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The Australian Mining Industry: More than Just Shovels and Being the Lucky Country

IP Australia Economic Research Paper 04

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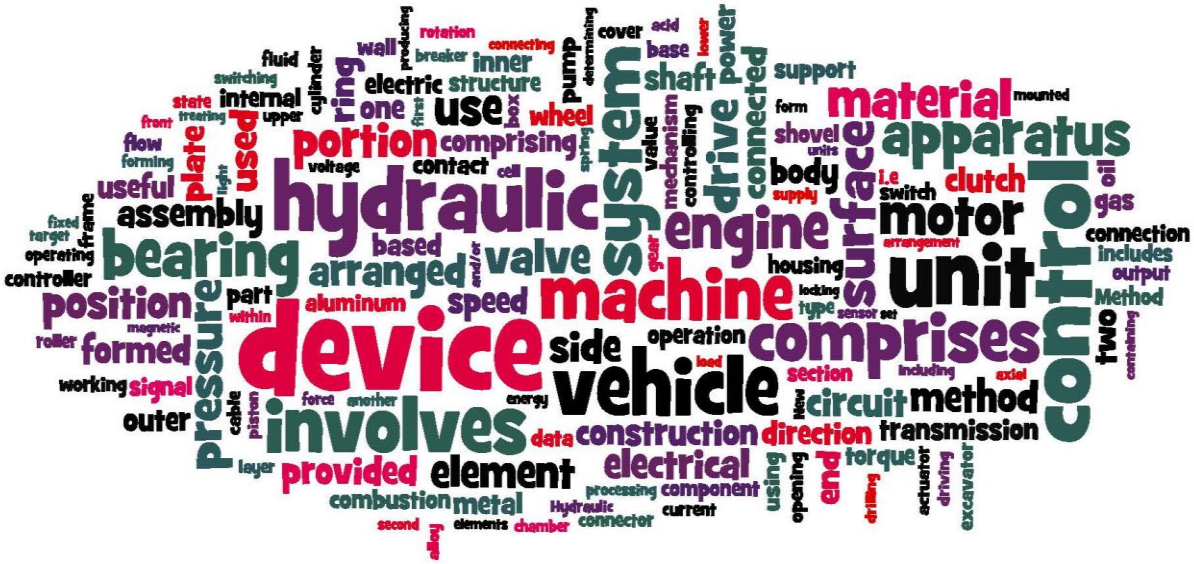


Glossary

ABN	Australian Business Number
ANZSIC	Australian and New Zealand Standard Industrial Classification
AusPat	IP Australia's online database containing applications filed and granted in Australia
CRC	Co-operative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EPO	European Patent Office
HAN	Harmonised Applicants' Names
IP	Intellectual Property
IPC	International Patent Classification
IPGOD	Intellectual Property Government Open Data
METS	Mining Equipment Technology Services
OECD	Organisation for Economic Cooperation and Development
PATSTAT	EPO Worldwide Patent Statistical Database
PCT	Patent Cooperation Treaty
R&D	Research and Development
REGPAT	OECD Regional Patent database
SME	Small and Medium-sized Enterprise
WIPO	World Intellectual Property Organization

Executive Summary

It is hard to overstate the significance of the mining industry's contribution to the Australian economy. Although mining is often seen as a low technology industry, Australia's unique environment has meant that the development of specialised technologies and systems is required and a series of lucrative enterprises have been born out of this. Despite this, the narrative around mining is generally not focused on the technology, innovation or intellectual property that drives the industry today. This paper aims to address that by performing an investigation of the mining sector using patents to determine innovation trends and who is undertaking this work: the operating miners themselves, publicly funded entities or the METS (Mining Equipment Technology Services) firms.

This paper uses an open database, Intellectual Property Government Open Data (IPGOD), which matches the Australian IP registries to firm level data, in combination with world patent databases to detail the patent filing activity and innovation areas in the mining sector. The ultimate aim is to determine whether Australians are innovators in the field, creating and exporting technology, or do Australian miners simply use other companies' tools and innovations to dig their resources out of the ground.

ABN data for relevant companies was sourced and used with IPGOD or company names were used with the OECD's HAN database to retrieve cleaned unique applicant names. The patents for these applicants were retrieved from PATSTAT. In addition we used the Australian & New Zealand Standard Industrial Classifications in IPGOD to identify applicants who self-report as being part of the mining industry. The period we examined was from 1994-2011 and we looked at patent families or individual inventions.

We identified 6,539 Australian mining inventions filed between 1994 and 2011. The resulting data indicated that the METS sector was the primary filer, followed by operating miners and finally the publicly funded entities. The operating miners were primarily concerned with new methods of processing of ore, specifically the refining of ore and the production of iron or steel. METS firms filed patents mainly in dredging and soil shifting equipment as well as gearing systems, electric switches and relays. Publicly funded entities filed in areas such as investigating different material properties, digital data processing and the separation of materials using evaporation, distillation.

We did not observe a drop in patent filings predicted with the reduction in research funding in the mining sector. In contrast, we saw an increase in patent filings due to an increase in patent filings by METS firms.

Inventors of the mining patents filed by METS firms and operating miners do not typically reside in Australia but in Japan or Germany. Conversely, inventors from publicly funded entities reside in Australia. In addition, most METS applicants and just over half of operating miner applicants are also located off our shores.

1. Introduction

1.1 The Mining Industry in Australia

Australia has the world's largest reserves of lead, nickel, uranium and zinc (Australian Trade Commission 2013). The minerals industry contributed at least 10 per cent of the GDP in Australia in 2012-2013 and employs over a quarter of a million Australians (Minerals Council of Australia 2014). The recent mining boom in Australia has created a high level of demand for the development of specialised technologies and systems, many of which have become lucrative enterprises in their own right, both nationally and internationally. Despite this, the narrative around mining is generally not focused on the technology, innovation or intellectual property that drives the industry today.

How do we define the mining industry in Australia? The obvious place to start is with the firms which operate the mines themselves, referenced herein as the operating miners; however the mining industry extends beyond that. For the purposes of this paper, mining will be considered similar to the minerals industry and will not focus on the oil/gas industries or fabricated metals production. As such, our definition of the mining industry includes the exploration of new mineral deposits, their extraction from the ground, the isolation of the ore and its subsequent preparation for metal production. These are all areas where the literature shows real productivity gains from the introduction of new technology (Bartos 2007; Boudreau-Trudel et al. 2014), but little research exists on who creates that new technology.

The next important group of firms to consider when talking about the Australian mining industry is the Mining Service Firms or METS (Mining Equipment Technology Services) firms. METS firms do not operate the mines themselves, but have evolved in Australia to support the mining industry.

We also include publicly funded entities, including universities and Co-operative Research Centres (CRCs). CRCs are scientific research organisations that receive government funding through an established program.

Finally, we look at the firms within Australia that are identified as part of Australian & New Zealand Standard Industrial Classification (ANZSIC) division B.

1.2 Mining Equipment Technology Services (METS) Firms

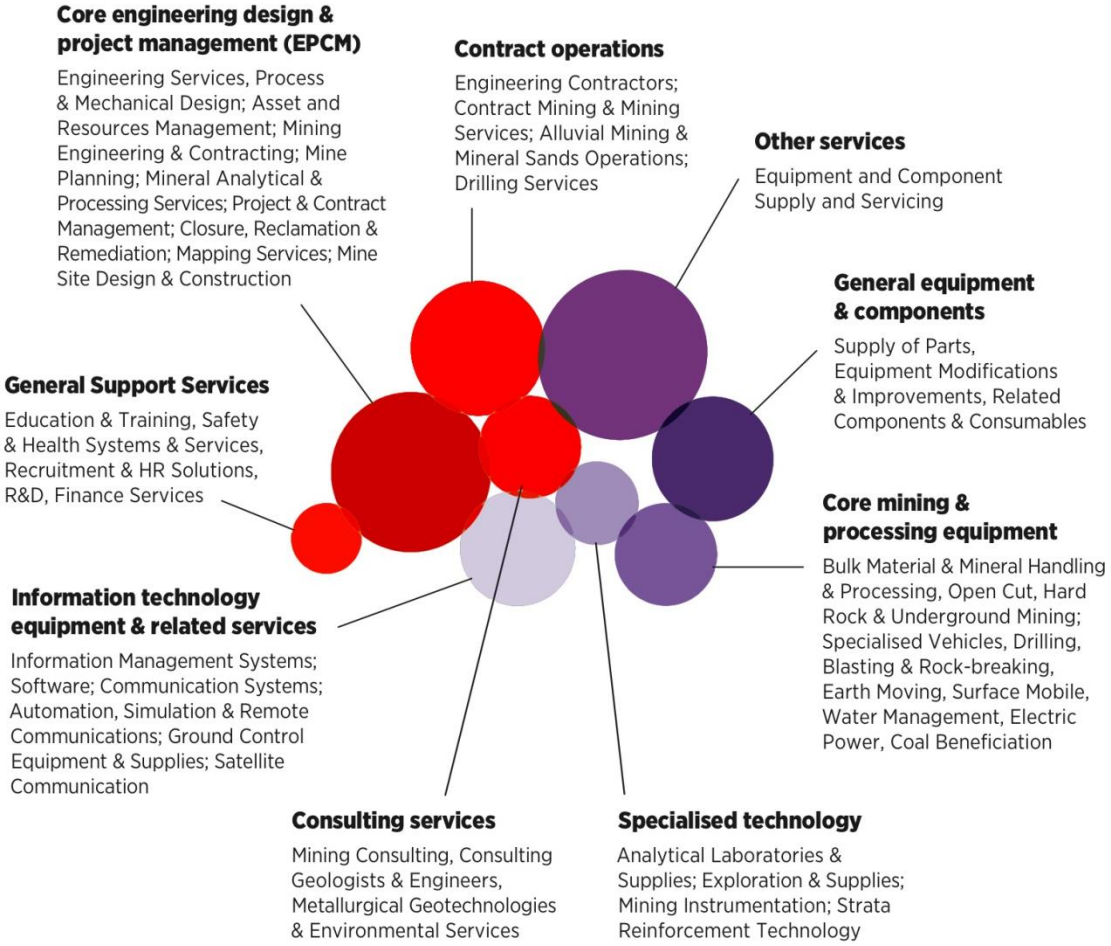
METS firms are uniquely Australian with a long history, emerging due to a need to support miners to explore, mine and refine ore extracted from our unique environment, the first being established in 1859 (Austmine 2013). There are varying definitions identifying firms as METS but for the purposes of this report we are using the Department of Industry and Science's definition of METS firms as those that provide technology and services to the operating miners and whose primary source of income is from the miners (either directly or indirectly).

The METS sector continues to grow; data from the Mineral Council of Australia indicates that the METS sector has increased five-fold in the past fifteen years with most METS companies established in the past thirty years. This is in part due to the success of these firms and also the proactive nature of the industry, with 55 per cent currently exporting and another 18 per cent planning to export (Austmine 2013). METS firms also tend to be highly flexible and work across a series of resources and phases of production, including metal ore, coal mining and exploration. Eighty-four per cent of METS firms are Australian owned and a large portion are SMEs.

A summary of the types of services that METS firms provide to the industry is shown in Figure 1. Figure 1 illustrates that the main areas of operation are engineering design & project management services and equipment supply & servicing, which overlaps with areas such as supply of parts and consultancy services.

METS firms are an important component of our analysis as they invest strongly in innovation, spending A$1.6billion in R&D in the 2011-12 financial year. METS firms receive the majority of their income from the provision of goods and services to the mining sector. With decreasing R&D budgets, it is likely that operating miners will continue to look to METS firms to innovate in their place (Austmine 2013).

Figure 1: Types of METS firms with examples of products and services. Size is an indication of the amount of work in the area and overlaps indicate related areas of work.



Source: Scott-Kemmis 2013.

1.3 IPGOD

In 2014 IP Australia released the Intellectual Property Government Open Data (IPGOD). IPGOD takes intellectual property data from AusPat, some dating back over 100 years, and matches it with firm level business data such as firm size, geo-location and ABN information. Firm level data is only provided for Australian companies, but this still provides an important link between economic and innovation data that was previously unavailable. The database is not limited to patent data but also includes designs, trade marks and plant breeder's rights information; all linked using a cleaned name and ABN. This data was useful in identifying applicants within patent databases.

2. Objectives and Methodology

2.1 Objectives

This report aims to determine the scale and technology interest of mining firms operating in Australia but more specifically to answer the following questions:

- As one of the top five producers of the world's minerals, is Australia generating its own technologies for use in extracting these minerals or making use of foreign technologies?
- Which Australian mining companies are patenting and in which technology areas are they patenting?
- What technologies are Australian miners generating? And where are these technologies exported?
- Are METS companies performing all the innovation in Australia? If so, in what areas?
- Are different entity types—operating miners, METS firms and publicly funded entities—collaborating to perform innovation?
- Are SMEs more adaptive and likely to innovate?
- Are there ANZSIC classes beyond division B (mining) we should consider as "mining"?

