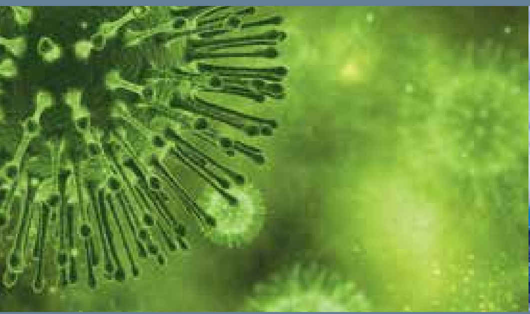
Patent Landscape Report: Microalgae-Related Technologies

in cooperation with the Moroccan Office of Industrial and Commercial Property (OMPIC) and the Moroccan Foundation for Advanced Science, Innovation and Research (MASCIR)




2016

Moroccan Office of Industrial and Commercial Property

MAScIR Moroccan Foundation for Advanced Science, Innovation and Research

WIPO WORLD INTELLECTUAL PROPERTY ORGANIZATION

A PATENT LANDSCAPE REPORT ON

MICROALGAE-RELATED TECHNOLOGIES

PREPARED FOR THE

WORLD INTELLECTUAL PROPERTY ORGANIZATION (WIPO)

BY

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IN COOPERATION WITH THE

MOROCCAN OFFICE OF INDUSTRAIL AND COMMERCIAL PROPERTY (OMPIC)

AND THE

MOROCCAN FOUNDATION FOR ADVANCED SCIENCE, INNOVATION AND RESEARCH (MASCIR)

2016

EXECUTIVE SUMMARY

The report covers in detail published patent applications and granted patents within the space of microalgae. Additionally, the report uses reference information, such as news and other business data sources to extend the information into real-world applicability, and also to verify the interest and commercial activity of entities mentioned within the study. The patent landscaping process applied to the microalgae field has uncovered several interesting facets of this industry.

GENERAL FILING TRENDS

Innovation associated with this technology has grown substantially over the last 20 years, with a stronger growth over recent years. This could be explained by the emergence of 3rd generation biofuel based on microalgae which was reflected on a number of related patent documents.

The vast majority of activity in microalgae is Asian, followed by activity from the United States and then Europe. China is the major source of patent filings associated with the technology, with a CAGR of 24% between 2009 and 2013, covering almost 50% of all patent filings over the last 20 years. In second place, with an overall CAGR at 13% over the period 2009 and 2013, the US, however, seems to express a waning interest for the field. Japan and Korea, respectively at the third and fourth place, representing respectively 10 and 9% of worldwide filings, seem to have a similar profile, but their situation is quite different. Japan demonstrates regular growth in patent filings at 8%, while Korea could become a major worldwide player, since its growth rate is the most significant CAGR, after China, between 2009 and 2013 at 23%. In Europe, France represents only 3% of the total number of filings worldwide, despite being the first European applicant in 5th position behind Korea.

To better understand IP strategies, the office of second filing, namely where patent protection was sought after the initial patent application (since patent protection is territorial) can provide insight into which country is likely to represent a good market, or be a location for manufacturing for the products generated from the technology. If Asia remains the dominant country, other areas such as Australia and Latin America are much better represented, indicating that they correspond to potential commercial markets. American and European players are extending their protection in the major areas: North America, Europe and Asia. The analysis also shows that Latin America is an area of growing interest: the number of second filings in Mexico, Argentina, Peru, Colombia and Chile has increased significantly over the last years. Nevertheless, almost 80% of patent families in the microalgae landscape have no subsequent filing outside of their priority country. That is predominantly the profile of the Japanese and in particular Chinese-based entities within the dataset. That is an indicator of their lack of intention to go out of their domestic market.

DSM appears as the leader in the field, with 131 patent families. This position has been gained through a strong acquisition strategy with the takeovers of Martek and Ocean Nutrition Canada. The vast majority of the top 20 applicants in the microalgae space are Chinese organizations. China is enjoying a dominant position mainly through academic research. However, Asian applicants are relatively recent newcomers in this field. They were almost absent from the global landscape before 2009. Asia is also characterized by a predominance of academic research, except for Japan which has an industrial fabric similar to that of Europe or the USA.

