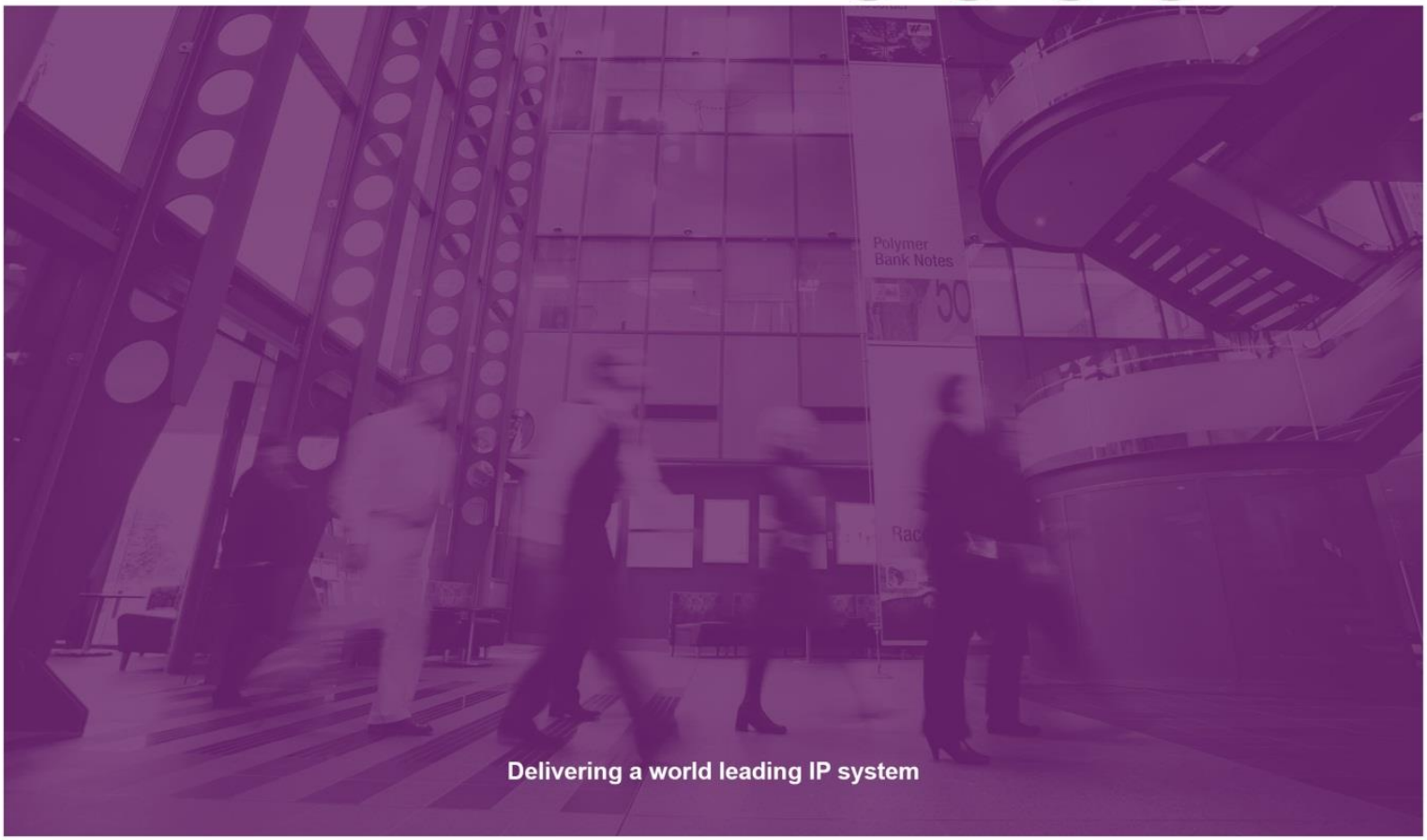
Australian Government
IP Australia

Patent Analytics Report: Agricultural Nanomaterials

January 2016



Enquiries
National Patent Analytics Hub
Email: analytics@ipaustralia.gov.au

Contents

Executive Summary

Climate, water availability and soil quality all affect the availability of food supplies. Agricultural practices, and in particular the use of additives or pest control, can increase yield. Increasingly, such practices incorporate the use of nanomaterials.

This report analyses nanomaterials in agricultural uses through the lens of intellectual property. It uses the scale and intensity of patent activity to provide an overview of innovation in this technology.

This study identified 128 innovations related to agricultural nanomaterials. These results were categorised into three broad classes according to their proposed use and then analysed to give a picture of the landscape in this area of research.

The applicants that made major contributions to this field have origins from the United States of America, China and Germany, whereas Australia, with only a single innovation, has had minimal patent involvement in the contribution to this field of study.

Given Australia's expertise in other areas of agricultural technology, this report shows that Australians are not inventing in the area of nanomaterials.

Introduction

The purpose of this report is to explore the patent landscape of agricultural technologies, specifically in the areas of soil enhancements and plant protection agents through the use of engineered nanomaterials and zeolites.

The main focus of this report will be to investigate global patent trends within these technologies and more specifically to identify who is filing patent applications and where. The information may provide insight into links between patent activity and farming needs or climatic issues.

Another aim of this report is to see if the use of nanomaterials is increasing as an emerging technology to solve the challenges of meeting the growing demand of food supply due to the constraints of climate, water availability and soil quality.[1]

Patents can be used as indicators of research output. A patent is a right that is granted for any device, substance, method or process that is new, inventive, and useful (see Appendix C for more information on the patent system). Patent rights are legally enforceable and give the owner exclusive rights to commercially exploit the invention for a limited period of time.

It is a requirement of patent law that patent documents are published and that they fully disclose inventions. As a result of the disclosure requirement, patent literature reflects developments in science and technology. Patent documents include other useful information, such as international patent classifications and information about inventors and applicants.

Through the extraction and analysis of data associated with patent documents, it is possible to measure aspects of inventive activity such as scope, intensity, collaboration and impact. These metrics can be developed across technology sectors and by various units of measurement, such as individuals (inventors), institutions (applicants), regions and countries.

