenerative fuel cells.

An example of a patent in this technology is AU20140289965 'Flowing electrolyte battery and method of controlling a flowing electrolyte battery' filed by Redflow. This patent describes methods for removing the energy stored and the associated zinc plating (e.g. in an emergency or maintenance) in a zinc bromide flow battery by mixing the fuel ('electrolyte') paths from each electrode in a controlled manner.

Figure 6: Regenerative fuel cell patent filings by Australians, by applicant, 2001-18

Source: PATSTAT 2019 Autumn Edition



Hybrid batteries

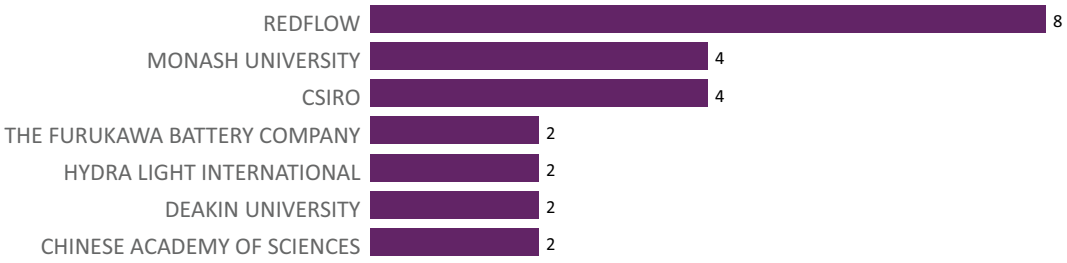
Hybrid batteries have a single electrode that functions as a battery and a single electrode that functions as a fuel cell. This type of operation has potential to be the future of battery technology in mobile applications with metal-air batteries.

These operate as a battery at the metal electrode and as a fuel cell at the air electrode and can store significantly more energy by weight than conventional batteries.

Australians filing patents in hybrid battery technologies are shown in Figure 7.

Figure 7: Hybrid battery patent filings by Australians, by applicant, 2001-18

Source: PATSTAT 2019 Autumn Edition



[27] Redflow 'About' https://redflow.com/about-us/

An example of a hybrid battery patent is AU20170381393 'Metal-air fuel cell' by Hydra Light International. This patent is for a 'mechanically rechargeable' (i.e. the fuel sources are replaceable) metal-air battery/fuel cell that can be activated or deactivated by changing the amount of water in the cell, which may increase shelf life.

Non-rechargeable (primary) batteries

Alkaline batteries and many forms of high-performance lithium cells are amongst the available styles of non-rechargeable (primary) batteries. Innovation here is lower than other areas as the potential applicability of rechargeable batteries is so large. Most patent families relating to non-rechargeable batteries also contain technical information related to rechargeable batteries, regenerative fuel cells or hybrid batteries. Figure 8 shows the top patent filers in primary (non-rechargeable) batteries.

One example of a patent specifically related to primary batteries is WO2007059589 'A water activated system including a flexible substrate' from the CSIRO. This is a flexible battery that may be incorporated into a garment. The battery is inert until exposed to water, giving it a shelf life of up to ten years or more.

Figure 8: Primary (non-rechargeable) battery patent filings by Australians, by applicant, 2001-18

Source: PATSTAT 2019 Autumn Edition

CASE STUDY

The UltraBattery

The UltraBattery[28,29,30] is an Australian success story, with global partnerships developed from CSIRO research, pioneered by Dr Lan Lam. Dr Lam has been listed as an inventor on 14 CSIRO battery patent families, including the UltraBattery technology. This battery system was developed by CSIRO together with the Furukawa Battery Company of Japan (co-filers on eleven of Dr Lam's CSIRO patent families),[31] and tested in the United Kingdom through the United States-based Advanced Lead-Acid Battery Consortium.

Compared with conventional batteries, the UltraBattery has higher capacity turnover, lower lifetime cost per kilowatt hour, higher DC–DC efficiency, fewer refresh charges required and a higher rate of charge acceptance. The hybrid energy-storage battery design combines two everyday energy-storage devices in a single cell with a common electrolyte: the lead-acid battery (the battery found in cars) and a supercapacitor (the device that powers camera flashes). The result is an economical, super-fast-charging battery with long-life power. Combining the two technologies in one battery cell means the UltraBattery works very efficiently compared with conventional technologies, largely because it can operate for long periods at partial charge.

The UltraBattery is a multifunctional energy-storage solution, for applications including electric vehicle batteries, storing renewable energy, smoothing electricity supply, in hybrid power, and in grid ancillaries.