Europe and North America exhibit a higher industrial maturity in the field. Latin America is experiencing a considerable growth mainly through academic research. In this region, the microalgae sector seems to be developing driven by the Brazilian inventive activity, in particular in the animal feed and energy sector.

TECHNOLOGY AND COMMERCIAL FINDINGS

In terms of field of **applications** major findings include:

- Chinese entities focus on nutritional and medicinal applications. This is linked to their historical use of microalgal biomass;
- The United States focus majorly on biofuel applications, with large projects funded in this area. With regards to processes, Bioengineering is particularly developed in the United States;
- Japan and Korea are more focused on extraction of pigments for applications in the food industry. Korea has also a strong focus on pharmaceutical applications.

In terms of **strains**, the choice is an essential step in the value chain. It is mainly related to the targeted product and the cultivation method. Spirulina and Chlorella are the major strains, way ahead of the other strains. Both cover 36% of the patents in the field of microalgae. These strains are well known, particularly in Asia, for their nutritional properties.

Haematococcus and Dunaliella are also of great interest for the industry. From these strains, two pigments can be extracted: Astaxanthin and Beta-carotene. These two products are amongst the first extracts of microalgae that found a place on the market. Astaxanthin, extracted from Haematoccus, represented a production volume of 300 tons a year and a value of US$10M (2014) whilst Beta-carotene, 1 200 tons a year (2010) and US$285M (2012).

Regarding the **cultivation modes**, just over 5% of the patent documents mention them clearly. Based on the trophic mode used, autotrophy, the best known mode, is related to a diversified player panel: academic / industry / end users / companies specialized in microalgae. While patent applications related to Heterotrophy seem to be filed by specialized players, such as Solazyme, Roquette and DSM, Mixotrophy is developed mainly by Fermentalg and Heliae.

Up and Downstream processes - If for more than 10 years major research and development have been devoted to the optimization of cultivation modes and systems, harvesting and extraction now represent the main challenges. Harvesting and Extraction are the key enabling steps for microalgae production scale-up and cost reduction. They still represent a technical challenge in terms of development. The very recent slowdown observed in patent applications for processes, such as Conversion and Growing, may be partly due to the slowdown in the biofuel research.

Among the major industrial players present on ***growing technologies***, worthy of mention are:

- Sapphire Energy, using Raceway, a low cost growing system for biofuel production;
- Joule, working on an axenic system of the Closed Photobioreactor type, which is a hybrid system between an open pool and a plastic bag;
- Aurora Algae, focusing on an Open Pond technology, filed for bankruptcy in 2015. The choice of production site: water availability / sunshine / labor cost are essential factors in the development of this solution; and
- Heliae, developing both a closed raceway usable whatever the trophic culture mode, and a tubular Photobioreactor in partnership with Schott.

With regards to the different ***harvesting technologies***, spray drying and freeze drying are used in particular for products sold as dry biomass. Dry biomass is used in particular for food, animal feed and aquaculture applications. This technique provides the finished product directly; and flocculation is a technique mainly deployed for the treatment of wastewater / bioremediation.

Concerning ***extraction***, despite a wide range of existing techniques, few have managed to gain a foothold over the base solvent extraction techniques or techniques without organic solvent (extraction claimed without solvent and aqueous extraction or hydrolysis).

Conversion is the step of the value chain with the lowest growth and with the smallest number of patents, which seems to show that the interest in the development of these processes is low.
Conversion is a step that has so far been mainly developed by the biofuel sector, which also explains the low number of patents involved and the presence of specialist companies, such as CNOOC (China National Offshore Oil Corporation), ENI, Butamax, Chevron and BFS.

Major findings include:

- Solazyme is part of the microalgae specialists having invested heavily towards biofuels;
- Fermentation which is used in particular for the production of alcohols is the most claimed technology and experiences sustained growth; and
- Liquefaction is the 2nd fastest growing conversion technology.

Products from microalgae and their applications

Expected to be the 3rd generation biofuels solution, microalgae have quickly been developed for the biofuel industry with a marked inflection point in 2006. Lipids and pigments, which are the second metabolites of interest, also developed early on, still continue to see a steady growth in recent years.

Since 2010, new categories of products are emerging, proteins and polysaccharides, in response to new challenges in the food and animal feed markets, as well as in the cosmetics field.