2.2 Methodology

2.2.1 Definition of Mining Patents

It is difficult to provide a definition of mining patents in terms of a set of relevant IPC marks (see Box 1) as typical mining technologies encompass a wide variety of technologies, including: refining of metal ore, forming of alloys, sound protection, conveyers for material handling, specialised vehicles, site building construction, explosives, remote monitoring of operations, exploration techniques, relevant health and safety techniques, the reclamation of sites no longer viable and remote power supplies.

Instead, we used an alternate strategy. We obtained a list of mining firms and searched, using them as applicants, in patent databases before performing an analysis to determine what type of technologies they were protecting. These applicants fell into three entity types: operating miners, associated METS firms and relevant publicly funded entities, such as universities and CRCs.

Initially, a list of 154 operating miners was extracted from a data snapshot purchased from the Research Information Unit, a group which specialises in research and publications concerning mining, oil and gas industries (Resource Information Unit 2014). ABN data for each of these firms and any of their identified controlled entities was manually retrieved.

A list of METS firms, and their associated ABNs, was provided by the Department of Industry and Science. The list incorporates what are known as Tier 1 firms, those which have a direct relationship with the operating miners, and Tier 2 firms which deal with the Tier 1 firms directly and so forth. A total of 1,399 unique METS firms were identified, although ABN data was not available for all of these firms.

The publicly funded entities were identified as a limited list of relevant universities, located in what are considered mining states, including University of Queensland (UQ), Queensland University of Technology (QUT), Curtin University, Murdoch University and the University of Western Australia (UWA); and four relevant CRCs currently (or recently) funded—CRCMining, Deep Exploration Technologies CRC (DET-CRC), CRC Ore and Energy Pipelines CRC—including their controlled entities. CRCMining also files under the names CMTE Development Ltd., EzyMine, and EdanSafe. Lastly, we included the CSIRO.

Our final source of firms was via a search for specific ANZSIC divisions in the IPGOD database. The ANZSIC was developed by the Australian Bureau of Statistics to distinguish and monitor different industries and it has a hierarchical structure. Firms identify their main business activity within this classification scheme when registering an ABN. Division B relates to mining and is therefore the most relevant for our purposes. The applicants for subdivisions B06 (coal mining), B08 (metal & ore mining)

and B10 (exploration and other mining support services) were extracted from our internal version of IPGOD, while also identifying them as a METS firm, an operating miner or a publicly funded entity.[1]

Box 1: The Patent System

Patents comprise a technical disclosure of the nature of an invention and include a legal statement which defines, in words, the scope of the monopoly the applicant seeks. A standard patent provides a twenty-year monopoly for the applicant in Australia. For each patent there are both inventors and applicants which may not necessarily be the same. The inventor is typically an employee of the applicant. It is a requirement of the law that a patent provides a full disclosure of the invention such that a person who is skilled in that particular technology area is capable of reproducing the invention. The level of detail is given in exchange for the twenty-year monopoly and is intended to inspire fellow innovators in the field to advance the art.

There are various jurisdictions through which an applicant can apply for protection of their invention including Australia, the European Patent Office (EPO), the United States and Japan. Under the Patent Cooperation Treaty (PCT) applicants may also apply for what is known as an international patent application, which allows their invention to be assessed in terms of the newness and inventiveness of the invention by an international authority, after which it is published before entering processing in the jurisdictions elected by the applicant. This is known as the international filing route but applicants may also file directly in each jurisdiction.

Patents are classified according to the international patent classification (IPC), administered by the World Intellectual Property Organization (WIPO). The IPC is a hierarchical system wherein details describing the invention are added at each level. For instance, 'E' is the broad class representing fixed constructions, 'E21' is earth or rock drilling or mining, and 'E21F' is mining safety devices, transport and ventilation or rescue apparatus. An invention may be classified within more than one mark and in this instance the first mark listed is considered the most important and is known as the primary mark. Any other marks are then referenced as secondary marks.

Patents are often used as an indicator of research performance as they are easily quantifiable. Extraction, analysis and interpretation of patent filing trends can provide a wealth of information in regard to the direction of innovation and research in the future as well as providing an indicator of firm performance.

2.2.2 Methodology

Once firms and their ABNs were identified, ABN data was run against IPGOD to retrieve a cleaned applicant name for each firm. Applicant names across different patent databases vary and it is often hard to identify which name will be recorded as the applicant. IPGOD only provides firm level data for Australian firms, so foreign firms that were of interest were validated against the OECD's HAN database by manually identifying a patent that was assigned to each firm.

Once firms were identified, a search was run in the EPO PATSTAT database (version April 2013) with the firms identified as applicants to retrieve the patent applications and families.

As universities file patents across a wide array of technologies, post processing was performed to include only those patents that fell into the same IPC subclasses found in the patents filed by the operating miners and METS firms.

2.2.3 Timeframe for Analysis

Patents with a priority date between 1 January 1994 and 31 October 2011 were used in this analysis. The priority date is the most relevant for ascertaining the date of invention. It is the earliest date recorded on patents and therefore allows the comparison of dates unaffected by administrative variations or delays.[2]

[1] ANZSIC codes for individual firms are not available for public inspection.

[2] The April 2013 edition of the PATSTAT contains all publications to the end of March 2013, essentially comprising publications with a priority date up to October 2011.

3. The Big Picture

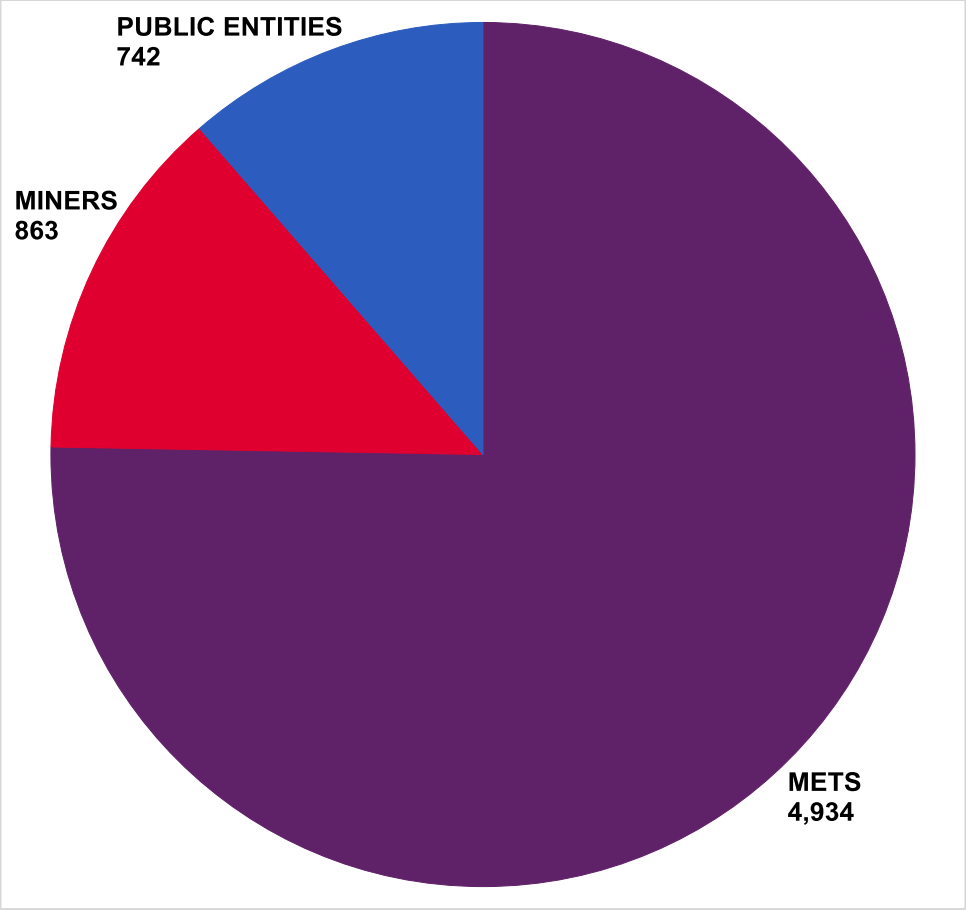
3.1 Summary Data Set

Data from each of the operating miners, METS firms and publicly funded entities was brought together to provide a dataset of mining patents, with a total of 19,009 unique patent applications identified. This dataset was then extended to include what is known as family members of the original set in order to capture as much data as possible.

A patent family is a collection of published patent documents relating to the same invention that are published at different times in the same country or published in different countries or regions. A patent family generally relates to one invention. Patent families enable us to analyse inventive activity regardless of the number of countries in which protection is sought. In general, each patent family represents a single invention. In total, we found 6,539 mining inventions, or patent families.

The summary in Figure 2 shows the resulting patent families, broken down by entity type. Figure 2 indicates that the METS firms are performing the bulk of the innovation in mining in Australia and the publicly funded entities have the fewest inventions. However considering the relative proportion of the number of applicants in each of these entity types, the publicly funded entities file the most patents per applicant.

Figure 2: Number of inventions by type of applicant. METS firms have filed the most patent families.



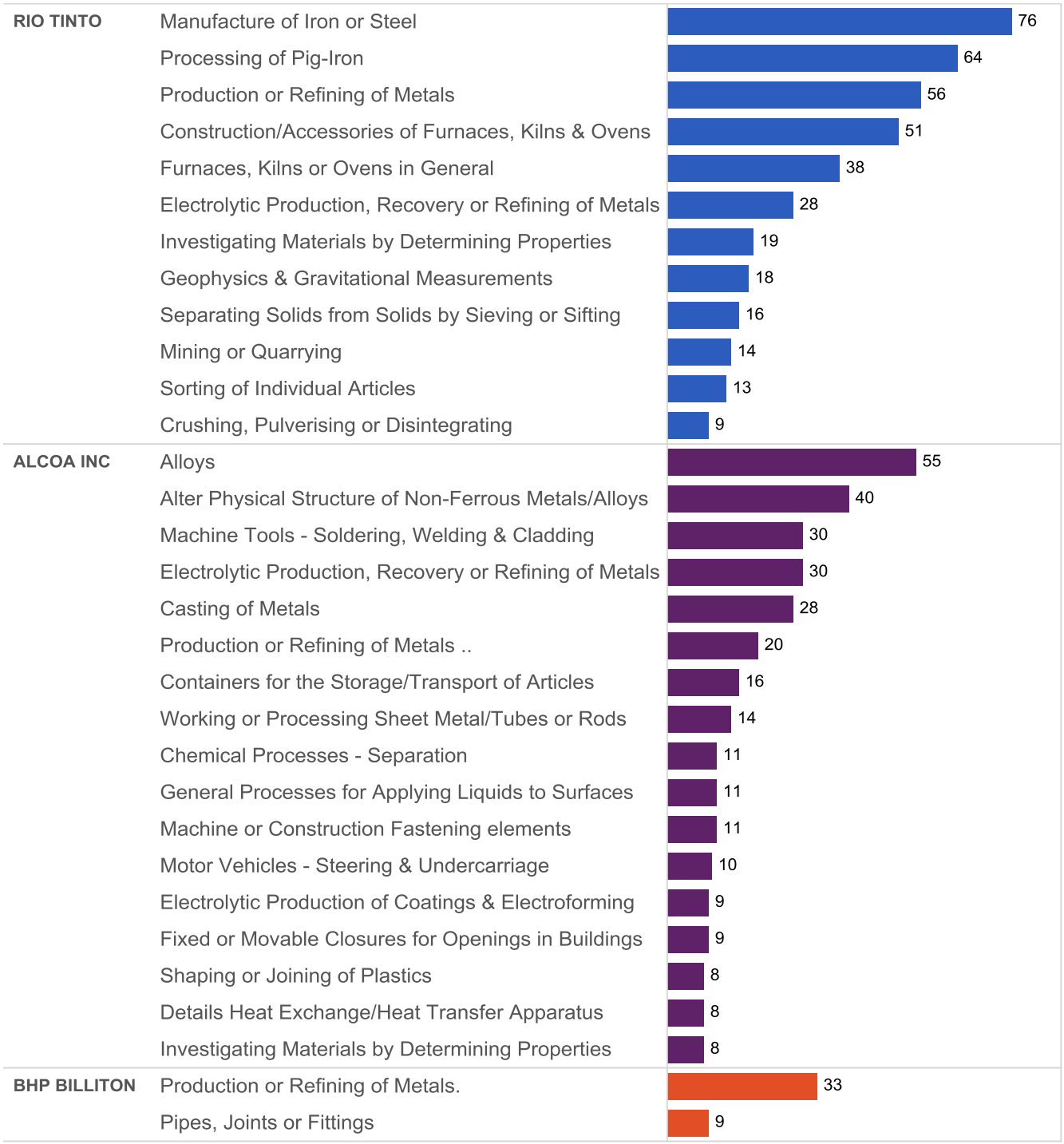
Source: PATSTAT April 2013

3.2 An Investigation of the Major Players

According to the ASX Metals and Mining Sector Profile, the major players in Australia, as determined by market capitalisation, are BHP Billiton, Rio Tinto Alcan, Newcrest Mining, Fortescue Metals and Alcoa. Rio Tinto files patents under one of its controlled entities in Australia, Technological Resources Pty Ltd. OneSteel, the BHP steel division, was divested from BHP Billiton in 2000 and as such has not been included in this analysis.