WO2008113133 Optimised energy-storage device

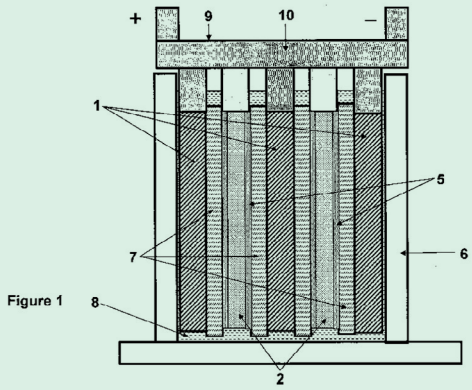


Figure 1

For electric vehicles, the UltraBattery provides multiple advantages over the existing nickel-metal hydride batteries, including that it is approximately 70 per cent less expensive with comparable performance in terms of fuel consumption. With funding from the United States Department of Energy, the UltraBattery has been commercialised by Ecoult,[32] a company established in 2007 by CSIRO, and is being used by Honda in its new Odyssey hybrid model.

The technology is reaching North American markets through United States battery manufacturer East Penn Manufacturing Co. Inc (who acquired Ecoult in 2010), with independent Ecoult operations now ceased and projects transitioned to East Penn's operations in the United States. The UltraBattery is being tested for use in rural India by the Institute of Transformative Technologies and battery manufacturer Exide Industries.

[28] UltraBattery http://ultrabattery.com/
[29] CSIRO (18 October 2019) Case study: UltraBattery https://www.csiro.au/en/Research/EF/Areas/Grids-and-storage/Energy-storage/UltraBattery
[30] ecoult (2014) White Paper: Public-Domain Test Data Showing Key Benefits and Applications of the UltraBattery® https://www.ecoult.com/landing/white-paper
[31] Nakajima, H., et al. (2013) Development of UltraBattery, Furukawa Review No. 43, pages 2-9 https://www.furukawa.co.jp/review/fr043/fr43_02.pdf
[32] ecoult (2020) UltraBattery®: High Efficiency and Long Life in Partial State of Charge Applications https://www.ecoult.com/landing/white-paper

BATTERY PARTS

The design and manufacture of battery parts, such as covers, is a critical part of battery energy-storage capability. Here, we have divided the patent families that relate to battery types or to general battery technologies into three groups that each primarily relate to non-active battery parts (used for construction), electrodes or cell chemistry / other.

The patent families were grouped using a hierarchical order shown in the legend of Figure 9. This hierarchical classification means that each patent family is assigned first to non-active battery parts, if applicable, and if it is not related to non-active battery parts, then it is assigned to battery electrodes, if applicable, otherwise cell chemistry / other.

Top applicants – battery parts

Figure 10 shows the Australian entities who have filed patents relating to battery parts. Whilst CSIRO still holds a strong position, we see a different mix of top filers across the technologies of battery electrodes, non-active battery parts, and cell chemistry compared to complete battery patents.

This information highlights Australians with current knowledge in different areas of battery manufacture and interest in developing the underlying research.

Figure 9: Battery technology patent filings by Australians, by battery part, 2001-18