Health, energy and human nutrition are the three main applications for products from microalgae. Animal feed and aquaculture have gained interest over the last five years. The "Animal Nutrition - Feed" sector is growing rapidly, especially in the area of high-protein meals due to the challenge of finding alternatives to animal meals. The objective for the Animal Nutrition sector is to improve eggs, meat and milk quality and boost animal growth. Pigments derived from microalgae, such as carotenoids, for example, are of interest for eggs as they allow natural coloring. The "Aquaculture" sector is experiencing a growth well above the microalgae landscape average growth. The objective for this application sector is to capitalize on the active ingredients produced naturally by the microalgae, by optimizing the cultivation conditions.

The “Energy” sector is experiencing a relatively slow growth compared to other segments. There is not such a high interest like in the past, mainly because of the related production costs, which are still too high, and the sometimes too complicated scale-up.

The use of microalgal biomass as a source of protein in the human diet is one of the first line of development that has been achieved, especially in Asia. With actors such as Roquette Freres, this segment has regained interest in the last four years. The development of new microalgae as food protein source has clearly become a strong driver of innovation in the microalgae industry.

Many players are positioning their product at the interface of nutrition and health by protecting treatment methods (DHA) against Alzheimer's, or using Lutein to fight against eye diseases, or protecting dermatological benefits of polysaccharides.

Protein production, regardless of the targeted application, is now one of the new drivers. The utilization of pigments for cosmetics and aquaculture is also experiencing strong growth, with 31% and 35%, respectfully. The use of polysaccharides for cosmetics is also an area of interest as shown by Solazyme with the alguronic acid which is the flagship ingredient of the Algenist cosmetics range.

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1. INTRODUCTION AND BACKGROUND TO THE PROJECT

1.1. Introduction

WIPO's Patent Landscape Reports series started as ahttp://www.wipo.int/ip-development/en/agenda/ development project "Developing Tools for Access to Patent Information" (DA_19_30_31_01). WIPO was mandated to produce Patent Landscape Reports (PLR) in areas of particular interest to developing and least developed countries, such as public health, food security, climate change, and the environment. As of 2014 the reports became a regular WIPO activity.

The present PLR aims to provide patent-based evidence on the available technologies, patenting and innovation trends in the area of microalgae-related technologies. It is prepared in collaboration with WIPO and the Moroccan Office of Industrial and Commercial Property (OMPIC, www.ompic.ma), as well as the Moroccan Foundation for Advanced Science, Innovation and Research (MAScIR, www.mascir.com).

Patent landscaping is a process whereby larger, specifically selected collections of patent documents (whether granted or otherwise) are analyzed to derive important technical, legal and business information.

While patent documents are published, and thus, are publicly available information, selecting the relevant set of data, preparing it for analysis and selecting appropriate analysis types and visualization itself requires a great deal of time and expertise. Aggregation of patent information provides technical and commercial conclusions, such as macro-economic or geographic trends in innovation or identifying changes in activity or technology commercialization strategy – whether industry wide or from a single organization perspective. It also provides an overview of the major players within a space, as well as identifying more niche corporations or research institutions with expertise and interest in the field.

The landscape report exclusively researches inventions described in patent publications, and not any other sources of technical information for inventions. Also, as the study only aims at providing an overview of patent activity in the area of microalgae, it does not focus on aspects of validity of protection or freedom-to-operate, i.e. it does not provide information on whether a patent has entered into force or is still valid.

1.2. Background on Microalgae

Microalgae, also called phytoplankton, are small living organisms from 1 to 50 micrometers, at the interface between the plant kingdom and the animal kingdom. These photosynthetic microorganisms, devoid of leaves or roots, are part of what is known as aquatic biomass. They can be found in fresh or salt water on all parts of the globe. Microalgae are the basis of many food chains and represent an incredible diversity of over 100,000 species with identification, study and taxonomic classification still ongoing today.

In a context of growth and the emergence of many economies in Asia, Africa, Latin America, access to natural resources has become a critical issue. Moreover, commodification of resources will be an increasing phenomenon by the middle of this century with an estimated global population of 9 billion. The challenge is the development of a sustainable economy in order to avoid the conversion of all the land into agricultural land, the dependence on fossil fuels or the intensive exploitation of marine resources. It is in this context that microalgae today arouse the interest of the industry and the scientific community.