Definitions

Nanomaterials is a broad term used to describe the different types of structures that have characteristic dimensions ranging in size from 1nm to 100nm.[2,3] This group of materials includes nanoparticles, and micro- and meso-porous materials whose pores are on a nanoscale. Their properties often differ from those of bulk materials.[4]

Zeolites are porous inorganic materials comprising crystalline structures. Zeolites, once restricted to being comprised of aluminosilicate materials, are now defined by the arrangement of the framework within the structure.[5] Zeolites can be natural or engineered, but their size or structures are on the nanoscale level, which gives them their unique properties.[6] Zeolites have an increased surface area that allows the delivery of fertilisers and other such enhancers to soils for more efficient distribution.

When considering agriculture, nanomaterials and zeolites can be divided into two categories, soil enhancements and plant protection agents.

---

[1] Spiertz 2013, 'Challenges for Crop Production Research in Improving Land Use, Productivity and Sustainability', *Sustainability,* no. 5, pp. 1632–44

[2] Rao et al. 2001, 'Science and technology of nanomaterials: current status and future prospects', *J. Mater. Chem.*, vol. 11, pp. 2887–94

[3] Kreyling et al. 2010, 'A complementary definition of nanomaterial', *Nano Today,* no. 5, pp. 165–8

[4] Fahlman 2011, *Materials Chemistry*, Springer Netherlands

[5] Meier 1986, 'Zeolites and zeolite-like materials', *Pure and Applied Chemistry*, vol.58, no.10, pp. 1323–8

[6] Chudasama et al. 2005, 'Pore-Size Engineering of Zeolite A for the Size/Shape Selective Molecular Separation', *Industrial & Engineering Chemistry Research*, vol. 44, no. 6, pp. 1780–6

Soil enhancements fall into one of two categories, physical soil enhancements (PSEs) or chemical soil enhancements (CSEs).[7] PSEs are materials added to improve the physical qualities of the soil, such as water absorption or to make water available to the plant, to reclaim or regenerate soil and general improvements in the soil conditions for growth.

CSEs are added to the soil to improve its chemical characteristics. This can include fertiliser delivery and release, mineralisation of the soil to provide essential nutrients, binding of undesirable components in soils such as heavy metals and gases that would be otherwise be released into the atmosphere, along with the targeting of toxins of a chemical or biological nature in soils.[8]

Plant protection agents (PPAs) are defined as materials that combat pests that directly affect the wellbeing of agricultural crops. They include herbicides, insecticides and fungicides.[9]

[7] Zeolite Australia Pty Ltd, Zeolite in Agriculture

[8] Nanowerk, Nanotechnology in Agriculture, 25 August 2014

[9] Parisi et al. 2014, 'JRC Scientific and Policy Reports', *Proceedings of a workshop on "Nanotechnology for the agricultural sector: from research to field*, European Commission, Seville, Spain

Technology Analysis

We searched the PATSTAT[10] database for patents relating to agricultural nanomaterials for the period from 2000-2013. The detailed searching strategy can be found in Appendix A.

The search results were categorised into the following groups (see Appendix B for more details of categorisation):

1. Plant protection agents (PPAs): patent families including nanomaterials which improve plant quality
2. Physical soil enhancements (PSEs): patent families including nanomaterials which improve the physical qualities of the soil
3. Chemical soil enhancements (CSEs): patent families including nanomaterials which improve the chemical qualities of the soil
4. Other: patent families that may include one relevant IPC mark but do not relate to agricultural nanomaterials.

The above groups were manually classified sorted and provide more useful analysis than the IPC. The IPC was not suitable for our analysis, as in the agricultural field it predominantly accounts for the materials used rather than for the purposes of the technology.

The patent families categorised into *Other* have not been included in the remainder of this report. The remaining 128 patent families are discussed in this report.

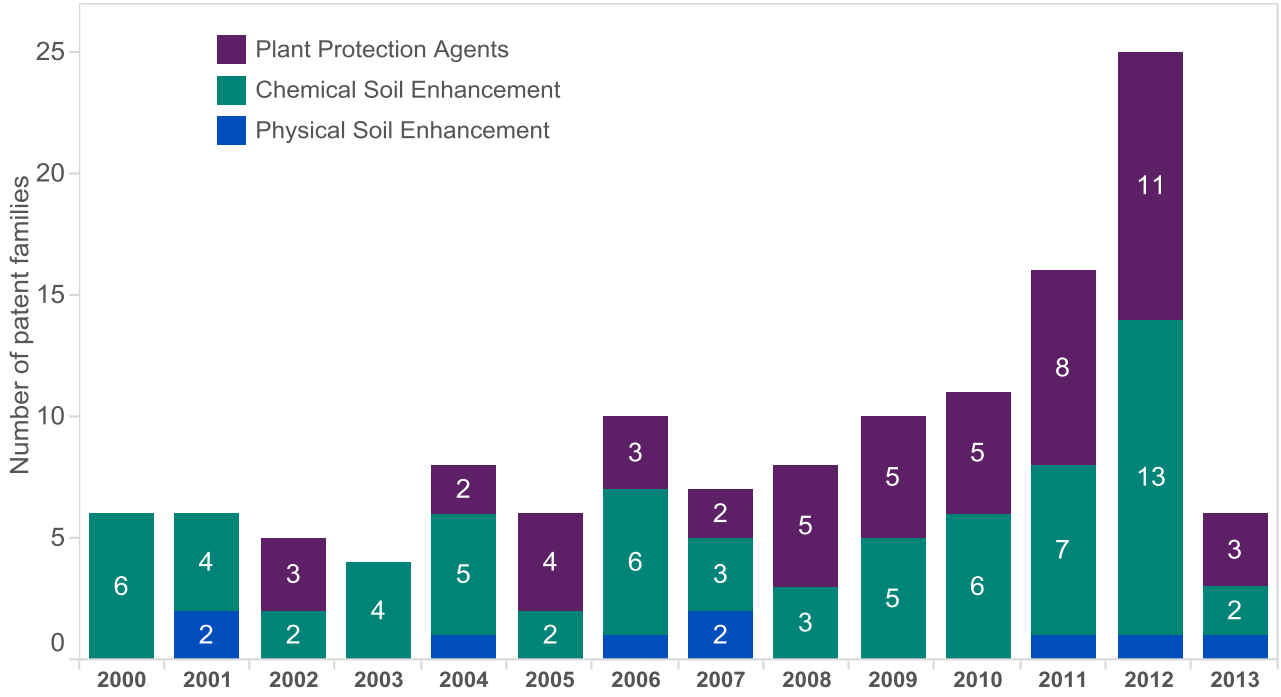
[10] The Spring 2015 edition of the PATSTAT database used to identify PCT applications in this study contains all publications to the beginning of February 2014, essentially comprising publications with a priority date up to August 2013. Some documents with later priority dates are published less than 18 months from the priority date and are in the database.