Source: PATSTAT 2019 Autumn Edition

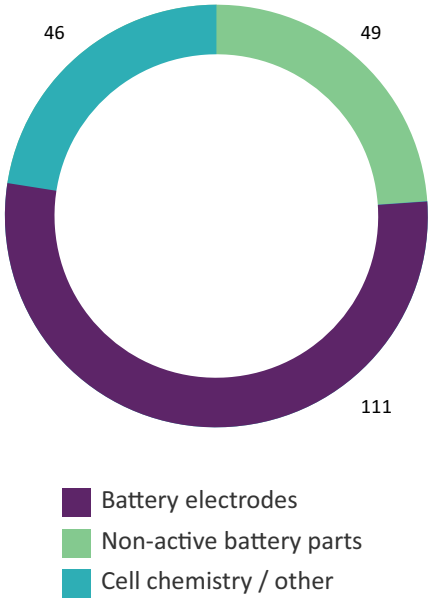
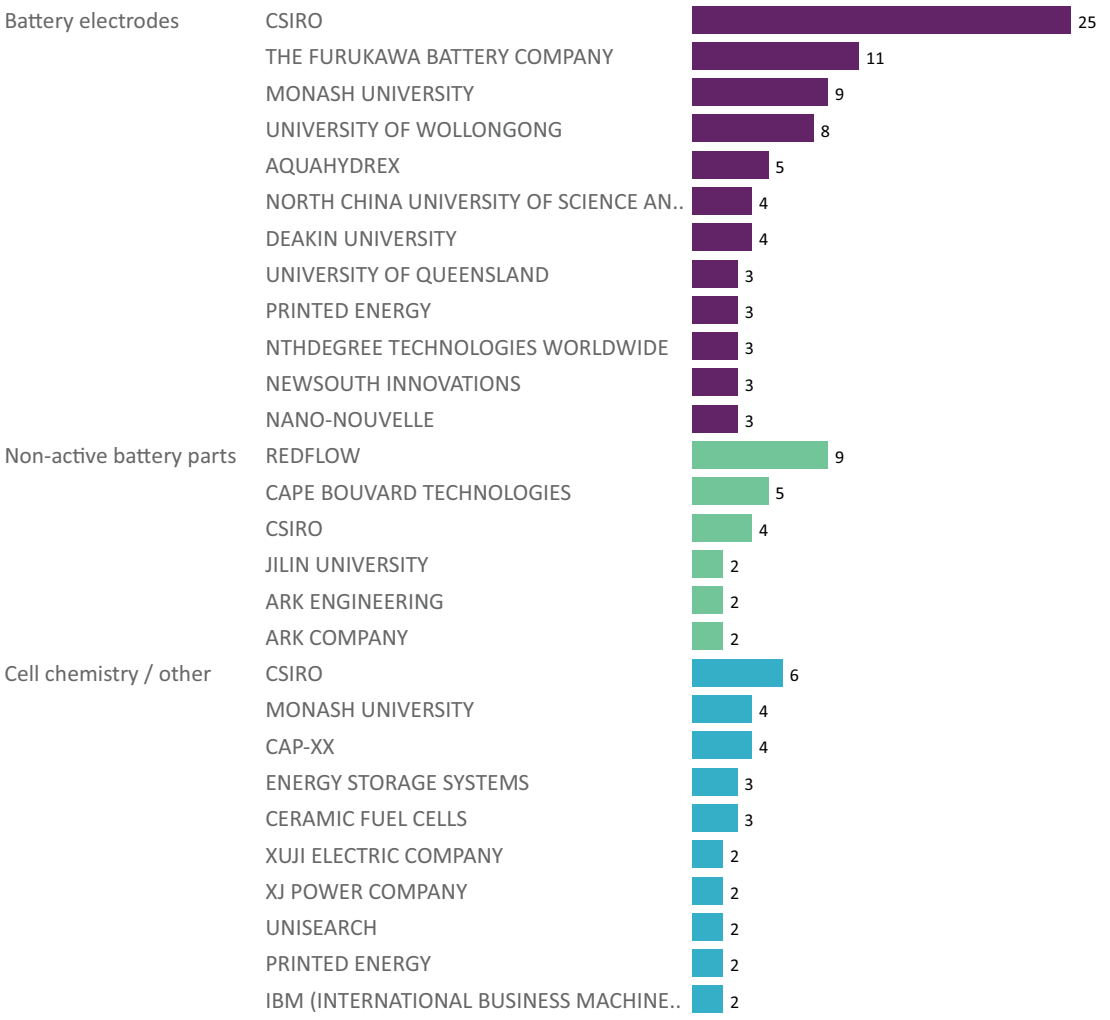


Figure 10: Battery technology patent filings by Australians, by battery part, by applicant, 2001-18

Source: PATSTAT 2019 Autumn Edition



Battery electrodes

Electrodes exist at both poles of both batteries and fuel cells. In batteries they are the site of reaction and often must incorporate the active material, or allow fuel to flow through for reaction. Electrodes are the subject of significant innovation efforts and are the largest subcategory in battery parts. Most of the major filers in this dataset have interest in electrode technology.

An example of an electrode patent is AU20130273919 'Gas permeable electrode and method of manufacture' from Monash University. This patent relates to an electrode constructed to allow gasses produced in the cell reaction (for example a battery, a fuel cell or a cell for electrolysis) to escape, preventing formation of hazardous pressures or bubbles, a major safety issue in the industry.

Non-active battery parts

Non-active battery parts are used for battery construction. Although cell chemistry and electrode design drive many major innovations in battery technology, the non-active parts of batteries are also vital to real-world use and commercial success. Examples include the assembly of battery packs, safety features, interconnections and flow of fuel in regenerative fuel cells.