Figure 3 shows the top technology areas for the major players (for which there are at least 8 inventions). Newcrest Mining and Fortescue Metals did not file any patents during the study period.

Figure 3: Top technology classifications identified by primary IPC subclass by ASX Major Players.



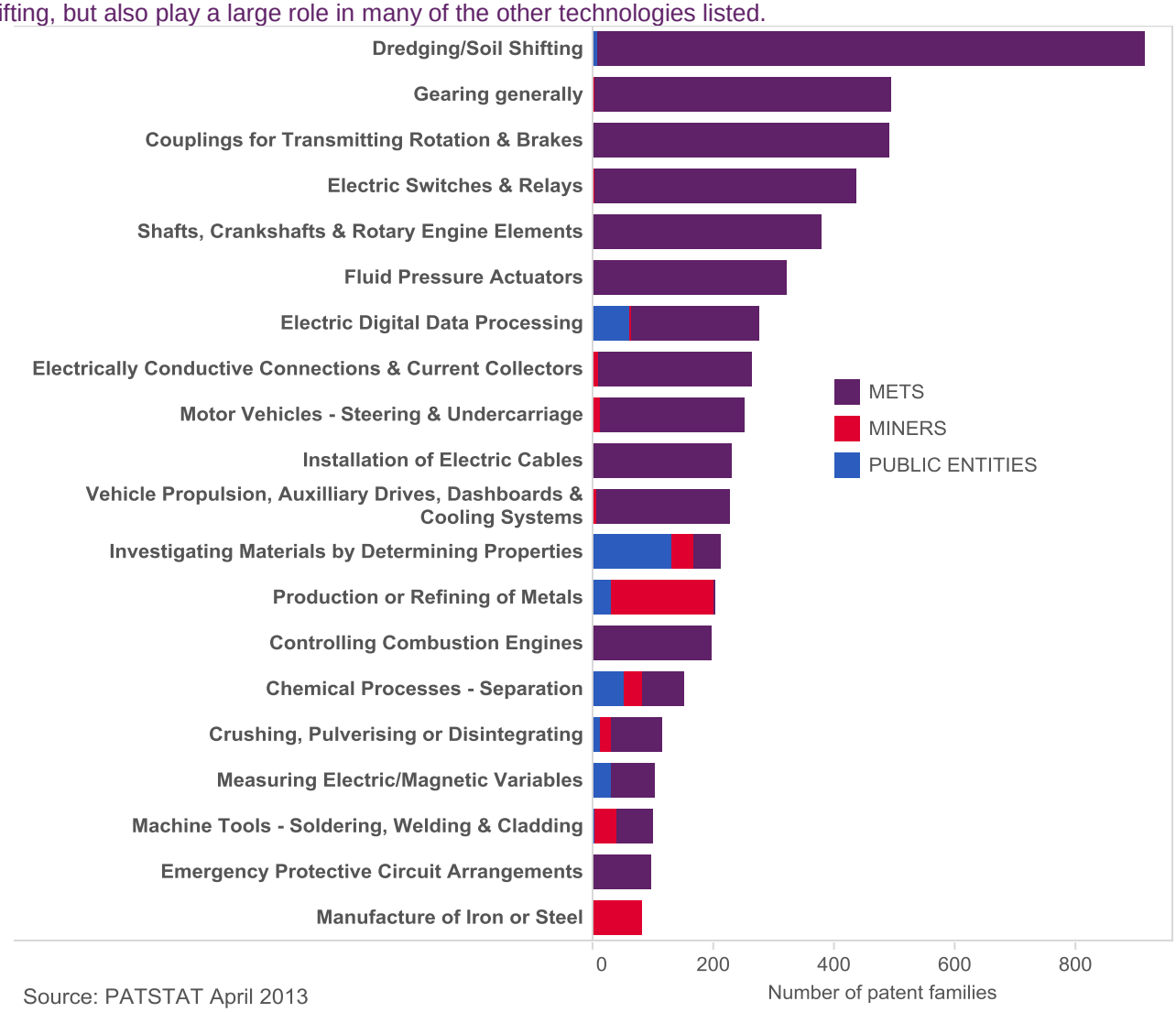
Source: PATSTAT April 2013

While our original definition of mining that does not include oil and gas refining still applies, BHP Billiton has filed patents in the technologies that you would expect for a company dealing with gas pipelines and separation of gas mixtures, as well as in the production and refining of metals. Alcoa files across the most diverse range of technologies, but Rio Tinto has the largest number of inventions. Rio Tinto has been very assertive in promoting their technology and innovation division (T&I), including the development of their Mine of the Future program (Rio Tinto 2014). Rio Tinto invested an average of US$376 million annually between 2011-2013 in T&I, although the number of employees in this group across all countries decreased from 1031 in 2012 to 730 in 2013 (Rio Tinto 2014).

3.3 Top Technology Areas by Each Entity type

The primary focus of this report is to determine who files patents and in what technology areas they are protecting their innovation. Figure 4 shows the top research areas as identified by the primary IPC subclass, further broken down into the entity types: METS, operating miners and publicly funded entities. The majority of the inventions are for dredging and soil shifting equipment including draglines and bucket cars, conveying equipment on dredgers, super structures for shifting soil, booms and teeth for buckets. Both public entities and METS firms innovate in this area.

Figure 4: Top technologies by primary IPC subclass and applicant type. METS firms file extensively in dredging/soil shifting, but also play a large role in many of the other technologies listed.



Source: PATSTAT April 2013

The remaining categories are all technologies that you would expect to see on a mining site or used in the industry: specialised vehicles and their components, crushing and drilling machines, separation and refining processes for the processing of ore into valuable commodities and electrical components such as circuits and cables. The large number of inventions in vehicle components, such as shafts, fluid pressure actuators, control of combustion engines, propulsion and steering systems and dashboard

designs, relative to the methods of processing ore, may be due to stepwise advancements in transport capacity as a means to improve efficiency. Applications within the electric digital data processing area include a parts ordering system for heavy construction vehicles and a method for controlling the power output of an engine.

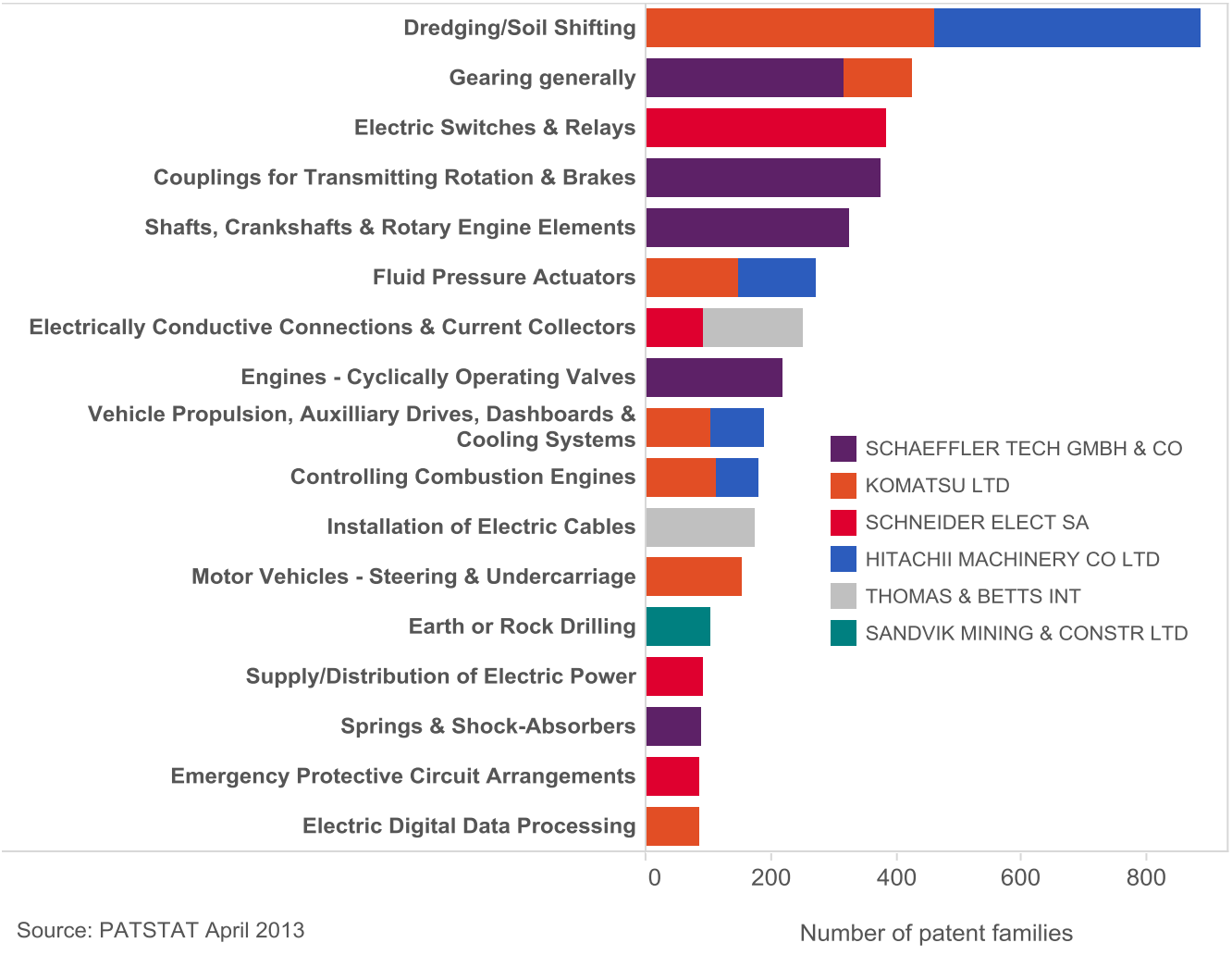
It is interesting to note the differentiation of technology innovation by each applicant type. Operating miners concentrate on the processing aspect of mining operations, leaving METS firms to produce any required equipment. This view is supported by Bartos (2007), who stated that mining companies now rely upon equipment manufacturers to perform incremental advances in new equipment technologies. The research areas of publicly funded entities are spread across the top technology areas.

3.3.1 Top Technology Areas of METS Firms

Since METS firms are the most prolific filers, we investigated their top technology areas in more detail. A summary of technology areas highlighted for the top METS firms is shown in Figure 5, which identifies the applicants for IPC subclasses listed in Figure 4.

The three main areas are dredging & soil shifting (E02F), gearing generally (F16H) and electric switches & relays (H01H). The remainder of the marks deal with other electrical elements or vehicle components. The majority of dredging & soil shifting patents are filed by two large Japanese METS firms, Komatsu and Hitachii Construction & Machinery, and include methods for casting wear-resistant parts, a diagnosis device for a self-propelled vehicle and a method of monitoring articulated equipment on side using a series of cameras providing a bird's eye view. Gearing generally includes non-specific rotary gears via endless belts or toothed wheels etc. In this technology area the two main METS filers are Komatsu and Schaeffler Technologies.

Figure 5: Top METS patent applicants by primary IPC subclass, as identified by colour legend. Schaeffler Tech and Komatsu are the most prolific filers.



Source: PATSTAT April 2013

The Schaeffler Group is a privately owned firm which produces bearing elements for various industrial uses. The electric switches & relays area is dominated by European multi-national company Schneider Electric, which specialises in power distribution and automation/control systems, and Thomas & Betts International, which produces electronic components such as power connection/control and safety technologies. Inventions within the electric switches & relays area include a vacuum cartridge used as a medium voltage switch, a fuse assembly for use in an underground power system and an electric protection device comprising at least one electromagnetic coil.

METS companies on the whole are quite specialised and develop individual components that come together to form a mining system, including electric cabling, gearing or vehicle components such as steering or rotary engines. One of the disadvantages of our approach is an inability to identify the applications that are directly mining related, particularly in the field of dredging and soil shifting equipment where smaller sized units would not be found on mining sites but would be more applicable to other industrial settings.