Scale of Patent Activity

Figure 1 demonstrates agricultural nanomaterial patent applications over the period 2000-2013. The patent families, shown according to earliest priority year, have been sorted into PPAs, PSEs and CSEs. The total number of patent family applications per year in the field of agricultural nanomaterials has steadily increased from six families in 2000 to 25 families in 2012. 2007-08 saw fewer agricultural nanomaterial patent applications lodged, however this in line with a general trend of fewer patent applications lodged as a result of the global financial crisis.[11]

The increase in applications is predominantly due patent families related to PPAs and CSEs. The number of PSE patent families has remained low, with PSE applications being filed in approximately half of the years from 2000-2013.

Figure 1: Patent Applications by Technology Class and earliest priority years



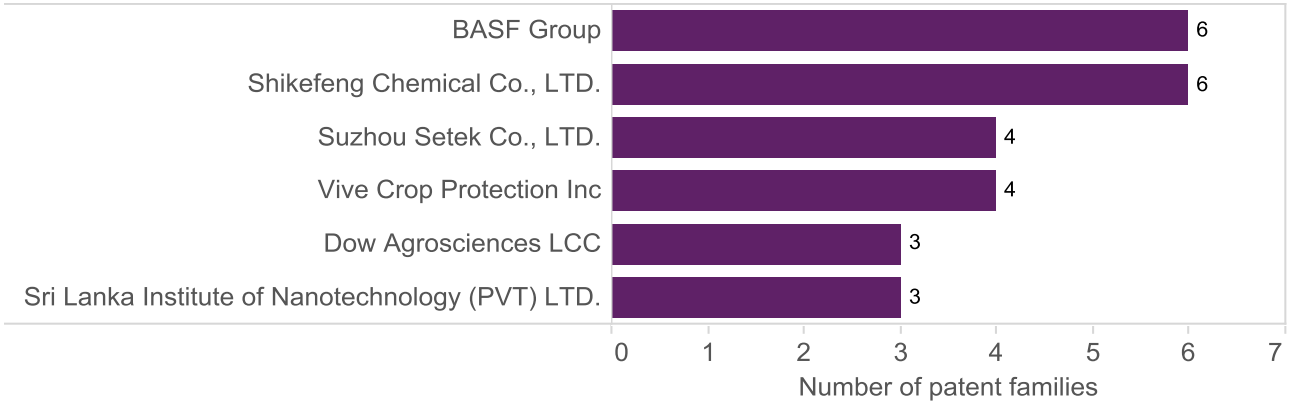
Source: PATSTAT Spring Edition 2015

Top Applicants

From the 128 patent families related to agricultural nanomaterials, 91 distinct applicants were identified. Figure 2 shows the top ranked applicants in this area. BASF Group (BASF) and Shikefeng Chemical Co., Ltd (Shikefeng) are the most active applicants, each with six patent families.

[11] IP Australia '[Report on patent backlogs, inventories and pendency]', 2014

Figure 2: Top Applicants in Agricultural Nanomaterials



Source: PATSTAT Spring Edition 2015

BASF, headquartered in Germany, is a multinational chemical company whose portfolio includes the development of crop protection products in the agricultural industry. BASF has patent families in the area of PPAs, and the most recent patent family has a priority date in 2010. The majority of the BASF patent families have priority dates from 2005-2008. In particular, WO 2006/002984 A1 relates to liquid pesticide concentrate compositions which comprise at least one organic pesticide compound that is sparingly or even insoluble in water and which upon dilution with water forms stable aqueous nanoparticulate formulations. This patent family has 21 applications.

Shikefeng, a Chinese company, has six patent families all in the area of CSEs. While Shikefeng is equal top according to patent families, we are yet to see the extent of the patent families, with each of the applications due to enter the national phase before the middle of 2016.

Suzhou Setek Co., Ltd (Suzhou), also a Chinese company, has four patent families all relating to a selenium plant nutrient. It is easily absorbed by plant roots and transferred into selenium. The result is more effective and efficient than the traditional technique of spraying. The nutrient is used to produce selenium rich rice, corn and grapes.[12]

Vive Crop Protection Inc. (Vive) applied for their first agricultural nanomaterials patent in 2008 and the remainder since 2011. Dow Agrosciences LCC (Dow) is a relative newcomer to the technology with all of their patents being applied for in 2011-12.

We did not identify any collaboration in the field of agricultural nanomaterials based on co-ownership of patents. Each of the 128 patent families has a single applicant.

Applicant Origin

Although BASF and Shikefeng are the applicants with the largest number of patent families, the United States is the country with the most applications. Figure 3 demonstrates the breakdown of country of applicant origin, along with the technical specialisation for each country. The top three countries hold almost 50 per cent of the total patent families.