An example of a patent in the area of non-active parts is WO2019028515 'A structural battery' from Cape Bouvard Technologies. This patent describes a container for holding multiple electric cells with temperature control and structural reinforcement to improve the safety of the battery pack.

Cell chemistry / other

Other elements of batteries include changes to the chemistry of electrolytes and similar features. This subdivision catches all patents without classification into electrodes or non-active battery parts.

The patent WO03079381 'An electrolyte for an energy storage device' from Energy Storage Systems is an example of this. The patent describes an electrolyte suitable for use in many kinds of energy storage devices including capacitors and batteries that are suitable for use at high temperatures through mixing of multiple solvents.

BATTERY COMPOSITION

The development of lithium batteries is an Australian focus due to our rich mineral resources.

Lithium's very high electro-chemical potential (its willingness to transfer electrons) makes it a powerful component of battery cells. There are different combinations of positive and negative electrode materials that can make up a lithium ion battery. For positive electrodes, examples include lithium iron phosphate, lithium cobalt oxide, lithium nickel cobalt aluminium oxide, lithium nickel manganese cobalt oxide, and lithium manganese oxide. For the negative electrode there is graphite and lithium titanium oxide. All of these are currently under intensive world-wide and Australia-wide development and improvement.[33]

Lithium batteries rely on ten core mineral elements: lithium, cobalt, nickel, graphite, manganese, iron, phosphorous, titanium, aluminium and copper. These comprise the key components of every lithium-ion battery and are all mined in Australia. Lithium solid-state batteries have recently attracted great interest as potentially safe and stable high-energy storage systems. However, key issues remain unsolved, hindering full-scale commercialisation.[34]

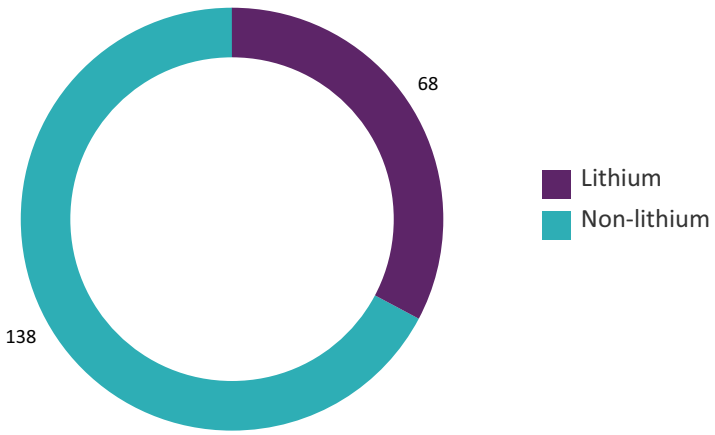
Here, we divide all Australian battery-related patent filings into those that disclose a use in lithium-based batteries, and those that do not (Figure 11).

Top applicants – battery composition

Figure 12 shows the top Australians who have filed patent applications in lithium batteries and non-lithium batteries. Figure 12 demonstrates that lithium battery technologies are a specialised area of research and development, with different applicants filing in lithium compared with non-lithium battery technologies.

Figure 11: Battery technology patent filings by Australians, by battery composition, 2001-18