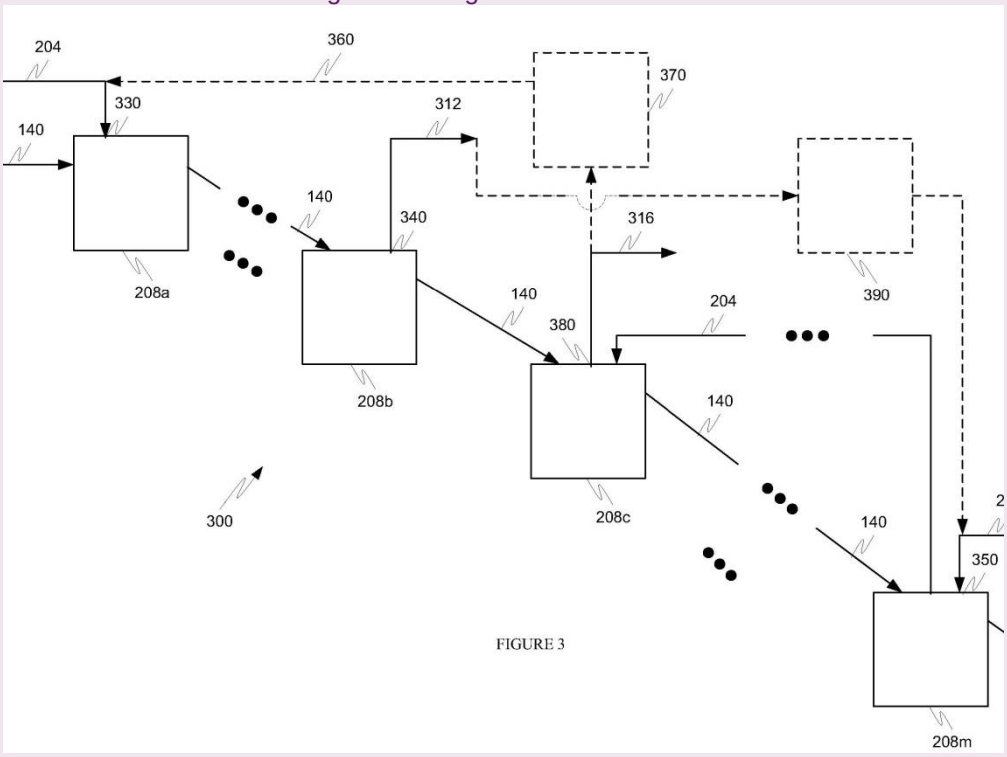
Box 2: Case Study – The Production and Refining of Gold

The production and refining of metals is by far the largest area of research conducted by the operating miners. One recent example filed by Barrick Gold Corporation (WO 2012/076981) is a new method of refining gold or silver by adapting an old process which runs a resin through a series of tanks each containing a metallic slurry with varying levels of gold/silver dissolved therein.

Typically the limiting factor during the refining process is the amount of gold that can be absorbed by the resin as it passes from tank to tank. In the new method disclosed here, fresh resin is mixed in both the first and last tanks which contain the highest amount of gold/silver present and the lowest amount of gold/silver respectively. There is slurry movement both in the main direction of flow through the tanks from highest to lowest purity levels and in a counter current from lowest to highest purities. This results in improved gold recovery from the slurry.

Figure 6 demonstrates flow through the tanks both downstream and in a counter flow upstream.

Figure 6: Resin Leech Circuit demonstrating flow through tanks



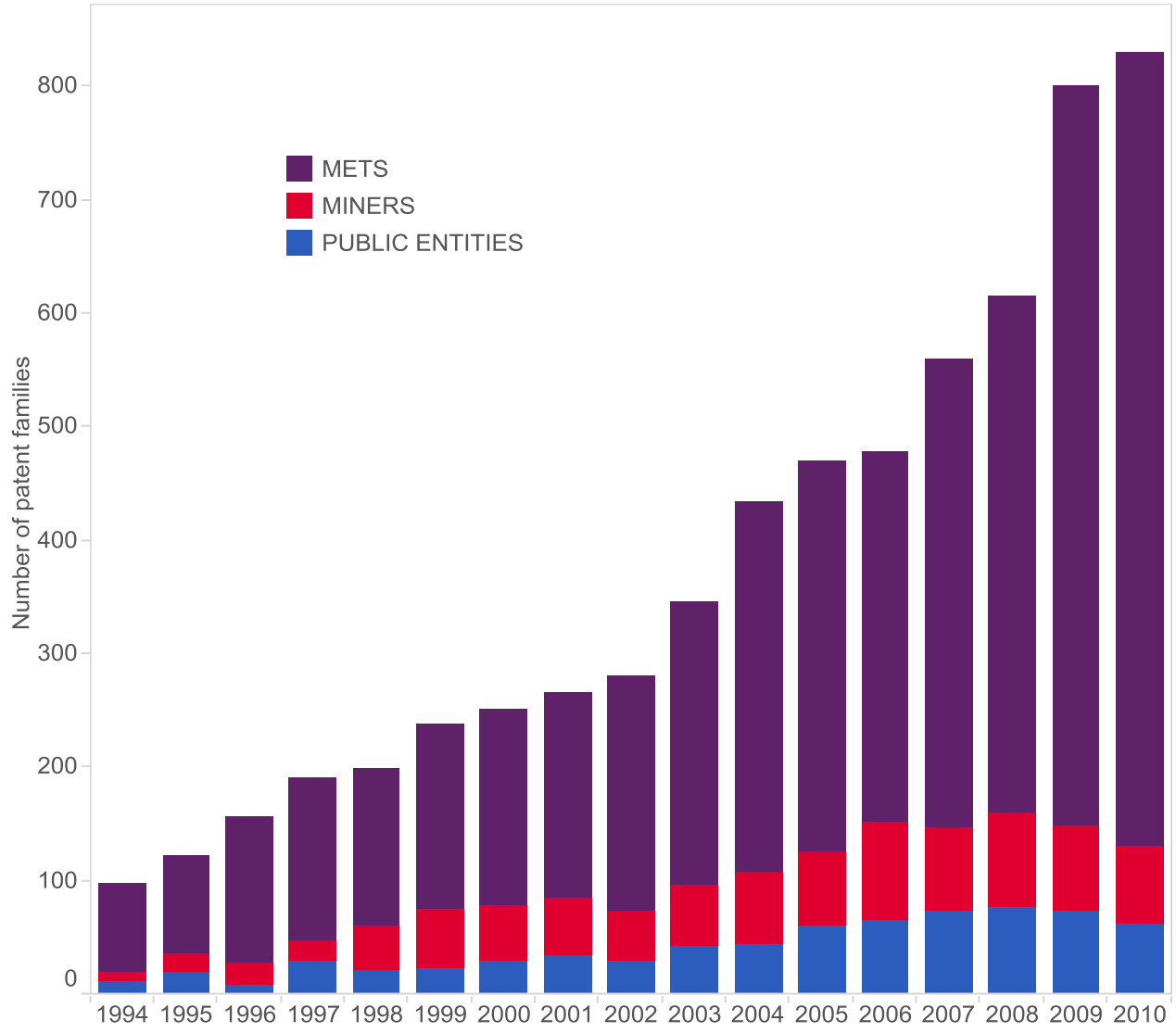
Source: WO 2012/076981 (Figure 3)

3.4 Patent Filing Trends

As indicated previously, there has been a drop in R&D spending by operating miners. Is the trend in patent filings in line with the reduction in R&D spending? The stacked bar chart in Figure 7 shows the overall filing trend for the study period broken down by entity type. It indicates that there is a steady increase in patent filing until 2010, despite the global financial crisis in 2008, from 97 families in 1994 to 830 in 2010. In contrast, there was a downturn in patent filings worldwide in 2009 with a negative growth rate of 3.6 per cent (World Intellectual Property Organization 2012). Although we may assume that there would be a drop in mining patents accompanying the global financial crisis, it appears that the mining sector was either sheltered from the effect of the crisis or responded positively to the crisis in reaction to increased pressures placed upon them to reduce cost of production. Moreover, the increase in patent families over the study period is not in line with the notion that a reduction in R&D budgets would result in less innovation and thus a reduction in patent filings.

As expected, METS firms have filed most of the patents, with a dramatic increase in filings from 2006. The number of patents filed by publicly funded entities and operating miners increased slightly over time up until 2008.

Figure 7: Number of patent families by priority year, and by entity type. There has been general increase in patents filed by all entity types until 2008. Data from 2011 is not shown in this chart.



Source: PATSTAT April 2013

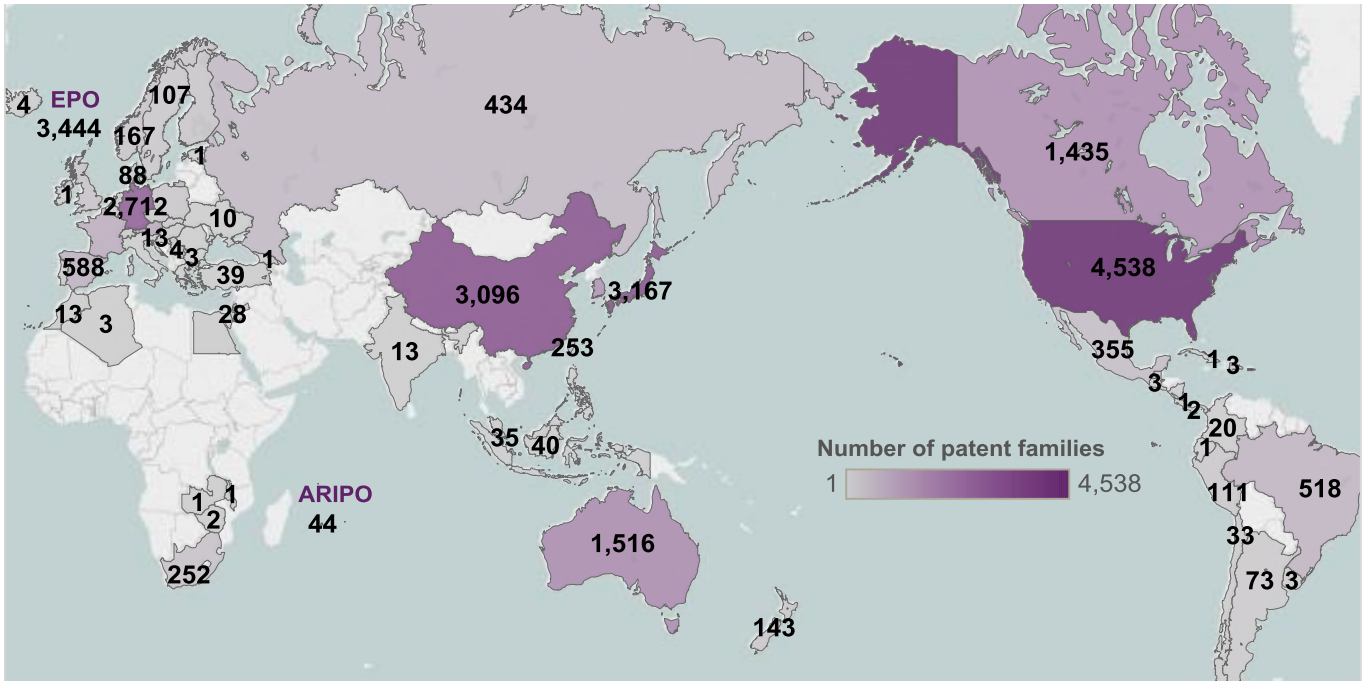
3.5 Geographic filing breadth

In order to determine the impact of Australian mining patents, we consider the location of family member filings or the countries in which the applicants filed their inventions. The number of countries in which protection is sought in is an indication of the value of the invention. It can also be used to determine which countries miners operating in Australia are concerned with gaining protection in or expect competition from. Last year's IP Report indicated that Australian inventors are more than three times more likely on average to protect their invention abroad than at home, and in particular in the United States, over the past ten years (IP Australia 2014).

A map of family member countries for the summary dataset is shown in Figure 8, with the colour providing an indication of the number of patent families prosecuted in each country. Australia is an important country to seek local protection (1,516 out of a possible 6,539 patent families were prosecuted in Australia), but the largest number of patent families prosecuted was in the United States (4,538), followed by the EPO (3,444), Japan (3,167) and China (3,096). In comparison, a total of 7,951 patent applications were filed in the United States, as part of the 4,538 patent families prosecuted there, due to divisional applications and other filing strategies. Both China and the United States have their own large mining industries and are also major patenting hubs. Japan has a large number of applications due to the two prolific METS filers, Komatsu and Hitachii Construction & Machinery, whose workforce are substantially all Japanese. While it appears more applications are filed with the EPO than in individual European countries, there is generally an additional time delay before patents are filed in the European contracting states. The European Patent Convention provides a legal framework for the granting of European patents by a single, harmonised procedure. Once a European patent is granted, it comes into existence as a group of national patents in each of the designated contracting states. The number of patents originating from China has increased dramatically during our period of analysis, so the large number of patents filed there is unsurprising (Hu et al. 2009). Developing nations such as Mexico (355) and Brazil (518) also have a sizable number of patents.

Finally it is interesting to note that Chile, which one of the world's largest suppliers of copper and whose economy relies so heavily upon its copper industry, has only 33 patents filed by miners operating in Australia. One reason for this may be that Chile does not have a strong patent system (Abud et al. 2013).

Figure 8: The number of patent families prosecuted in each jurisdiction. ARIPO is the African Regional IP Office; EPO is the European Patent Office. The most patents families have been prosecuted in the US, EPO, Japan, China, Germany and Australia.



Source: PATSTAT April 2013

Box 3: Case Study – The SmartCap

Mine operators are concerned with the health and well-being of their employees on site. Long hours and repetitive work structures mean that operators of heavy vehicles can fatigue and no longer be in full control of the vehicle. The SmartCap is a technology developed by CRCMining in order to address this concern (WO 2009/000030; smartcaptech.com). The SmartCap resembles a standard baseball style cap, but includes within the lining of the cap a series of sensors, similar to EEG sensors, which read scalp potential through the hair. The resultant signal is amplified and filtered to produce a signal indicative of driver alertness. A base unit, located within the cabin of a vehicle, contains a dock for three of these electronic units ensuring that one will always be charged and thus available during the shift. A centralised remote controller monitors these signals and provides alarms to the driver if certain fatigue criteria are met.