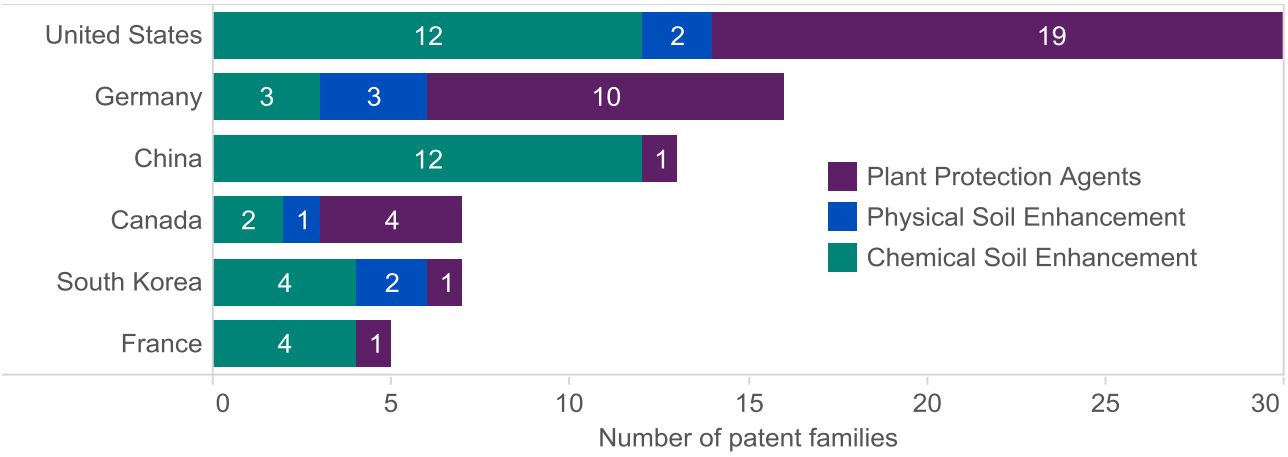
The United States and Germany show a focus in the area of PPAs. Germany's focus in this area is not surprising given BASF's technical specialisation is also PPAs.

China, ranked third overall, has the majority of its patent families in the area of CSEs. BASF (China) Company Limited is the applicant of the sole PPA family, WO 2011/138701 A1 for a pesticidal dispersion comprising nanostructured dispersed phase, originating in China.

[12] Suzhou Nanotechnology 'Nanotech Selenium-Rich Produce Leads Agricultural Revolution in SIP', 10 May 2013

Figure 3 also shows that the remainder of the world are not patenting in large numbers in the area of agricultural nanotechnology. Australia does not rank among the top applicants, despite its large agricultural export market.[13]

Figure 3: Applicant Origin



Source: PATSTAT Spring Edition 2015

Target Markets

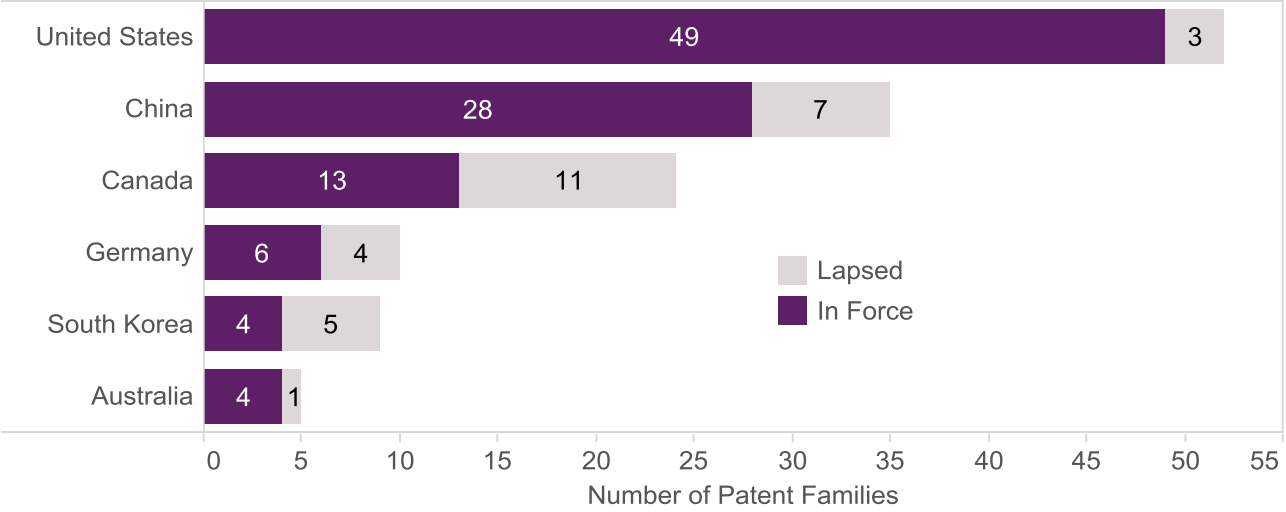
Country of patent application is a proxy for assessment of target markets for agricultural nanomaterials. Figure 4 shows patent applications in major jurisdictions which are in force at the date of conducting that patent search in the PATSTAT database. Additionally, by analysing the numbers of patents still in force in these jurisdictions, it is possible to get a picture where the applicants consider the biggest markets for the inventions.

Figure 4 indicates that applicants are primarily protecting their inventions in the United States and China, and that the majority of the patents remain in force. This is unsurprising given the number of applicants originating from these countries.

There is also substantial activity in Canada, however only approximately half of these patents remain inforce. This theme continues for the remaining countries identified in Figure 4. Australia does feature in the top ten as a target market for agricultural nanomaterial patents, however, only four patents remain in force.

[13] Australian Trade Commission 2014, '[Economic analysis]'