Known for their richness in oils (lipids), proteins and polysaccharides, microalgae are now the subject of numerous developments aimed at exploiting their potential. Historically, they have been used for centuries, in Asia, for human food, animal feed and agriculture. From the fifties to the sixties, while in Asia their potential as a food source was particularly studied, many production facilities have hatched across the continents for the culture of Chlorella. In the seventies, interest also rose for Spirulina.

Since the eighties, many major production sites have grown in Asia, USA, Israel and Australia, and today more than 200 species of microalgae are grown industrially. If their role in the human diet is now well established, many applications are under development today: biofuel production of pharmaceutical compounds, bioremediation, cosmetic active ingredients etc…

Used in their simplest form of dried biomass in traditional medicine and in food for several decades in Asia, Spirulina and Chlorella geni are the major productions of the microalgae industry today for the food supplement market, with annual production of 2000 to 5000 tons and annual turnover US$ 40M respectively.

However, the use of microalgae for the production of high value-added molecules is still a developing market with small volumes despite their strong potential. Astaxanthin (carotenoid used as a pigment) is one of the most developed products in the field and is used as an additive or dietary supplement.

Today, the high production costs and low volumes of molecules extracted hinder the full exploitation of microalgae's potential in the high added-value molecules market. A value chain is starting to emerge, however there is still a set of multiple possible technological alternatives for each of the links in the chain: closed or open culture, extraction of the molecule of interest on dry or wet biomass, with or without solvent extraction, chemical or mechanical, etc.

There is aset of options, while the related choice to be made currently depends on the target market, the molecule produced and the biology. The biodiversity of microalgae in terms of metabolism impacts the culture conditions, as well as the harvesting process: their size, shape, mobility, floatability and physical structure (cellular membrane) directly impact the success of the harvesting process. As an example, sedimentation-based processes do not suit dinoflagellates microalgae due to their mobility in water (presence of flagel). Similarly, the context of extraction will shape the value

chain: is the biomolecule thermosensitive? Is it subject to oxidation? Can the lipid part be easily be separated from the other fatty acids?
The market application of the biomolecule will also determine the choice of processes: what cost can the target market bear? Can the quantity objectives be met?

The objective of this study is to provide an overview of the state of the microalgae research and industry today, taking the patenting activity as an indicator of innovation and development. The study consists of two major parts:
- An overview of the current trends in technology and geographical distribution of patent protection, as well as key players in the field;
- The technical and industrial trends and challenges, related to microalgae genders, processes, products and targeted applications.

2. DESCRIPTION OF THE SEARCH METHODOLOGY

This section of the report provides a detailed description of the key steps followed which led to the creation of patent datasets underpinning this patent landscape, related to the field of microalgae. The purpose of this report is to disseminate information to both experts and non-experts alike. It describes the search strategy, tools and databased used to retrieve and organize the documents and the challenges and limitations encountered and the methods used to overcome them.

2.1. Data source

The present PLR uses FAMPAT[1], a global collection of patent applications and granted patents organized by simple patent families (i.e patent applications relating to the same invention are building a group, a so-called "family", each member of which has for the basis of its "priority right" exactly the same originating application or applications) covering more than 100 patenting authorities around the world, including searchable full-text from 22 patent offices, produced by the commercial provider Questel.

Questel has developed a family definition that combines the rule of strict family from EPO, combined with additional rules to consider different definitions of patent family. All counts of records in the study refer to FAMPAT patent families or inventions, and not to individual patent documents. For example, the European application, European granted patent and the US granted patent for a single invention family is counted as "1" in all the analyses in this report unless otherwise noted. This provides a more accurate measure of the level of inventive activity from an entity within the technical space, and a truer picture of the overall level of innovation across the field as a whole.

[1] http://www.intellogist.com/wiki/Patent_Families#FamPat, WIPO Guidelines for Preparing Patent Landscape Reports, 2015, p. 26, available at http://www.wipo.int/edocs/pubdocs/en/wipo_pub_946.pdf.

As each FAMPAT record contains potentially many individual publication events all with different dates, the report uses the earliest known office of first filing date for each patent family. This is considered as the representative patent family member which is being used by the report to refer to the patent family. The Office of First Filing (OFF) or Priority, refers to the first application for a particular invention which, when filed at any patent office becomes the "priority application", with the date of this event defining the priority date. The country of the first filing is defined as the priority country.