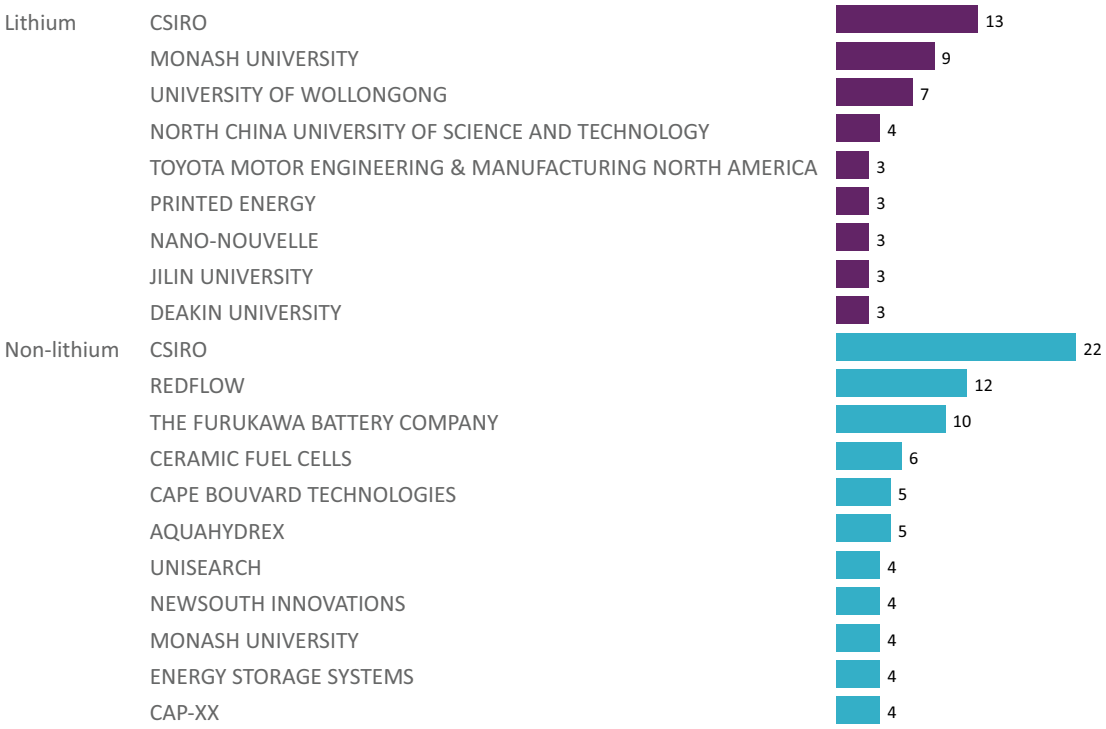
Source: PATSTAT 2019 Autumn Edition



[33] Australian Trade and Investment Commission (2018) The Lithium-Ion Battery Value Chain - New Economy Opportunities for Australia, Commonwealth of Australia, Canberra https://www.austrade.gov.au/ArticleDocuments/5572/Lithium-Ion%20Battery%20Value%20Chain%20report.pdf.aspx
[34] Janek, J. and Zeier, W.G. (2016) A solid future for battery development, Nature Energy, article number 16141 https://www.nature.com/articles/nenergy2016141.pdf

Figure 12: Battery technology patent filings by Australians, by battery composition, by applicant, 2001-18

Source: PATSTAT 2019 Autumn Edition



Lithium batteries

Lithium is clearly a major focus of current research efforts by the major filers, with chemistries involving this one element accounting for about one-third of all patent families filed by Australians in battery technologies.

An example is the patent co-filed by the University of Wollongong collaborating with the North China University of Science and Technology, CN106299356A 'Efficient microwave radiation synthesis method of lithium vanadate Li_3VO_4 nanoflower for lithium ion batteries'. This patent descibes making lithium vanadate nanostructures using a new synthesis method, which are useful for improving performance of lithium-ion batteries.

Non-lithium batteries

While lithium technologies are an important development, non-lithium battery technologies remain the backbone of current energy-storage systems. This categorisation also includes patents that do not specify a particular chemistry. A large number of patent applicants are investigating alternative technologies to lithium-based energy storage. These include CSIRO's UltraBattery (lead-acid) and Redflow's flow batteries (zinc-bromine).

An example patent on non-lithium technology is AU20160363672 'Sodium-ion electrolyte composition' by Monash University and Deakin University. This relates to a new sodium-ion electrolyte that is solid up to 25°C. This electrolyte improves protection against fire due to its low volatility, and is suitable for solid-state sodium-ion batteries, which use sodium in the place of lithium due to its abundance and potential advantages in a solid-state setting.

RELATED INFORMATION

Trade marks

Trade mark filings indicate commercial success through brand protection. Australian entities are active in this area, with 3487 trade mark filings related to batteries, 2052 related to energy supply and storage, and 396 related to industrial power.

While trade marks do not provide details of technological developments, this information supports the finding that battery technologies are an area of commercial investment and growth in Australian.