Figure 4: In Force and Lapsed patent applications since 2000



Source: PATSTAT Spring edition 2015

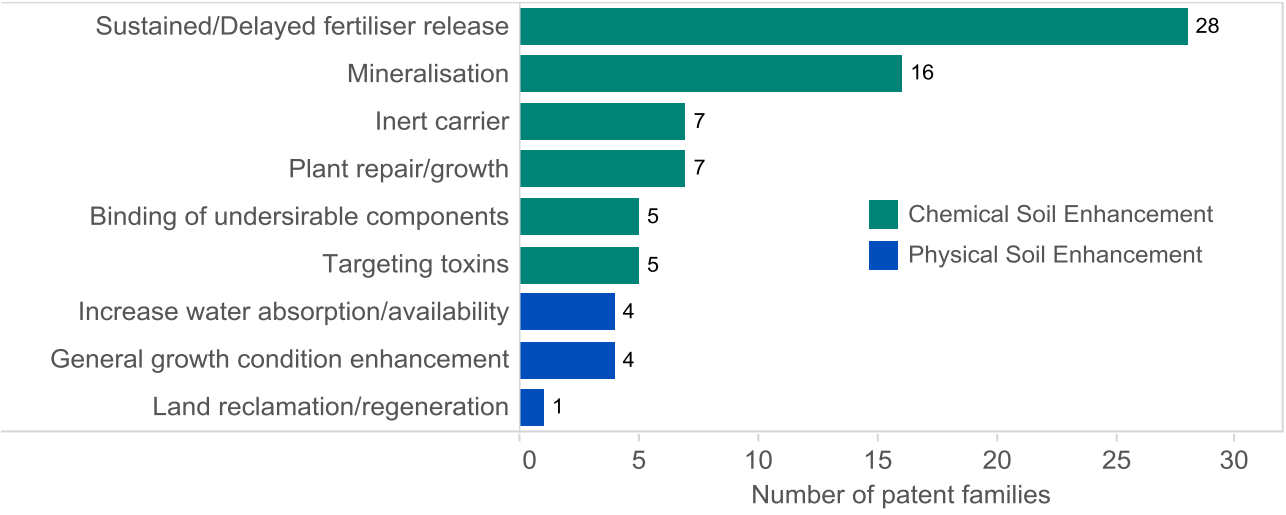
One of the patents that remain in force in Australia is AU 2009295586 B2. This patent relates to methods for producing polymer nanoparticles and formulations of active ingredients and is owned by Vive of Canada. The patent AU 2014201945 B2 is a recently examined and accepted divisional application of AU 2009295586 B2 and relates to a nanoparticle associated fungicide.

Technology Breakdown

Soil Enhancement

Chemical and physical soil enhancements can be divided into further sub-groups as shown in Figure 5. Each patent family was assigned a technology subcategory based on the intended use of the enhancement determined by reviewing the abstract and description associated with each of the patent families (see Appendix B for further information).

Figure 5: Soil Enhancement Technology Breakdown



Source: PATSTAT Spring edition 2015

Chemical Soil Enhancement

Seventy patent families relating to CSEs have been further categorised into the following:

- Sustained/Delayed fertiliser release

- Inorganic fertilisation
- Inert carriers
- Plant repair/regrowth
- Binding of undesirable components
- Targeting toxins

The most common type of CSE is the sustained or delayed fertiliser release inventions, with 40 per cent belonging to this category. These inventions use nanomaterials to provide a fertilising system that either delays fertiliser release or increases the time period that the fertiliser system is actively enhancing the soil. The most active applicant in this area is Shikefeng. The company was founded in 2001;[14] however all of the patent families were filed in 2012 or 2013. The patent families relate to fertilisers for soybeans (WO 2014/101266 A1), corn (WO 2014/101265 A1), paddy rice (WO 2014/101269 A1) and tobacco (WO 2014/101267 A1), as well as two more general fertiliser patent applications published as WO 2014/101268 A1 and WO 2014/101270 A1.

The Sri Lanka Institute of Nanotechnology (SLINTEC) file applications related to the sustained/delayed fertiliser release.[15] SLINTEC is a joint public-private partnership between the government of Sri Lanka and leading private sector companies. They have recently reached an agreement which will see it locally synthesise and formulate herbicide in Sri Lanka.[16] SLINTEC has three patent families in this area, namely WO 2014/087202 A1, WO 2011/154843 A2 and WO 2011/151724 A2, all for inventions relating to sustained release of agricultural macronutrients.

Inorganic fertilisers, inventions using nanomaterials to improve the soil quality for example by adding minerals, are the next most common type of CSE. These patent families include WO 2005/117581 A1, owned by Envirofocus of New Zealand, which relates to a plant treatment agent that comprise a zeolite core with a plurality of layers that are useful for the controlled release of fertilisers and nutrients to plants. In particular, the coatings used are diatomite nanomaterials that allow the treatment agents to slowly dissipate into the soil to ensure slow release of nutrients to the target plants which significantly reduces pollution run-off. This patent family includes 8 applications.

Inventions in the area of plant repair and regrowth use nanomaterials to directly act on plants through the soil to facilitate regrowth. One Australian originating patent family was identified, namely WO 2012/116417 A1. The patent family is a CSE in the area of plant repair/growth, specifically for foliar fertiliser. The fertiliser was invented at The University of Queensland and the first patent was applied for in 2011.

In the specialisation of binding undesirable components, nanomaterials are added to the soil act to bind components that are harmful to the soil growth media. Red Lion Chem Tech based in the United States, is the owner of patent publication number WO 2014/047363 A1 for a composite of zeolite and ferric oxide hydroxide for the removal of inorganic nitrogen and phosphorus wastes from livestock waste. Red Lion Chem Tech was founded in 2011 and uses nanotechnology for applications such as remediation, moisture and humidity control and long term prevention of moisture damage.[17]

Toxins may be targeted by the use of nanomaterials to negate harmful chemicals or microorganisms. An example of this is patent publication number WO 2013/162163 A1 owned by Thermolon Korea Co Ltd, which relates to an antimicrobial ball including silica nanotubes and zeolite to inhibit bacteria and fungi from plant roots.

---

[14] Bloomberg Business Shikefeng Chemical Industry Co Ltd

[15] Sri Lanka Institute of Nanotechnology, About Us

[16] SLINTEC SLINTEC signs agreement with CIC Holding for ground breaking research

[17] Red Lion Chem Tech About Red Lion Chem Tech

Physical Soil Enhancement

PSEs, sometimes known as soil conditioners, have fewer patent families than CSEs with only eight falling into this category. These eight families may be broken down into two subcategories:

- Increase water absorption and availability
- General growth condition improvement

The most common type of PSEs relate to water retention and absorption, or making water in the soil more readily available. For example, S&B Industrial Minerals' patent publication WO 2008/080616 A2 relates to a soil conditioning composition that contains zeolites that are used to aid water retention. Specifically the composition contains cellulose fibres, phyllosilicate and tectosilicate which are zeolites. This patent family has two members.

Nanomaterials may be added to provide a general improvement in the physical growing conditions, as demonstrated by patent publication number WO 2003/008517 A1 owned by Japanese company Columbus Corporation Co Ltd entitled 'Composition for soil containing industrial waste as primary component.' The composition is prepared by adding the sludge from a paper making process to fly ash, zeolite and/or diatomaceous earth, and an aqueous adhesive. The resulting composition exhibits a growth promoting effect for plants and an increase in their yield.