The tables and charts included in the report use this date, unless otherwise noted, because it provides the most accurate indication of the time of the inventive activity. The definition of patent sources, i.e. the location from which patent families are emanating, is based on the Office of First Filing (OFF). It should be noted that this definition is not 100% accurate, but provides a useful and fair method of identifying the usual country of first filing of entities, which typically coincides with their home patent office.

2.2. Search strategy

2.2.1. Bibliographic study and delineation of studied area

The first and perhaps most critical step in the development of a patent landscape is the development of a clearly defined and sufficiently focused area and scope of search of the report.

This patent report focuses on technologies related to algae cultivation, harvesting and exploitation. Information gathered through bibliographic research and the authors' knowledge base around microalgae technologies was used to develop the patent search strategy (for key words relating the studied area see Annex A).

The scope of the search was as follows:

Geographical coverage: All countries and patent collections covered by the patent database used, including patent families originating from Morocco, Philippines, Japan, Brazil, China but also other countries from Asia, Latin America and Africa, as the subject of microalgae is particularly important to those regions, were included in the search.

Time period coverage: In order to provide a historical perspective, highlight how the area has evolved over time and show the recent emergence of the field in the mid-2000s, as well as provide an indication of those free-from-rights technologies, the study covers the last 20 years. **Due to the delay between the filing of patents and the publication by patent offices, usually taking place 18 months later, the last complete year of information is 2013.**

2.2.2. Search string creation and quality control

Several searches were carried out: a different approach was used for each search string, while the results of each one of them were reviewed. The creation of the search strings was performed iteratively, with the results of each generation of search strings reviewed and evaluated to inform and tailor the search to become more accurate. As each search string was created, the results were sampled and reviewed for relevancy, while keywords and classifications were amended as deemed appropriate. Further, the results of each string were data- mined for further key terms of interest, synonyms and alphanumeric technology classification codes of relevance, which were then incorporated in revised search strings. This process was repeated until revisions performed only minor variations in results. At this point, the search string was finalized with all its configuration.

The use of keywords and patent classification codes search strings for the creation of discrete technology datasets in patents and literature databases is a standard best practice for information science, informatics and bibliographic data of this type.

For more details about the search strategy used for the creation of this report, please consult Annex B.

2.3. Definition of the taxonomy to segment the patent dataset

The aim of this step is to organize and segment the dataset constituted in order to be able to conduct in-depth analysis and cross-analysis of the segments. The queries are broken down in technological sub-blocks for each segment, allowing simultaneous segmentation of all patents.

The segmentation (See Annex C) can be summarized in the following four key areas:

- **Microalgae strains**[2]: scanning of each document with a lexicon of more than 500 kinds of micro-algae, diatoms, cyanobacteria. This strategy enabled the identification of the top 20 main geni, as well as the top 20 emerging geni used in the industry. This strategy enables a true and unbiased analysis of the database.

- **Up and downstream processes**: from growing to product extraction and conversion, the different steps of the value chain were further segmented according to the technologies used into:
    - Cultivation mode : Auto-, Hetero- or Mixotrophy

[2] Strain is used as a general term to make reference to microalgae geni. The words genus, and genre may be used as well.

- Growing technologies: Open system (Open pond and raceway) or closed system (Photobioreactor, Fermentors…)
- Harvesting Technologies
- Extraction Technologies
- Conversion Technologies

- **Products obtained from microalgae**, including:
  - Lipids: Essential fatty acids (Omega-3 and Omega-6), Non-essential fatty acids (Omega-7, Omega-9, Very long Chain Fatty acids…) and Phytosterols.
  - Proteins: Peptides, Amino acids or Proteic flour.
  - Pigments: Carotenoids, Phycobiliproteins or Chlorophyll.
  - Fuels: Biofuels, Biodiesel, Bioethanol or biogases, such as Hydrogen, Methane…
  - Polysaccharides: Hyaluronic like Polysaccharides, Exo polysaccharides and strains specifics product which belongs to this category.
  - Others: Vitamins, Carboxylic acids, Chemical building blocks, etc.