Designs

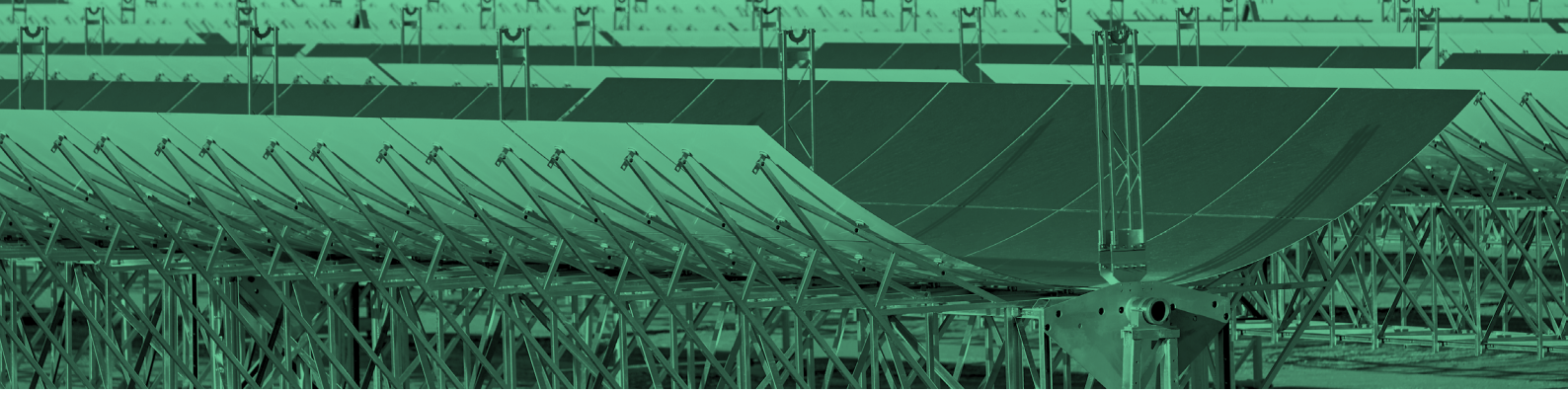
Similarly to trade marks, designs filings indicate commercial success through market protection. Designs rights give businesses a competitive edge by protecting the look of a product.

There are 72 battery-related designs rights registered in Australia. These designs filings are primarily directed to the look and design of structures for battery casings, covers and packs, filed by companies that are interested in selling the final products.

Most of the 37 companies with Australian addresses that have filed designs related to batteries are subsidiaries of international businesses.

Six Australian-owned companies have filed design rights related to batteries, including commercial leaders.

- Altrace Pty Ltd
- Ark Corporation Pty Ltd
- BlueAnt Wireless Pty Ltd
- Energy Renaissance Pty Ltd
- Redarc Technologies Pty Ltd
- Strategies Unleashed Pty Ltd



CONCLUSION

This report set out to explore global patent data to identify Australian capability and innovation in battery energy storage.

With 206 patent families filed by Australians in battery technologies, we found that this is an area of growth and specialisation where – led by CSIRO – Australia has the potential for strong international impact through developing and commercialising our world-leading research contribution in this field.

This report identifies Australians who are actively working in different fields of battery development, and the accompanying interactive visualisation[35] allows the reader to drill down into each patent and identify individuals and companies that hold this knowledge. This type of information can help to identify expertise in areas that could help to build Australia's battery manufacturing capability, and inform strategic decisions to build Australia's national energy capability.

Australians filing patents in battery technologies co-filed 70 patent families collaboratively (one third of all applications). This may reflect the predominance of universities and public research institutes in this area in Australia. In turn, this suggests both an early stage of technological maturity in this area, and global interest and investment in research and development in the energy-storage sector.

Overall, this patent analytics report on batteries shows a sector with strong growth and potential to build Australian capability. This would benefit the broader Australian economy in the context of intense global interest. This report provides evidence to inform policy and decisions, to ensure that Australians benefit from secure national energy capability.

[35] https://public.tableau.com/views/Batteriesanalysis/Batteries?%3Aembed=y&%3Atoolbar=no&%3Adisplay_count=no&%3AshowVizHome=no

APPENDIX A: DEFINITIONS

Patent, applications and publications

A patent is a right that is granted for any device, substance, method or process that is new, inventive and useful. Australian patent rights are legally enforceable and give the owner, or patentee, exclusive rights to commercially exploit the invention in Australia for a period of up to 20 years. In this report, an application refers to a single patent filing. A patent application is usually published within 18 months of its earliest filing date (also known as the priority date). We consider that the priority date is most relevant to our analysis as it is the closest date to that when the invention occurred.

There are two major routes for filing a patent application: the international route and direct filing. The international route involves filing a PCT application, which establishes a filing date in all 152 contracting states.[36] Subsequent prosecution at national patent offices, referred to as national phase entry, is made at the discretion of the applicant. A patent can only be enforced once it has been granted and a PCT application must enter the national phase in each country to proceed toward grant. Alternatively, applications can be filed directly in the countries of interest, without using the PCT system.