Figure 9 shows a model wearing the SmartCap system with the electronics unit located under the visor of the cap. All the necessary components, including battery, amplifiers, processors and Bluetooth module, are located within this card-like unit.

The international application has resulted in national phase applications in Canada, Australia, China, Europe, Japan, New Zealand, Russia and the United States of America.

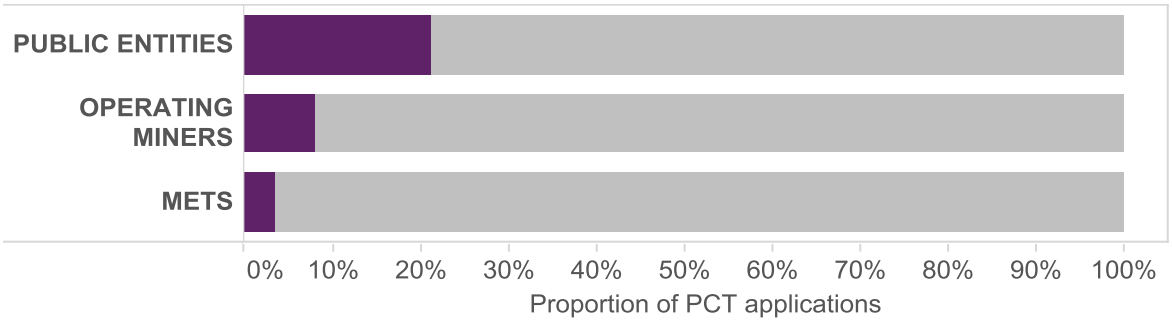
Since the publication of this patent there has been a subsequent development (WO 2014/094036) which improves the incorporation of the sensors into the sweatband of the baseball cap. This sweatband may also be incorporated into a hard hat.

Figure 9: SmartCap System as worn by model
Source: SmartCap Overview, smartcap.com/smartcap-overview/

3.6 Collaboration of Mining Firms

Figure 10 shows the degree of collaboration by different entity types, where collaboration was determined by looking at PCT applications with more than one applicant (or where applications include co-applicants) and their entity types. These results are based on the subset comprising PCT applications only so is not comprehensive but does provide an excellent indication. METS firms collaborate the least (3.6 per cent) and publicly funded collaborate the most (21 per cent). These results indicate make sense as publicly funded entities often have the skilled personnel, but not the funding or an indication of the requirements of the mining industry. This figure omits any co-applicants that did not form part of our initial search strategy and could thus not be categorised as a publicly funded entity, operating miner or METS firm.

Figure 10: Collaboration of different entity types. Purple indicates collaboration. Twenty-one per cent of public entities working in the mining sector collaborate with other entities and 43 per cent of all collaborations are with entities that were not part of our initial search strategy and in all likelihood are not primarily mining companies



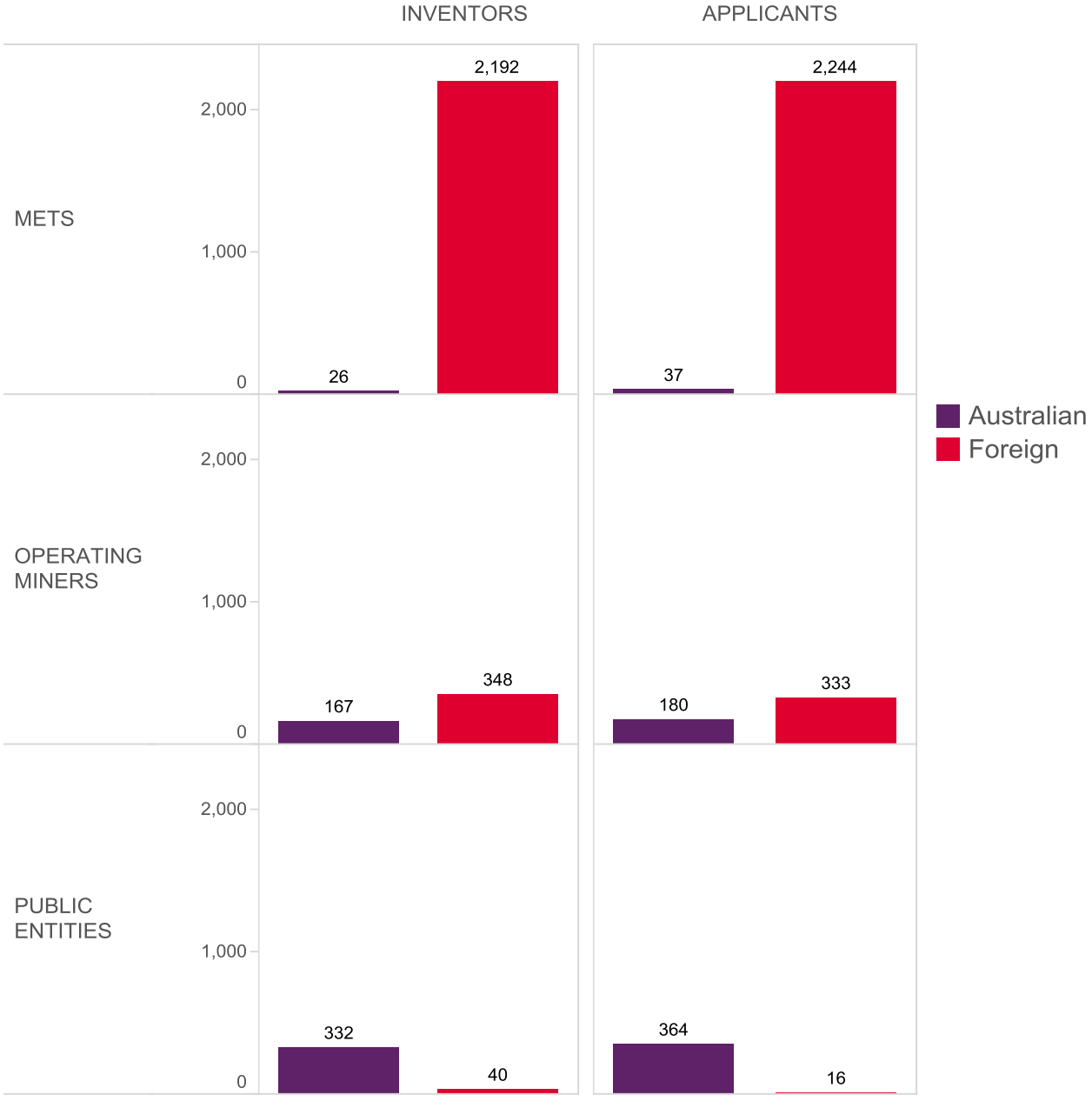
Source: OECD, REGPAT July 2014

4. The Australian Perspective

4.1 Who Owns and Invents the Shovels

In order to determine whether Australia imports or exports technologies (or shovels) used in Australian mines, it is not enough to just examine where these patents are first filed as applicants may choose to file in a country other than their own for commercial or legal purposes. Instead, the address of the inventor or applicant at the time the patent was filed is used. In this way the location of invention (based on inventors) and ownership (based on applicants) can be determined. Address data for applications other than PCT applications was incomplete, so the information shown in Figure 11 is only indicative, as it only covers inventions filed under the PCT. The results were further broken down into entity types to indicate the relative proportions and publicly funded entities were filtered to include only those IPC subclasses filed by METS or operating miners. Entities that did not form part of the original search strategy were omitted from our analysis, with the exception of foreign universities for the analysis of foreign applicants.

Figure 11: Comparison of the number of PCT applications for Australian/Foreign inventors and applicants for each entity type. Almost all METS applications were filed by inventors located overseas.



Source: OECD, REGPAT July 2014

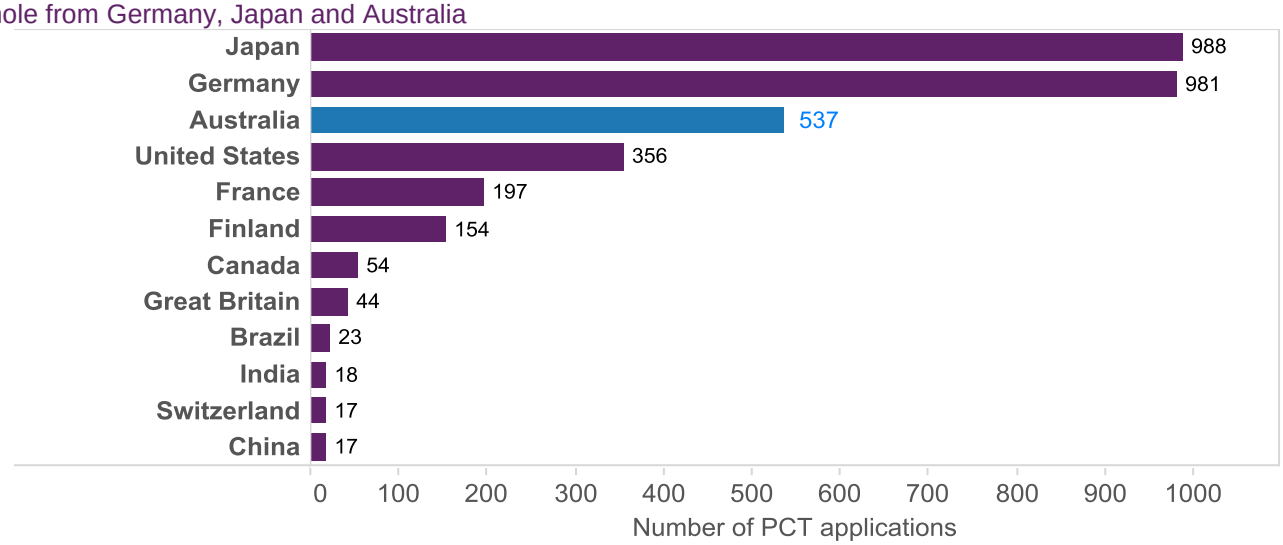
The left hand side of Figure 11 shows almost all of the patents filed by METS firms operating in Australia originate overseas. Operating miners have approximately one third of their inventors located in Australia. However, most of the publicly funded entities' inventions are attributable to local researchers. There are also a number of inventions by foreign inventors working for public entities in Australia (13 per cent) indicating that there is some degree of technology transfer occurring within the research sector. Technology sourcing from international researchers allows an industry to expand more efficiently without having to 'reinvent the wheel' each time, as some countries possess particular strengths which can be tapped into. This supports the idea that innovation is becoming increasingly international (Harhoff et al. 2014). In contrast, reports indicate that the majority of METS firms (84 per cent) are Australian owned (Austmine 2013). This apparent conflict indicates that Australian METS firms did not file PCT applications in the study period or that they import their technology.

The right hand side of Figure 11 was produced to provide a complimentary analysis of who owns the technology. Applicant location was determined by the registered location of their headquarters. There is a close correlation between both halves of this figure indicating that inventions are being produced overseas, particularly in the case of METS firms, and are owned by overseas entities. Almost two per cent of METS inventions are owned by Australian applicants compared with 35 per cent of operating miners' patents. In terms of technology transfer, four per cent of universities filing patents are located overseas, which indicates that the international researchers that are doing the work in the mining sector here in Australia are registering their patents with Australian universities on the whole.

4.2 Australian Inventions

Figure 12 identifies the inventor location of PCT applications by their registered address when filing the application. This was the most reliable way available to identify Australian-originated inventions. Thus we can use inventor location to create a set of truly Australian patents. Figure 12 indicates that inventors that have filed a PCT application are located primarily in Germany, Japan and Australia. There are 537 PCT applications with an Australian inventor out of 4,159 PCT applications in total.

Figure 12: Top inventor locations for PCT applications in our dataset. Australian Mining inventions originate on the whole from Germany, Japan and Australia



Source: OECD, REGPAT July 2014

Table 1 displays the top technologies, by primary IPC subclass, that have been protected by PCT applications with at least one Australian inventor. Publicly funded entities mostly file patents in chemical areas, such as investigating materials by determining properties, chemical processes of separation such as distillation and the new development of batteries or energy storage cells. Operating miners work in the processing of ore such as iron or steel and geophysics, which includes seismology and magnetic or optical prospecting. As Australian based METS inventors are small in number, there are not many Australian METS PCT applications, but the few that are present are located in the researching of explosives and new chemical processes for separation.

Table 1: Technology areas as indicated by primary IPC subclass, protected by Australian originated PCT applications. Australian inventors in publicly funded entities tend to work in technologies such as chemical investigation of materials or processes of separation and batteries or cells. For operating miners the largest areas of research are the manufacture of iron or steel and electromagnetic or optical prospecting (geophysics).