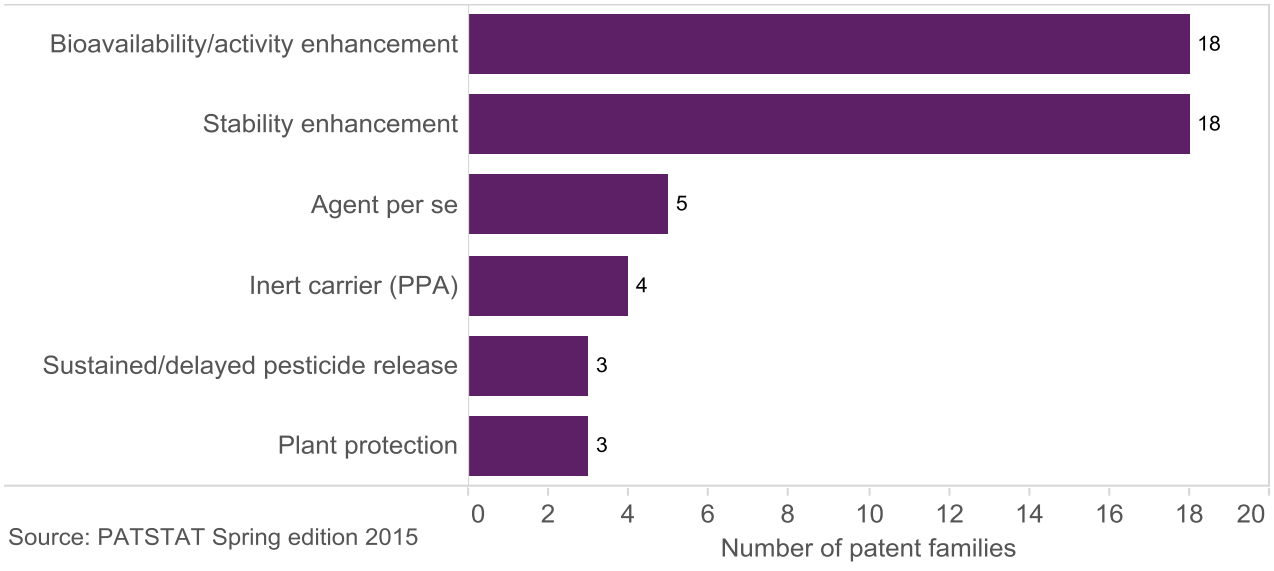
Plant Protection

The technology categories that make up PPAs include:

- Bioavailability/activity enhancement
- Stability enhancement
- Agent per se
- Inert carrier
- Sustained/delayed pesticide release
- Plant protection

One of the most common type of PPA category relates to improvements in bioavailability or activity as depicted in Figure 6. In this category, nanomaterials are used to enhance the use of active ingredients in pesticides and growth regulators. This PPA category has a total of 18 patent families. The other most common type of PPA patent families is directed to improvements in the stability of agents which also has 18 patent families.

Figure 6: Plant Protection Technology Breakdown



Source: PATSTAT Spring edition 2015

In the technology area of PPAs, inventions predominantly use nanomaterials to increase the effectiveness of plant protection agents or to increase the amount of the agent absorbed by the pest. BASF and Nanobiotekh Co (Nanobiotekh), a Russian Company, are the only applicants with multiple patent families in the area of bioavailability/activity enhancement PPAs. BASF's two patent families relate to liquid pesticide compositions (WO 2011/138701 A1 and WO 2006/002984 A1). Nanobiotekh have two patent families. One family, published as WO 2014/062078 A1, relates to compositions comprising nano-sized silver particles that increase the effectiveness of fungicides. The second family, WO 2014/062079 A1, relates to compositions comprising nano-sized silver particles that increase the effectiveness of plant growth regulators. Both patent families are for use in crops of cereals, legumes, fruits and berries. The remainder of the applicants in this area, including Dow Agrosciences (WO 2013/082016 A1) and Vive (WO 2010/035119 A1) have only one patent family.

In the area of stability enhancement, nanomaterials act to increase the stability of the plant protection agent. Vive is the most prolific applicant in this area with three patent families. Vive is a Canadian company which was founded out of the Department of Chemistry at the University of Toronto.[18] Vive's three patents relate to a nano-sized polymer-associated herbicide (WO 2013/186695 A1), a formulation including a strobilurin compound (WO 2013/093578 A1) and a formulation including pyrethroid compounds (WO 2013/041975 A2).

The University of Central Florida Research Foundation is the owner of a patent family in the area where nanomaterials are used to directly target plant pests. WO 2010/068275 A1 is directed to a silica-based formulations to treat citrus canker, inhibit the growth of mould and mildew and add nutrients to soil.

BASF also has one patent family in the area of inert carriers. Inert carriers use nanomaterial vehicles for delivering agents for plant protection. WO 2007/104750 A2 is directed to a method for projecting polymer nanoparticles which allows a herbicide to be produced in a desired concentration.

Sustained or delayed pesticide release, show in Figure 6, are inventions having nanomaterials delay the release of protection agents or increases the time period that the protection agent is active. Bionanoplus SL (Bionanoplus) and Dow each have two patent families. Bionanoplus's patent families, WO 2012/140252 A1 and WO 2013/120856 A1, are directed to polymeric encapsulation and are mainly used for drug delivery, however the encapsulation can also be used in agriculture. Bionanoplus is based in Spain. WO 2013/165793 A1 and WO 2012/097149 A1 belong to Dow and are related to pesticides. WO 2012/097149 has nine family members including AU 2012205552 B2 granted in early 2015.

[18] Vive About Vive

Conclusion

This report uses the scale and intensity of patent activity related to nanomaterials in agricultural technologies to provide an overview of innovation in the area.

Patent activity in the field has increased since the year 2000. A noticeable increase in patent families in the technology categories of CSEs and PPAs has predominantly contributed to this.