Patent families

Applications with the same priority, but filed in different jurisdictions, are known as patent families. Patent families enable us to analyse inventive activity regardless of the number of countries in which protection is sought. Patent families are used in analytics to represent a single invention. We determine patent families based on INPADOC database definition, with a unique family ID for patents that share a common priority document. The number of patent families is typically used as a metric. There are some exceptions when reporting individual applications, as each application represents a legal right in an individual country. When analysing applicants, related commercial entities are grouped by a singly, harmonised name. When individual publication numbers are quoted, we have chosen a representative publication from the patent family, typically US or WO English language documents.

Classification

Patents are hierarchically classified by technology into the hierarchical IPC or CPC systems. The CPC began in 2013 and provides significantly more depth to the hierarchy of the IPC.[37] For more information on the coverage of the CPC, see the CPC Annual Report 2017–18.[38]

Patent status determination

A patent application is considered as 'being sought or in force' when it has not lapsed (due to expiry or non-payment of renewal fees), been revoked or withdrawn. A family is designated as 'being sought or in force' if it contains at least one application that is 'being sought or in force'. The PATSTAT database is used to define the legal events 'Application Discontinuation' and 'IP Right Cessation'. These are considered to make an application lapsed, expired or withdrawn. Applications without these events are considered as 'being sought or in force'.

Country of origin

Many records in the PATSTAT database (around 50 per cent) do not have any associated country code information for applicants/inventors. In previous patent analytics studies, null data has generally been excluded from the country of origin analysis.

In this patent analytics report, we have used other data available in PATSTAT to provide additional insights for patent families that do not have applicant origin data available. This method of country code assignment leverages all data from the entire PATSTAT database, and not only country codes information from a subset of the data extracted for a specific technology area.

The country of origin of a patent family is assigned using a three-step process.

1. Where country code is available for applicant data, this is used as the country of origin.
2. If the country code is 'null' and the applicant name is associated with a standardised or cleaned version of their name (e.g. the PATSTAT standardised PSN name), there may be several versions of an associated applicant name with several entries for country code. A count of the total number of applications applied for with

[36] World Intellectual Property Organization (accessed 9 October 2019) www.wipo.int/pct/en/pct_contracting_states.html
[37] European Patent Office and United States Patent and Trademark Office (accessed 9 October 2019) www.cooperativepatentclassification.org/
[38] Cooperative Patent Classification, Annual Report 2017/2018, United States Patent And Trademark Organization and European Patent Office https://www.cooperativepatentclassification.org/wcm/connect/cpc/7487e512-5f6a-41e3-b0db-7afdc8b92fea/CPCAnnualReport_published.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE.Z18_92EE1J41N0BE50QEQ1PQ6P0007-7487e512-5f6a-41e3-b0db-7afdc8b92fea-mRF8p.X

each country code is used to determine the most representative country and that is applied. This is an independently developed technique analogous to the technique detailed by the European Commission.[39]

3. If the country code for the standardised name is 'null' or where no applicant details are recorded for the patent application, then the first application authority is used. This is the country the earliest priority document was filed into for the patent family and it is used as a country of origin. This authority is the first by date where the authority is a country and not an international body. For international applications, the receiving office is used where possible.

It is important to note that as patent families are used, most families that are filed internationally have reliable country code data, either through World Intellectual Property Organization, European Patent Office, United States Patent and Trademark Office, or other large patent offices. Applicants that often file internationally will have standardised name-associated country information for the same reason, even for local applications. The first application authority is therefore generally only used as a proxy for origin in the case of patent families that are filed to one jurisdiction only, increasing the probability that the country is correctly assigned.

Who are Australians?

In this analysis, a patent family is considered to have been filed by an Australian if any one of the patent applicants (generally companies, universities or research institutes) or inventors has listed an Australian address.

As a result of this definition, this analysis includes patent filings from some entities that are not Australian. These non-Australian entities are included for those filings where they either:

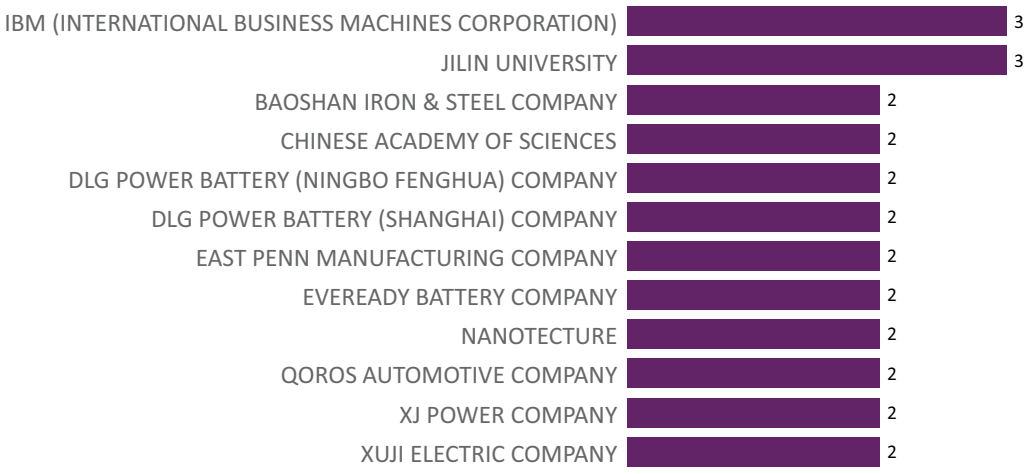
- Have co-filed patents with Australian applicants – such as the Furukawa Battery Company, that has co-filed a number of patents with CSIRO for the UltraBattery; or
- Have listed Australian inventors as working for or in collaboration with them (Figure 13 shows these entities).

Information on these filings and collaborations identifies dissemination of Australian knowledge and expertise. For example, the East Penn Manufacturing Co, which owns the rights to the UltraBattery, have filed patents that list Australian inventors but no Australian applicants. The inventors involved were a part of the East Penn subsidiary ecoult, a spin out of CSIRO, and one of these inventors has since become an executive at Redflow, another prominent Australian company in battery technology.

Such knowledge, and who holds it, is discussed in this report. Full details of all patent families are included in the accompanying interactive visualisation and raw data.

Figure 13: Battery technology patent filings showing applicants with more than one patent filing where an Australian is listed as an inventor but neither the filer nor any co-filer is Australian, 2001-2018

Source: PATSTAT 2019 Autumn Edition



[39] Pasimeni, F. (2019) SQL query to increase data accuracy and completeness in PATSTAT, World Patent Information, vol 57, p 1-7 https://www.sciencedirect.com/science/article/pii/S0172219018300875?via%3Dihub

APPENDIX B: SEARCH STRATEGY

Searching patent information to identify relevant records for analysis requires a stepped approach to identify broad categories of relevance, and then specific records within them that meet the technology brief.

The following details outline the search and analysis process conducted.

Data extraction and analysis

We used five phases of data extraction and analysis.

- Phase 1: Development of a search strategy (below).
- Phase 2: Data mining using the database PATSTAT 2019 Autumn edition. The unique INPADOC family members relating to batteries, and involving Australians, were identified and used as the basis of the analysis.
- Phase 3: Data cleaning, focusing on removing errors and harmonising applicant names and ensuring the return of correct records. This was done using python script, using a probabilistic signatures (pSig) Entity Resolution algorithm, followed by some manual correction.
- Phase 4: Data categorisation according to the technological focus of the patent families. The technological focus was determined using the CPC and IPC symbols.
- Phase 5: Data analysis using Tableau 2018.3 for calculation and visual presentation of patent metrics.

Search strategy

The search was limited to patent applications that had an earliest priority date between 2001-19 and a CPC symbol, IPC symbol as listed here.

Classification Symbols (note that /low indicates that all symbols lower in the hierarchy were included).

1. IPC/CPC Symbols:

   H01M2/low or H01M4/low or H01M6/low or H01M8/18/low or H01M10/low or M01M12/low

APPENDIX C: TECHNOLOGY ANALYSIS

Patent families were categorised into three groups: battery type, battery parts or battery composition, using IPC/CPC symbols and keywords. This classification was done in Tableau Desktop.

Technology categorisation

Functional category	Subcategories	IPC/CPC classification	Notes
Battery type	Rechargeable	H01M10/low or H01M4/13/low	
	Regenerative fuel cell	H01M8/18/low	
	Hybrid (fuel cell / battery)	H01M12/low	
	Primary (non-rechargeable)	H01M6/low	
Battery parts	Non-active parts	H01M2/low	Non-regenerative fuel cell patents manually removed
	Electrodes	H01M4/low	Non-regenerative fuel cell patents manually removed
	Cell chemistry / other	All others	
Battery composition	Lithium	H01M10/052/low	Also used lithium keyword in title; manually searched for lithium battery technology in description in the remainder
	Non-lithium	All others