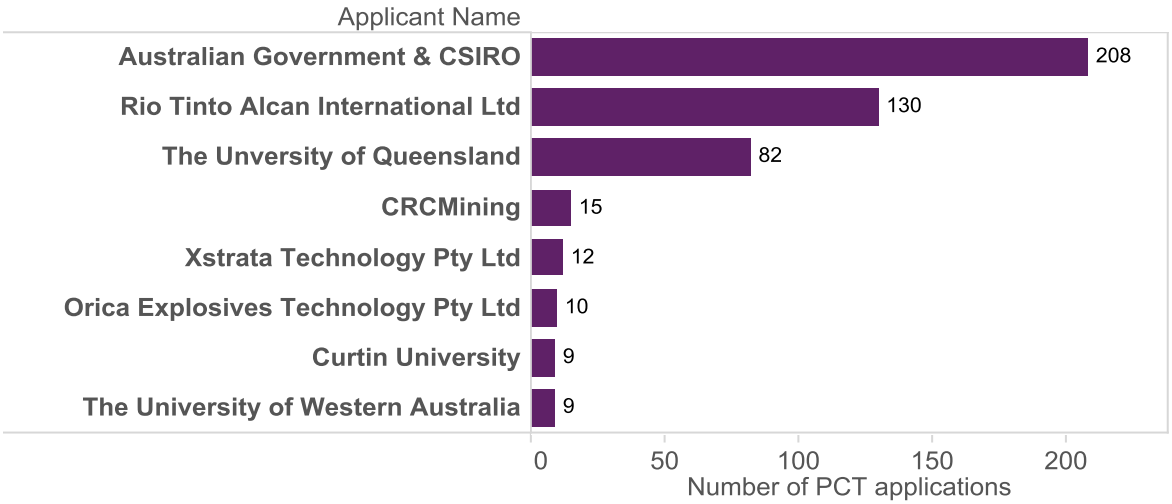
Primary IPC Subclass Description	METS	OPERATING MINERS	PUBLIC ENTITIES
Acyclic or Carbocyclic Compounds			7
Apparatus -General Chemical/Physical Processes	1		14
Batteries & Primary/Secondary Cells			24
Blasting Methods or Apparatus	5	1	1
Casting - Working Metallic Powder			5
Casting of Metals			4
Chemical Processes - Mixing			8
Chemical Processes - Separation	2	2	30
Compositions of Macromolecular Compounds			5
Crushing, Pulverising or Disintegrating	2	7	4
Earth or Rock Drilling		5	10
Electric Digital Data Processing			17
Explosive Charges for Fireworks & Ammunition	4		
General Processes of Compounding			11
Geophysics & Gravitational Measurements		26	2
Investigating Materials by Determining Properties	4	7	66
Manufacture of Iron or Steel		22	
Measuring Electric/Magnetic Variables			14
Mining or Quarrying	4	14	5
Optical Elements, Systems or Apparatus			6
Processing of Pig-Iron		17	
Production or Refining of Metals		23	14
Semiconductor Devices			12
Sorting of Individual Articles		8	1
Transmission Information Carrying Signals		1	10
Transmission of Digital Information			13
Wireless Communication Networks		1	7

Source: OECD, REGPAT July 2014

4.2.1 Top Australian applicants

Figure 13 identifies the top applicants within the subset of Australian-originated PCT applications, which have filed at least 8 PCT applications. Here the group identified as "Australian Government" are the departments and agencies that form part of either the Federal or State governments, such as the Australian Rail Track Corporation or the State Government of NSW. The CSIRO (and the Australian Government) is clearly the main filer of Australian PCT applications during the period of analysis followed by Rio Tinto and the University of Queensland. A large proportion of PCT applications originate from publicly funded entities with the University of Queensland, CRCMining & Australian Government, Curtin University and the University of Western Australia all contributing.

Figure 13: Top applicants for Australian PCT applications. CSIRO and Rio Tinto are the largest filers.

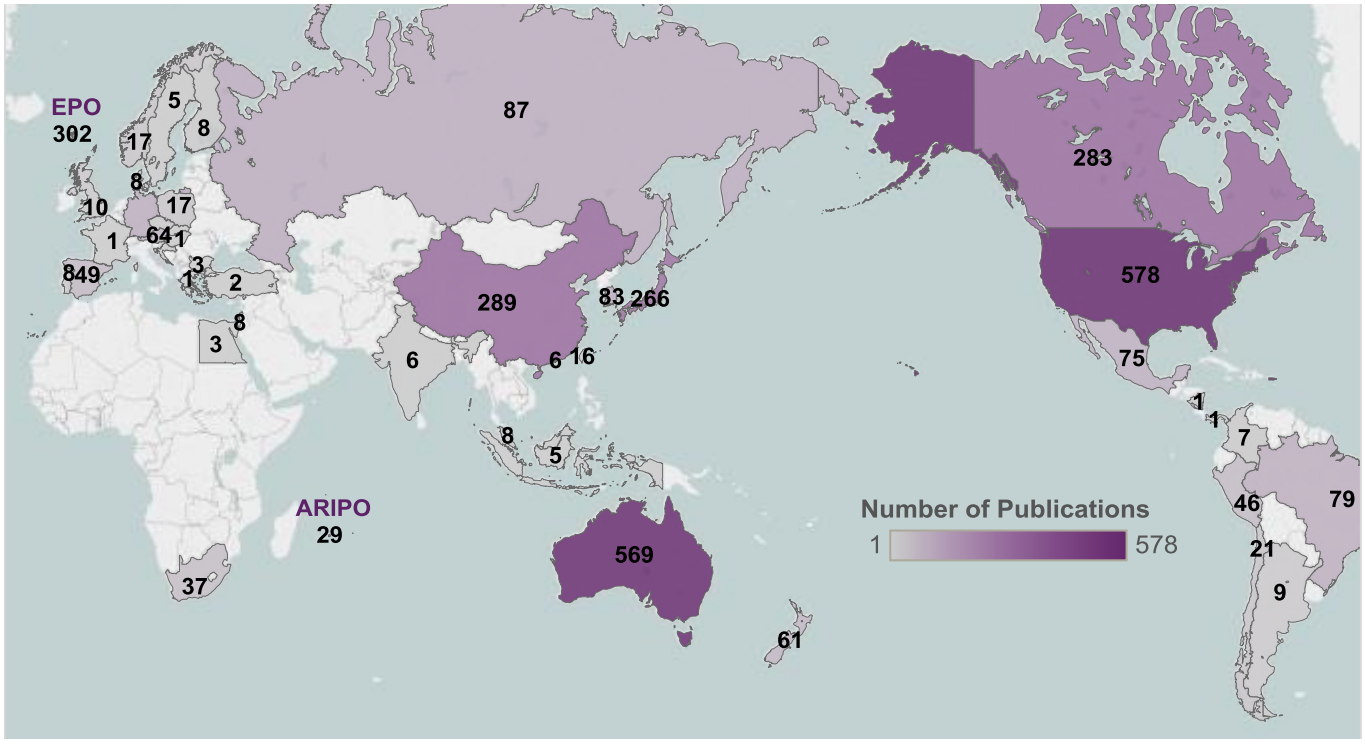


Source: OECD, REGPAT July 2014

4.3 Where Australian Mining Technology is Exported

A further investigation was performed into the Australian subset of PCT applications to determine possible export markets for Australian inventions. During the filing process for a PCT application, the applicant will elect a number of countries for prosecution. These countries are those in which the applicant seeks protection and we can use this as an indication for the markets to which they are likely to export. These countries are mapped in Figure 14 with the colour providing an indication of the number of filings in each country. The United States and Australia are the main focus of Australian applicants, but other major markets indicated here are Canada (283), China (289), Japan (266) and Europe (302). South and Central American countries such as Mexico and Brazil also have a respectable 75 and 79 respectively, even though these are not large patent offices.

Figure 14: Geographic filing breadth of Australian PCT applications. Australian and the United States are the main markets.



Source: OECD, REGPAT July 2014 & PATSTAT April 2013

4.4 Australian Firms Identified by ANZSIC Division B

While the primary applicants in our data set have been identified by various government agencies and companies as forming the Australian mining industry, Australian firms in ANZSIC division B are an interesting subset as they identified themselves as mining companies. These applicants have all filed a patent in Australia and so are identified in IPGOD. For the purposes of analysis, the location of each firm is identified using the address of their headquarters.

It is interesting to note that almost 90 per cent of the applicants identifying themselves as part of division B were not identified in our initial search strategy and were added into our analysis at a later stage. This may be due to the fact that these companies no longer operate mines in Australia or supply the industry. Otherwise these companies did not fit the definition of a METS firm as identified by the Department of Industry and Science.

Table 2: Top technology areas by primary IPC subclass and state location for firms in ANZSIC division B. The largest number of patents is filed in Production & Refining of Metals, Earth & Rock Drilling and Mining & Quarrying.

	State/Territory					
Primary IPC Subclass	**ACT**	**NSW**	**QLD**	**SA**	**VIC**	**WA**
Production or Refining of Metals		4	12		6	53
Earth or Rock Drilling		6	5	7		33
Liquefaction/Separation of Gases by Pressure or Cold						7
Compressed/Liquified Gas Vessels						6
Misc. Dyes, Paints, Polishes not provided for elsewhere						5
Natural Gas and Fuels not provided for elsewhere						5
Chemical Apparatus		4				4
Tunnels or Large Underground Chambers		3			26	3
Geophysics & Gravitational Measurements			4			3
Animal Husbandry						2
Separating Solids from Solids by Sieving or Sifting						2
Ammonia, Cyanogen and Compounds thereof						2
Micro-Organisms or Enzymes						2
Road/Railway Construction						2
Measuring Force, Stress, Torque & Power						2
Investigating Materials by Determining Properties			2			2
Blasting Methods			2			
Cracking Hydrocarbon Oils & Produc. of Liquid Hydrocarbon Mixtures		3				
Crushing or Pulverising	2		3			
Dredging or Soil Shifting		2				
Electrolytic Production, Recovery or Refining of Metals			2			
Flotation -Separation of Solid Materials			4		3	
Mechanical Metal Working - Rolling					2	
Mechanical Separation of Solid Materials			2		3	
Mining or Quarrying		7	5		3	
Mining Safety, Transport, Rescue and Ventilation		9				
Vehicles-Suspensions			2			

Source: IPGOD 2014 and PATSTAT April 2013

Table 2 indicates the primary IPC subclass of Australian patent applications filed by ANZIC division B firms, by state. Only technology areas containing at least two patent publications have been included in order to simplify the table. The Northern Territory has only a single patent and no patents were identified for Tasmania. Western Australia is the largest filer, followed by Queensland, Victoria and NSW. The firms direct most of their research into the production or refining of metals, as well as earth and rock

drilling and the generation of underground chambers. Firms from NSW concentrate on developing safety devices, such as an improved louver-type airflow regulator, and mining apparatus, such as a conveyor drive system associated with long wall mining equipment. The main area of research for mining firms in Victoria is shafts or tunnels. One example discloses a retaining method for a shaft using a series of mesh sheets secured using conventional rock bolts. One interesting technology area that has emerged from this analysis is Animal Husbandry by a WA firm in division B. There are two patents for marine partition modules for use in fish farming. These two patents were acquired by a mining exploration company in division B, but the reason is unknown.

4.4.1 Small to Medium Enterprises (SMEs)

A useful component of information provided by IPGOD is an indicator of whether the entity is small to medium enterprise (SME). An SME is defined as having less than 200 employees or not identified as part of the Bureau van Dijk database (Julius et al. 2014). In order to determine whether SMEs are more innovative, to counteract their smaller size, an analysis was performed to determine the number of patent filings for SMEs and where they are operating.

Approximately 32 per cent of the entities filing patents within this subset were found to be SMEs, with the number of SMEs compared to the remainder of applicants outlined in Table 3. More than half of the applicants from South Australia, NSW, Victoria and Western Australia are SMEs. Forty-one per cent of Queensland innovating firms are SMEs.

Table 3: Number of SME vs total number of other applicants for each state or territory. NSW, SA, VIC & WA have a high proportion of SME applicants.