We identified 128 patent families related to agricultural nanomaterials, of which almost half were in the CSE area of sustained or delayed release of fertilisers. In the area of PPAs, the major technology focus was in improving bioavailability or activity of protection agents with 20 patent families.

The presence of multiple applicants on a patent application was used as a proxy indicator of collaboration. This report did not identify collaboration in the patent area. Even the major contributors to patent activity, including multinational chemical companies, BASF and Vive, did not exhibit any level of collaboration using the methods of this study

By identifying the origin of the applicants of patent families, the jurisdictions providing the majority of contributions to the field of study were determined. The majority of contributions arise from the United States of America, China and Germany. However, only one patent family originates from Australia. Further analysis indicates that major markets are the United States of America and China. Additionally, these countries had the highest proportion of patents still in force approximating that these jurisdictions would have the greatest value to the applicant.

Appendix A: Methodology

Data Extraction and Analysis

To identify technologies related to pollen allergens we searched the Spring 2015 edition of the Worldwide patent statistical database (PATSTAT), developed by the EPO, and covering data from over 100 countries. It includes bibliographic and abstract data for publications to the beginning of April 2015, essentially comprising publications with a priority date up to November 2013 due to the 18 month delay between priority date and publication. However some documents with later priority dates are published less than 18 months from the priority date and are in the database.

In order to determine a complete coverage of the four technology areas, the search strategy has four different aspects that are documented in the specific PLSQL scripts below in Table 1:

Table 1: PL/SQL search transcript

Search Group	Search Query
i	SELECT DISTINCT ipc.appln_id FROM patstat.tls209_appln_ipc ipc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=ipc.appln_id WHERE ipc_class_symbol like 'A01N%' AND (regexp_like(aa.appln_abstract, 'nano(*)', 'i')) AND (regexp_like(aa.appln_abstract, 'herbicid(*)', 'i') OR regexp_like(aa.appln_abstract, 'soil(*)', 'i') OR regexp_like(aa.appln_abstract, 'agricultur(*)', 'i') OR regexp_like(aa.appln_abstract, 'pesticid(*)', 'i')) UNION SELECT DISTINCT cpc.appln_id FROM patstat.tls224_appln_cpc cpc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=cpc.appln_id WHERE (cpc_class_symbol like 'A01N%') AND (regexp_like(aa.appln_abstract, 'nano(*)', 'i') AND (regexp_like(aa.appln_abstract, 'herbicid(*)', 'i') OR regexp_like(aa.appln_abstract, 'soil(*)', 'i') OR regexp_like(aa.appln_abstract, 'agricultur(*)', 'i') OR regexp_like(aa.appln_abstract, 'pesticid(*)', 'i'));
ii	SELECT DISTINCT ipc.appln_id FROM patstat.tls209_appln_ipc ipc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=ipc.appln_id WHERE (ipc_class_symbol in ('A01C 1/00','A01G 1/00', 'A01G 7/00','C09K 17/00')) AND (regexp_like(aa.appln_abstract, 'nano(*)', 'i') OR regexp_like(aa.appln_abstract, 'zeolit(*)', 'i')) UNION SELECT distinct cpc.appln_id from patstat.tls224_appln_cpc cpc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=cpc.appln_id WHERE (cpc_class_symbol in ('A01C 1/00','A01G 1/00', 'A01G 7/00','C09K 17/00')) AND (regexp_like(aa.appln_abstract, 'nano(*)', 'i') OR regexp_like(aa.appln_abstract, 'zeolit(*)', 'i'))
iii	SELECT DISTINCT ipc.appln_id FROM patstat.tls209_appln_ipc ipc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=ipc.appln_id WHERE (ipc_class_symbol like ('C05%')) or (ipc_class_symbol like ('B09C%')) AND (regexp_like(aa.appln_abstract, 'nano(*)', 'i') OR regexp_like(aa.appln_abstract, 'zeolit(*)', 'i')) UNION SELECT distinct cpc.appln_id from patstat.tls224_appln_cpc cpc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=cpc.appln_id WHERE (cpc_class_symbol like ('C05%'))

	OR (cpc_class_symbol like ('B09C%')) AND (regexp_like(aa.appln_abstract, 'nano(*)', 'i') OR regexp_like(aa.appln_abstract, 'zeolit(*)', 'i'))
iv	SELECT DISTINCT ipc.appln_id FROM patstat.tls209_appln_ipc ipc INNER JOIN patstat.tls203_appln_abstr aa on aa.appln_id=ipc.appln_id where ipc_class_symbol = 'B82Y 30/00' AND (regexp_like(aa.appln_abstract,'soil','i') OR regexp_like(aa.appln_abstract,'agricultur(al|e)','i') OR regexp_like(aa.appln_abstract, 'herbicid(*)','i') OR regexp_like(aa.appln_abstract, 'pesticid(e|al)', 'i')) UNION SELECT distinct cpc.appln_id from patstat.tls224_appln_cpc cpc INNER JOIN patstat.tls203_appln_abstr aa ON aa.appln_id=cpc.appln_id WHERE (cpc_class_symbol = 'B82Y 30/00') AND (regexp_like(aa.appln_abstract,'soil','i') OR regexp_like(aa.appln_abstract,'agricultur(al|e)','i') OR regexp_like(aa.appln_abstract, 'herbicid(*)','i') OR regexp_like(aa.appln_abstract, 'pesticid(e|al)', 'i'));

The results from each of the four strategies above were combined to produce our data set including definition for each IPC marks (Table 2) used in the search.

Notes

(i) Both the CPC and the IPC marks relating to pesticides (A01N) were harnessed and narrowed using the keyword “nano” to obtain pesticide based applications with a focus in the nanomaterials area. The results were further refined using the keywords “herbicide”, “pesticide”, “soil” or “agriculture” to remove applications relating to the preservation of bodies (IPC: A01N 1/00) and mis-indexed medical or veterinary science applications (IPC: A61).

(ii) Both the CPC and the IPC marks relating to soil conditioners (C09K17/00), fertilisers (C05) and soil reclamation (B09C) were harnessed and narrowed using the keywords “nano” or “zeolite” to obtain soil enhancing based applications with a focus in the nanomaterials area.