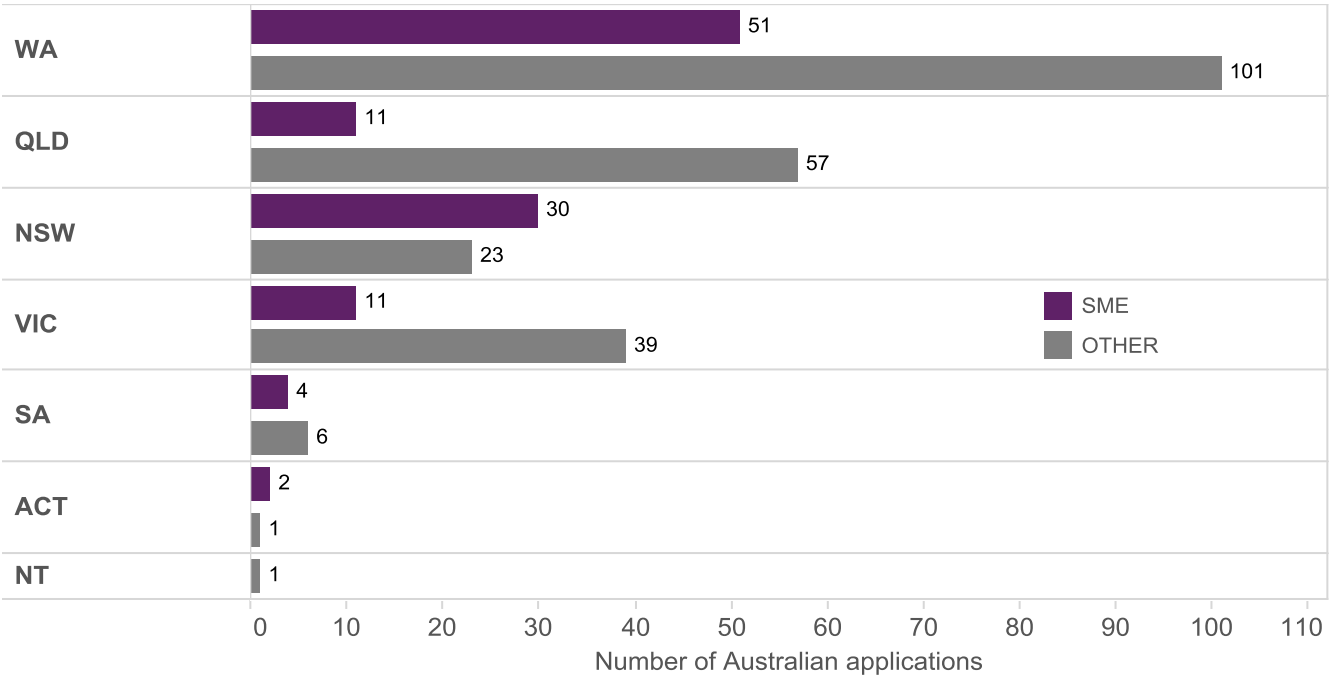
	SME	OTHER	Grand Total
ACT	1	1	2
NSW	17	12	29
QLD	9	13	22
NT		1	1
SA	3	2	5
VIC	7	5	12
WA	25	19	44

Source: IPGOD 2014 & PATSTAT April 2013

We compared of the number of patents filed by SMEs and larger firms in Figure 15. Taking into account the proportion of applicants that are SMEs, we may predict that a similar proportion of patents filed will be assigned to SMEs. For instance, in Western Australia SMEs make up 57 per cent of the total applicants. If they were just as effective at protecting their innovation as large firms, they would file approximately three fifths of the patents, but as shown in Figure 15, the SMEs file only one third of the patents in Western Australia. In the case of applicants located in QLD, which has more large firms, 41 per cent of the applicants are SMEs and they file only 16 per cent of the total applications for that state.

Thus using patents as a quantitative measure does not indicate that SMEs are more likely to innovate than large firms.

Figure 15: Relative number of patents filed by SMEs compared to other companies by state/territory. SMEs do not appear to innovate as much as large firms (or at least do not file as many patents).



Source: IPGOD 2014 & PATSTAT April 2013

4.4.2 Is ANZSIC Division B Comprehensive?

An individual or firm applying for a business registration self-identifies their ANZSIC class upon application and the primary assumption is that mining companies would register themselves in division B (mining). However, an investigation of METS firms, operating miners and publicly funded entities determined that operating miners on the whole filed in division B, while METS firms and publicly funded entities register in an array of ANZSIC divisions from A-S. Over one third of the entities outside division B are Manufacturing firms (39 per cent), 20 per cent indicated Wholesale Trade operations, 17 per cent were in Professional, Scientific and Technical Services, while only 6 per cent specified themselves as a mining firm. Only the CRCs were included in this analysis as universities are generally listed under Professional, Scientific Research and Technical Services (M).

Therefore, an analysis of ANZSIC division B shows that while most of the operating miners indicate their business is in division B, specifically as mineral ore mining and mineral exploration type firms, the inclusion of METS firms and mining related CRCs would greatly expand the ANZSIC divisions/classes that related to the mining industry, including Manufacturing (C), Wholesale Trade (F) and Professional, Scientific and Technical Services (M).

5. Case Study – Autonomous Vehicles

The adoption of autonomous vehicles is an example of the collaboration of METS firms with operating miners to produce equipment for use on site. The adoption of autonomous vehicles by mines, such as Rio Tinto's iron mines in the Pilbara, is a contentious issue not only due to safety concerns of unmanned vehicles, but also because it may lead to the redundancy of haulage truck and train drivers.

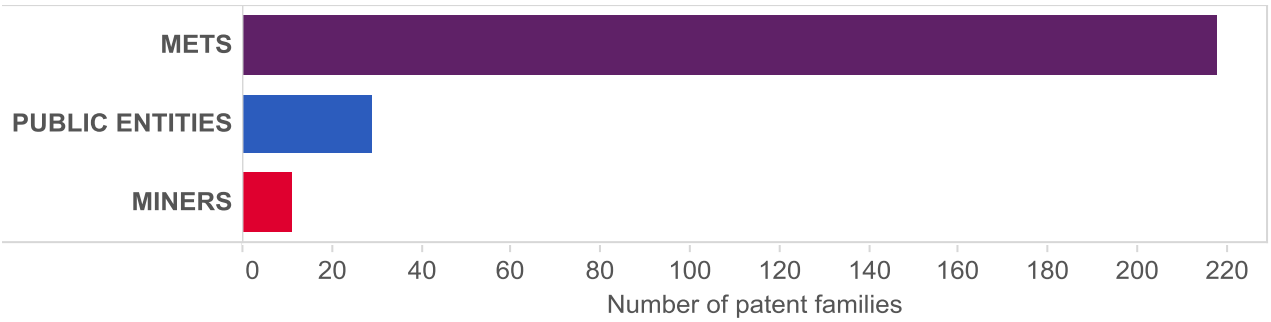
Relevant technology classifications in the IPC were searched within the summary dataset and the number of families per entity type is shown in Figure 16.

The relevant IPC subclasses are:

- B60W is a vehicle mark, which broadly encompasses dual control but also includes miscellaneous road vehicle control systems.
- B61L has to do with guidance and safety devices for railways systems.
- E21F encompasses mining safety such as preventing explosions, ventilation, drainage within tunnels and rescue apparatus.
- G01C and G01S are measuring or control marks specifically for distances, including surveying or navigating with the use of radio waves for navigation.
- Finally, G08G is a generic traffic control mark for road vehicles, aircraft and marine vehicles.

Figure 16 shows that the operating miners themselves are not very active in patents protecting autonomous vehicle components. There are only 11 patent families filed by operating miners in these classifications including a self-advancing water jet drilling system developed by BHP Billiton (CA 2239734) and a system developed by Rio Tinto to provide skilled remote assistance to staff maintaining equipment on site (WO 2010/139012). Even public entities have filed more patents in this area, with 29 patent families filed by either the CSIRO or by CRCMining.

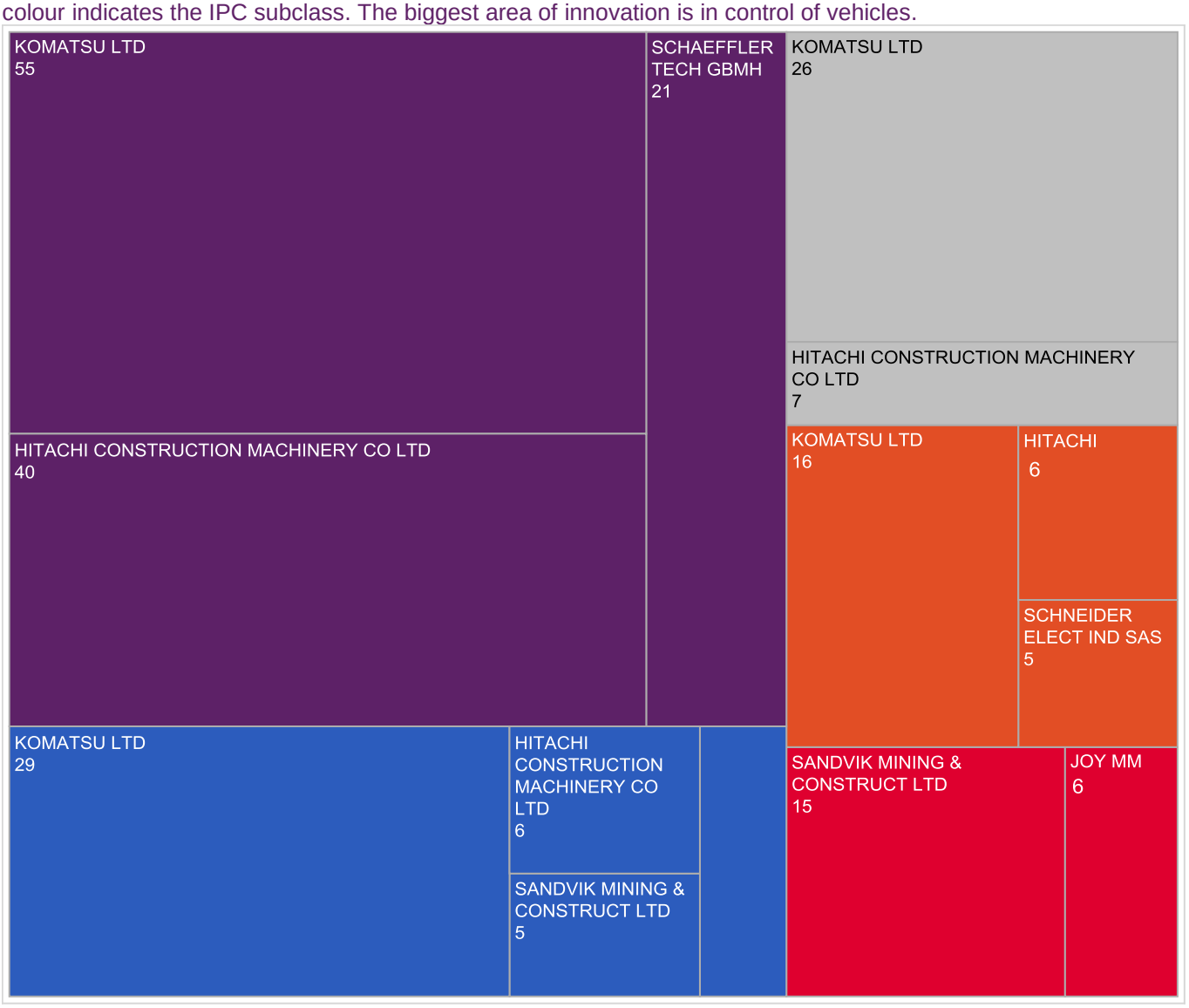
Figure 16: Number of patent families in Autonomous IPC Subclass by entity type. METS are performing the bulk of the innovation in this area.



Source: PATSTAT April 2013

The technology leaders in autonomous vehicles are METS firms, with 218 patents families. Figure 17 shows a breakdown of METS patents by IPC subclass and top applicants; Hitachii Construction & Machinery and Komatsu are the main players in the automation field. Representative filings by Komatsu in these subclasses include a sensing system which monitor vehicle performance based on sensor feedback (WO 1997/037117), a unit for controlling the speed of a construction vehicle (EP 2374680), a guidance system which aims to guide a vehicle along a pre-determined travel course (GB 2309556) and a method for detecting when a vehicle is deviating from its pre-determined path (WO 1996/037756), all of which support the development of a haulage truck control system. The majority of the filings are in the dual control mark, B60W, which includes control systems to propel the vehicle and maintain it on the correct path and estimation of driving parameters.

Figure 17: Number of patent families filed by METS firms in autonomous vehicles, by primary IPC subclass. The size of the square indicates the number of patent families or inventions (with 5 the minimum displayed) and the colour indicates the IPC subclass. The biggest area of innovation is in control of vehicles.



Source: PATSTAT April 2013

To further investigate other collaborations specifically developing autonomous vehicles in mining operations, patents with co-applicants were retrieved from the subset of our data that comprises PCT applications (see Figure 10). This was then filtered by the IPC subclasses that were indicated above identifying autonomous vehicle applications as well as drilling and mining marks E21B and E21C. There are only 4 relevant PCT applications and they are detailed in Table 4. The last two applications are shared between Rio Tinto and The University of Sydney and both define an autonomous vehicle capable of navigating between drilled holes to position sensors, to get readings on hole depth for instance (WO 2012/068629), and a method of automatically developing a mine plan based on core sample data and a calculated extrapolation which can then guide exploration (WO 2010/144953). CRCMining, as identified in one of our case studies, is a company once supported by the government through the CRC program and is now an independent entity. In collaboration with AJ Lucas Coal Technologies, which is a drilling company providing services to the coal and coal seam gas industry, CRCMining developed a coiled tubing drilling (CTD) system that allows greater control of the direction of the drilling head

(WO 2007/009189). CTD systems were developed to reduce the number of personnel required to operate the system. Finally Mitsui Matsushima, and one of their controlled entities, Matsushima Electrical Machinery Company, developed a personnel monitoring system which allows accurate location of personnel in an underground structure in the case of an emergency (WO 2008/041391).

These examples of collaborations, particularly between operating miners and public entities, show that miners are looking to researchers to fill the knowledge gap in their development of a piece of technology. In the case of the inventions identified in Table 4, the patents were either originally indicated as new and inventive by the International Searching Authority after filing or else granted at a later stage supporting the assertion that these types of partnerships are successful.

Table 4: Co-applicants in the autonomous vehicle PCT applications. Operating miners work with public entities in autonomous vehicle mining technologies

PCT Application	Applicant Name	
WO2007009189	AJ Lucas Coal Technologies Pty Limited	■
	CRCMining	■
WO2008041391	Matsushima Electrical Machinery Co., Ltd.	■
	Mitsui Matsushima Co., Ltd.	■
WO2010144953	Rio Tinto Alcan International Ltd	■
	The University of Sydney	■
WO2012068629	Rio Tinto Alcan International Ltd	■
	The University of Sydney	■

Source: OECD, REGPAT July 2014

■ OPERATING MINERS ■ PUBLIC ENTITIES

Box 4: Subsea Mining – The Future?

The discovery of rich deposits on or within the ocean floor has pushed mining in a new direction. Two firms, Canadian company Nautilus Minerals and newcomer Neptune Minerals have made serious investments in this area and Nautilus already has a license to mine off the Papua New Guinea coast. However, in order to receive any benefit from this investment and realise proper growth in this area, the industry requires the development of autonomous underwater vehicles to scavenge from the seafloor and carry up to the surface the valuable commodities contained within these deposits, often by floating.

Seafloor Massive Sulfides (SMS) are suitable deposits for subsea mining, and are targeted by both Nautilus and Neptune. SMS deposits form at hydrothermal vents where erupted fluids interact with seawater to form sulphur rich deposits including copper and zinc (Hoagland et al. 2010).

Since it was outside the scope of our summary dataset, a separate analysis of potential subsea mining firms and the two main players was performed and a summary of the resulting publications is shown in Figure 18. This search required either a combination of keyword terms, such as 'autonomous' and 'vehicle', or relevant IPC subgroups. The resulting main areas of development are offensive/defensive systems on vessels (which include the cleaning up of subsea explosive mines), with six of the ten applicants involved in this area, and the development of vessels to deploy autonomous underwater vehicles that would be suitable for operation on the seafloor to extract minerals.

However, before subsea mining becomes more prominent, concerns around the effect on the marine environment and the lack of international policy and governance in the area will need to be resolved. Currently, permission must be sought from the nearest coastal authority to perform marine research, but policy outlining prospecting and extraction has not been finalised (Hoagland et al. 2010).

Figure 18: Summary of main subsea mining technologies. Offensive/Defensive Systems are a primary focus due to the presence of defence organisations.

ATLAS ELEKTRONIK	Launching/Life Saving in Water/Searching Underwater	4
	Offensive/Defensive Arrangements on Vessels	11
	Ships/Waterborne Vessels/Equipment for Shipping	12
HONEYWELL INT INC	Measuring Distances/Levels and Navigation	5
	Offensive/Defensive Arrangements on Vessels	4
	Optical Elements, Systems or Appartus	6
IROBOT CORP	Offensive/Defensive Arrangements on Vessels	5
LOCKHEED MARTIN CORP	Offensive/Defensive Arrangements on Vessels	4
	Radio Navigation or Use of Radio Waves	7
	Weapons - Small Arms	4
NAUTILUS MINERALS PTY LTD	Launching/Life Saving in Water/Searching Underwater	4
RAYTHEON CO	Offensive/Defensive Arrangements on Vessels	4
US Government	Launching/Life Saving in Water/Searching Underwater	5
	Offensive/Defensive Arrangements on Vessels	15
	Radio Navigation or Use of Radio Waves	8
	Ships/Waterborne Vessels/Equipment for Shipping	15
	Transmission of Information Carrying Signals	6
VETCO GRAY INC	Earth or Rock Drilling	14

Source: DWPI October 2014

Number of patent publications

4 — 15

Conclusion

The bulk of patents filed in the mining sector in Australia are by the METS firms who are primarily staffed by inventors not located in Australia, with only 1.2 per cent of METS inventors being Australian. It is important to note that this figure is based on the filing of PCT applications only. We have also made the assumption that firms identified as METS are on the whole producing components for the mining industry and as such all of their applications are relevant. However it appears that foreign inventors are developing the majority of technologies, in particular the equipment, used by firms operating mines in Australia.

Looking at the big picture, METS firms filed 76 per cent of the inventions within our dataset. METS firms are mainly patenting dredging and soil shifting technologies as well as electronic switch components and gearing systems. Operating miners appear to focus more on the processing of ore rather than new 'shovels'.

Publicly funded entities play an important role in innovation in the mining sector, being relatively large filers in the area when considering the number of applications filed per applicant. The CSIRO (and the relevant Australian Government departments and agencies) is the largest filer of PCT applications within the publicly funded entities. For its relative size, CRCMining is also a prolific filer and is a proven success story, developing technologies such as the SmartCap, pulsed water jet solutions for rock cutting and shovel loading assist programs. Publicly funded entities play a substantial role in collaborations to develop new mining technologies, in particular with operating miners.

Other than the CSIRO and CRCMining, the top Australian applicants, in terms of PCT applications, were Rio Tinto, the University of Queensland and Xstrata Technology. Australian-originated PCT applications are being filed in areas of chemical processing, such as separation (including evaporation, absorption and filtration), investigation of materials by testing their properties (such as placing them under stress) and the development of new batteries or fuel cells. Most of these applications are being filed by publicly funded entities. There is also work within the geophysics and gravitational measurements technologies, which includes seismic and magnetic prospecting, by the operating miners.

IPGOD patent data indicates that SMEs operating in the Australian mining sector are less likely to innovate relative to larger firms. However, this assumes patenting activity is reflective an entities' level of innovation. If SMEs are less likely to protect their innovations through patenting than their larger competitors, this could explain their fewer patent filings and may not indicate these firms are less innovative. Literature indicates that METS firms are primarily Australian owned (84 per cent) and that two thirds are SMEs (Austmine 2013). Possible future work may find another means of investigating the innovation efforts of Australian METS companies, particularly SMEs, either via determination of whether they are exporting, export ready or identifying recipients of innovation awards.

On the whole, operating miners that file patents classify themselves in ANZSIC division B, in the class relevant for their primary ore source. On the other hand due to the nature of the industry, METS firms register in a wide variety of ANZSIC divisions, in particular Manufacturing (C), Wholesale Trade (F) and Professional, Scientific and Technical Services (M). CRCs working in the area also file in division M. As such, there could be an expanded definition of the mining ANZSIC classes to include these additional divisions.

One surprise emerging from this report is the lack of evidence of innovation in the energy production and environmental management sectors. As mining operations require a vast amount of water and energy and are typically remotely located, we would predict that METS firms would be working on developing better technologies in areas such as renewable energy production and desalination in particular, considering Australia's arid environment. However, our research in these areas may have been limited by the definition of a METS firm provided by the Department of Industry and Science. An investigation into what firms are innovating in these areas would nicely complement this report.

Appendix A: Search Strategy

Cleaned Applicant Names sourced from IPGOD 2014 and OECD HAN Database July 2014 were searched in either of EPO PATSTAT Database April 2013 or OECD REGPAT Database July 2014.

SQL statements

Validating Applicant Name

select a.han_id, clean_name, person_ctry_code, matched

from regpat.han_name a

join regpat.han_patents b on a.han_id=b.han_id

where patent_number in ('CC****'…)

Operating Miners

select DISTINCT a.appln_id, pat_publn_id, publn_auth, publn_nr, e.clean_name, d.person_ctry_code, person_name_clean, to_char(a.appln_filing_date, 'DD/MM/YYYY') as filing_date, f.prior_appln_id, lpad(ipc_class_symbol,4) as IPC_subclass, to_char(min(g.appln_filing_date), 'DD/MM/YYYY') as EPD

from patstat.tls201_appln a

join patstat.tls211_pat_publn b on b.appln_id = a.appln_id

join patstat.tls207_pers_appln c on c.appln_id = a.appln_id

join regpat.han_person d on d.apr13_person_id = c.person_id

join regpat.han_name e on e.han_id = d.han_id

join patstat.tls204_appln_prior f on f.appln_id = a.appln_id

join patstat.tls201_appln g on g.appln_id = f.prior_appln_id

join patstat.tls209_appln_ipc h on h.appln_id = a.appln_id

where e.clean_name in (*Clean names provided by RIU and ANZSIC search*)

and a.appln_filing_date > '1 jan 1994'

and h.ipc_position ='F'

group by a.appln_id, pat_publn_id, publn_auth, publn_nr, e.clean_name, d.person_ctry_code, person_name_clean, a.appln_filing_date, f.prior_appln_id, lpad(ipc_class_symbol,4)

METS firms

select DISTINCT a.appln_id, pat_publn_id, publn_auth, publn_nr, e.clean_name, d.person_ctry_code, person_name_clean, a.appln_filing_date, f.prior_appln_id, lpad(ipc_class_symbol,4) as IPC_subclass, min(g.appln_filing_date) as EPD

from patstat.tls201_appln a

join patstat.tls211_pat_publn b on b.appln_id = a.appln_id

join patstat.tls207_pers_appln c on c.appln_id = a.appln_id

join regpat.han_person d on d.apr13_person_id = c.person_id

join regpat.han_name e on e.han_id = d.han_id

join patstat.tls204_appln_prior f on f.appln_id = a.appln_id

join patstat.tls201_appln g on g.appln_id = f.prior_appln_id

join patstat.tls209_appln_ipc h on h.appln_id = a.appln_id

where e.clean_name in (*Clean names as provided by the Department of Industry and Science and ANZSIC search*)

and a.appln_filing_date > '1 jan 1994'

and h.ipc_position ='F'

group by a.appln_id, pat_publn_id, publn_auth, publn_nr, e.clean_name, person_name_clean, a.appln_filing_date, f.prior_appln_id, d.person_ctry_code,lpad(ipc_class_symbol,4)

Publicly Funded Entities

select DISTINCT a.appln_id, pat_publn_id, publn_auth, publn_nr, e.clean_name, d.person_ctry_code, person_name_clean, to_char(a.appln_filing_date, 'DD/MM/YYYY') as filing_date, f.prior_appln_id, lpad(ipc_class_symbol,4) as IPC_subclass, to_char(min(g.appln_filing_date), 'DD/MM/YYYY') as EPD

from patstat.tls201_appln a

join patstat.tls211_pat_publn b on b.appln_id = a.appln_id

join patstat.tls207_pers_appln c on c.appln_id = a.appln_id

join regpat.han_person d on d.apr13_person_id = c.person_id

join regpat.han_name e on e.han_id = d.han_id

join patstat.tls204_appln_prior f on f.appln_id = a.appln_id

join patstat.tls201_appln g on g.appln_id = f.prior_appln_id

join patstat.tls209_appln_ipc h on h.appln_id = a.appln_id

where e.clean_name in (*Clean names as provided by the Department of Industry and Science and ANZSIC search***)**

and a.appln_filing_date > '1 jan 1994'

and h.ipc_position ='F'

group by a.appln_id, pat_publn_id, publn_auth, publn_nr, e.clean_name, d.person_ctry_code, person_name_clean, a.appln_filing_date, f.prior_appln_id, lpad(ipc_class_symbol,4)

Family Members

select distinct pat_publn_id, publn_auth, publn_nr, publn_auth||publn_nr as Full_Pub_Num,

fam2.appln_id, publn_date, fam2.inpadoc_family_id, app.internat_appln_id, lpad(ipc_class_symbol,4) as

IPC_subclass, min(app.appln_filing_date) as EPD

from patstat.tls211_pat_publn pub

join patstat.tls219_inpadoc_fam fam2 on fam2.appln_id=pub.appln_id

join patstat.tls219_inpadoc_fam fam1 on fam2.inpadoc_family_id=fam1.inpadoc_family_id

join cpafre.summary_app_id me on me.appln_id=fam1.appln_id

join patstat.tls201_appln app on app.appln_id=pub.appln_id

join patstat.tls209_appln_ipc ipc on ipc.appln_id=app.appln_id

group by pat_publn_id, publn_auth, publn_nr, publn_kind, fam2.appln_id, publn_date,

fam2.inpadoc_family_id, app.internat_appln_id, lpad(ipc_class_symbol,4);

Subsea Mining

As primarily this search strategy required and analysis of keywords contained within titles and abstracts, patents within all full text patent authorities accessible through DWPI were searched, including US Granted, US Applications, European Granted, European Applications, WIPO Applications, Australian Innovation, Australian Granted, Australian Applications, British Applications, Canadian Granted, Canadian Applications, French Applications, German Utility Models, German Granted and German Application databases.

(ABD=(remote or autonomous or unmanned) AND ABD=(ocean or underwater or subsea) AND ABD=(vehicle or tether or umbilical)) AND (PRDS>=(19940101) AND PRDS<=(20140101)) OR (AIC=(B63C001100) AND ABD=(metal or metallic or mineral or processing or separate or ore or mining or mine)) AND (PRDS>=(19940101) AND PRDS<=(20140101)) OR (PA=(nautilus adj minerals or neptune adj minerals)) AND (PRDS>=(19940101) AND PRDS<=(20140101));

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