(iii) Both the CPC and the IPC marks relating to the treatment of soil in an agricultural sense (A01C 1/00, A01G 1/00 or A01G 7/00) were harnessed and narrowed using the keywords “nano” to obtain soil enhancing based applications with a focus in the nanomaterials area.

(iv) Both the CPC and the IPC marks relating to material based nanotechnology (B82Y 30/00) and were harnessed and narrowed using the keywords “soil” or “agriculture” to obtain nanomaterials with a focus in the agricultural area.

Table 2: Description of IPC marks

IPC Mark	Description
A01N	Preservation of bodies of humans or animal or plants thereof
C07K 17/00	Soil-conditioning materials or soil-stabilising materials
C05	Manufacture of fertilisers
B09C	Reclamation of contaminated soil
A01C 1/00	Apparatus, or methods of use thereof, for testing or treating seed, roots, or the

	like, prior to sowing or planting
A01G 1/00	Horticulture, in particular the cultivation of vegatables, flowers, rice, fruit, vines, hops or seaweed .
B82Y30/00	Nano-technology for materials or surface science, e.g. nano-composites

Appendix B: Technology classification

The search results were categorised according to the technological focus of the patent families as set out below. The technological focus was determined by reviewing the abstracts associated with each of the patent families taking into account the International Patent Classification (IPC) marks for the patent families. In cases where the abstract and IPC marks were insufficient to provide a clear description of the purpose of the invention, the body of the specification was scanned to provide further insight. It was determined by analysing the relevant information that the technological focus was provided in two broad categories being soil enhancement or the protection of plants. The patents identified in this study were accordingly sorted whether the nanomaterial facilitated an enhancement in the soil properties, or in the protection of plant species from various pests. The method that the particular inventions employed to provide the soil enhancement or plant protection was then assessed and classified sorted.

- Plant protection agents (PPAs): patent families including nanomaterials which improve plant quality, including:
    - Bioavailability/activity enhancement: Inventions which use nanomaterials that serve to increase the effectiveness of plant protection agents or to increase the amount of the agent absorbed by the pest
    - Stability enhancement: Inventions where nanomaterials act to increase the stability of the plant protection agent
    - Agent *per se*: Inventions where the nanomaterials are used directly to target plant pests
    - Inert carrier: Inventions where the nanomaterials are added as vehicles for delivering agents for plant protection
    - Sustained/delayed pesticide release: Inventions which use nanomaterials are used to delay the protection agents release or increases the time period that the protection agent is actively providing protection.
- Physical soil enhancements (PSEs): patent families including nanomaterials which improve the physical qualities of the soil, including:
    - Increase water absorption/availability: Inventions where the nanomaterials improve the physical properties of the soil by increasing its ability to absorb water or making water in the soil more readily available for use.
    - General growth condition improvement: Inventions where the nanomaterials added are said to provide a general improvement in the physical growing conditions of the soil.
    - Land reclamation/regeneration: Inventions where the nanomaterials are used to facilitate the reclamation or regeneration of land that has been lost to contamination.
- Chemical soil enhancements (CSEs): patent families including nanomaterials which improve the chemical qualities of the soil, including:
    - Sustained/Delayed fertiliser release: Inventions which use nanomaterials to provide a fertilising system that either delays fertiliser release or increases the time period that the fertiliser system is actively enhancing the soil
    - Inorganic fertilisation: Inventions where the nanomaterials that are added to the soil act to improve the soil quality for example by providing minerals to the soil
    - Inert carriers: Inventions where the nanomaterials are added as vehicles for delivering agents for soil improvement
    - Plant repair/regrowth: Inventions where the nanomaterials are added to the soil and have a direct action on plants through uptake into the plant to facilitate regrowth

    - Binding undesirable components: Inventions where the nanomaterials added to the soil act to bind components that are harmful to the soil growth media thus providing an improved soil quality
    - Targeting toxins: Inventions where the nanomaterials improve the soil quality by targeting harmful chemicals or microorganisms.
- Other: patent families that may include one relevant IPC mark but do not relate to agricultural nanomaterials.

Appendix C: The Patent System

Patents, 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 for a period of up to twenty years. In this report, an application refers to a single patent filing. The date which a patent application is filed is called the priority date. We consider that the priority date is most relevant for our analysis as it is the closest date to that when the invention occurred. A patent application is published within 18 months of its priority date. 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.

There are two major routes for patent applications: the international route and the direct filing. The international route involves filing a Patent Cooperation Treaty (PCT) application, which establishes a filing date in all 148 contracting states. Subsequent prosecution at national patent offices, referred to as national-phase entry (NPE), 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 to proceed towards grant. A direct filing is an application filed with a particular country of interest, without using the PCT system.

A patent application is considered to be in force when it has not lapsed (due to expiry or non-payment of renewal fees), been revoked or withdrawn. Data was taken from the most recent legal status action in the PATSTAT database. A family has been designated as being in force if it contains at least one in force application.

Patent families

Applications generally relating to the same invention but filed in different countries 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 commonly used in analytics as they generally represent a single invention. We determine patent families based on INPADOC classification. INPADOC patent families give a unique family ID to patents that have a least one priority document in common.[19,20] For metrics, the number of patent families is typically used. There are some exceptions where individual applications are reported on, as each application represents a legal right in an individual country. When analysing the number of applications or families per applicant, related commercial entities have been grouped under a single, harmonised applicant name.

When individual publication numbers are quoted, we have chosen a representative publication from the respective patent family. These are usually WO documents which are publications of PCT applications. These are useful as representatives and they are usually in English.

Classification

Patents are initially classified by technology into a hierarchical system known as the International Patent Classification (IPC). A further classification system referenced in this report is the Cooperative Patent Classification (CPC). The CPC began in 2013 and is a bilateral system which developed by the EPO and the USPTO which provides more in depth classifications.[21]

---

[19] Espacenet, Patent families

[20] Martinez 2010, 'Insight into Different Type of Patent Families', OECD Science, Technology and Industry Working Papers, No. 2010/2, OECD Publishing, Paris; see section 3.2, 'Extended families'.

[21] European and United States Patent Offices, Cooperative Patent Classification System