- **Final applications and targeted markets**, including:
  - Human nutrition: Alimentation, Food ingredient and Nutraceuticals.
  - Animal nutrition: Animal feed and Pet food.
  - Aquaculture: Fish, Crustaceans or Molluscs farming.
  - Cosmetic and Personal care
  - Bioremediation: Water treatment, Soil depollution, etc.
  - Energy: applications linked to fuels product
  - Pharmaceuticals: patient therapies and medical food included

The indexing was performed using specific keywords complemented by relevant IPC classes in particular for applications.

3. OVERALL TRENDS AND PATENT FAMILY ANALYSIS

The collection of 11 056 patent families (including both, granted patents and patent applications) was analyzed in detail for distinct microalgae geni, processing technologies, applications and end-user products. The analysis was conducted following consultation with OMPIC and MASCIR.

3.1. Patent activity

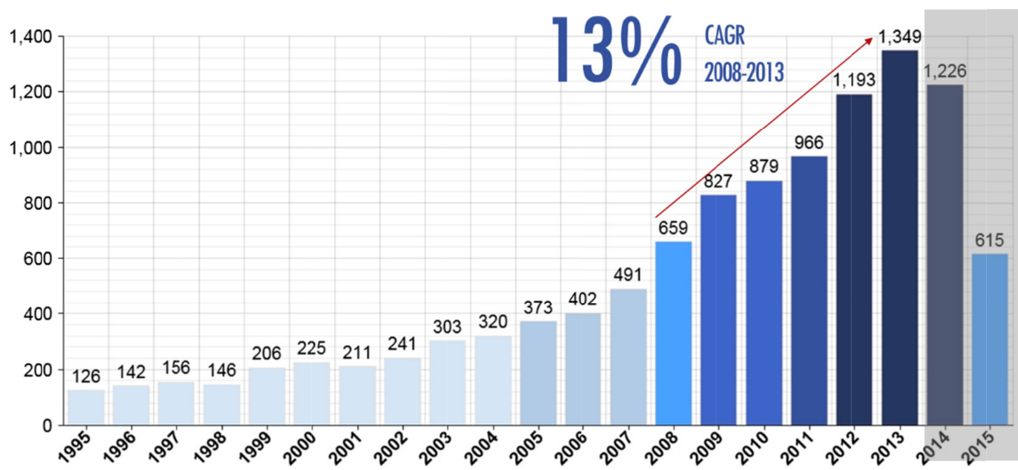


Figure 1 - Number of Patent families per Earliest Priority Year[3] (1995-2015)

Figure 1 shows the timeline of patenting activity related to the patent families included in the selected dataset. This timeline demonstrates that interest in this topic has been continuously growing, however with two distinct phases of activity: a first phase between 1995 and 2007 with a Compound Annual Growth rate (CAGR) of 11%, and a second phase between 2008 and 2013 with a CAGR of 13%. The emergence of 3rd generation biofuel based on microalgae in the second phase gave a second impetus to patenting activity in the field.

The earliest first filing year or the earliest priority year associated with each patent family is the most commonly used metric for measuring patent activity; unlike rules and procedures concerning publication, grants and confidentiality varying from jurisdiction to jurisdiction, the earliest filing/priority year is a s; Moreover, the earliest priority date is a good indicator of the date of innovation, where the applicant has decided to apply to acquire patent rights on his invention.

Using the earliest filing dates rather than publication dates means that for the last period, usually 18-months earlier counting from the time the patent search is carried out, there is no data, as patent documents are typically held confidential at patent offices for 18 months after initial filing until their

[3] Due to the delay between the filing of patents and the publication by patent offices, usually 18 months, the last complete year of information used in the current report is 2013.

publication. As the data collection for the microalgae report took place end of 2015, 2013 was the last year of complete patent information.

The figures 2 and 3 below provide an overview of the subject matter covered by the microalgae patent landscape in the form of a thematic concept map. The microalgae patent collection may be divided into a) **microalgae strains** (Botryococcus, chlamydomonas, Spirulina…), wild or genetically modified (nucleic acid sequence, Biosynthetic pathway, engineered microorganisms…), b) **microalgae cultivation** (Raceway, Photobioreactor, Heterotrophy…) to **conversion** (extraction...)**processes**, and c) **products and applications** (Cosmetic, biodiesels, Food Feed & Nutrition, Pharmaceutical composition, Fatty acids…) according to the concept map. These categories correspond to the first level of the taxonomy used for the patent dataset segmentation which will be further mined in Chapter 4.

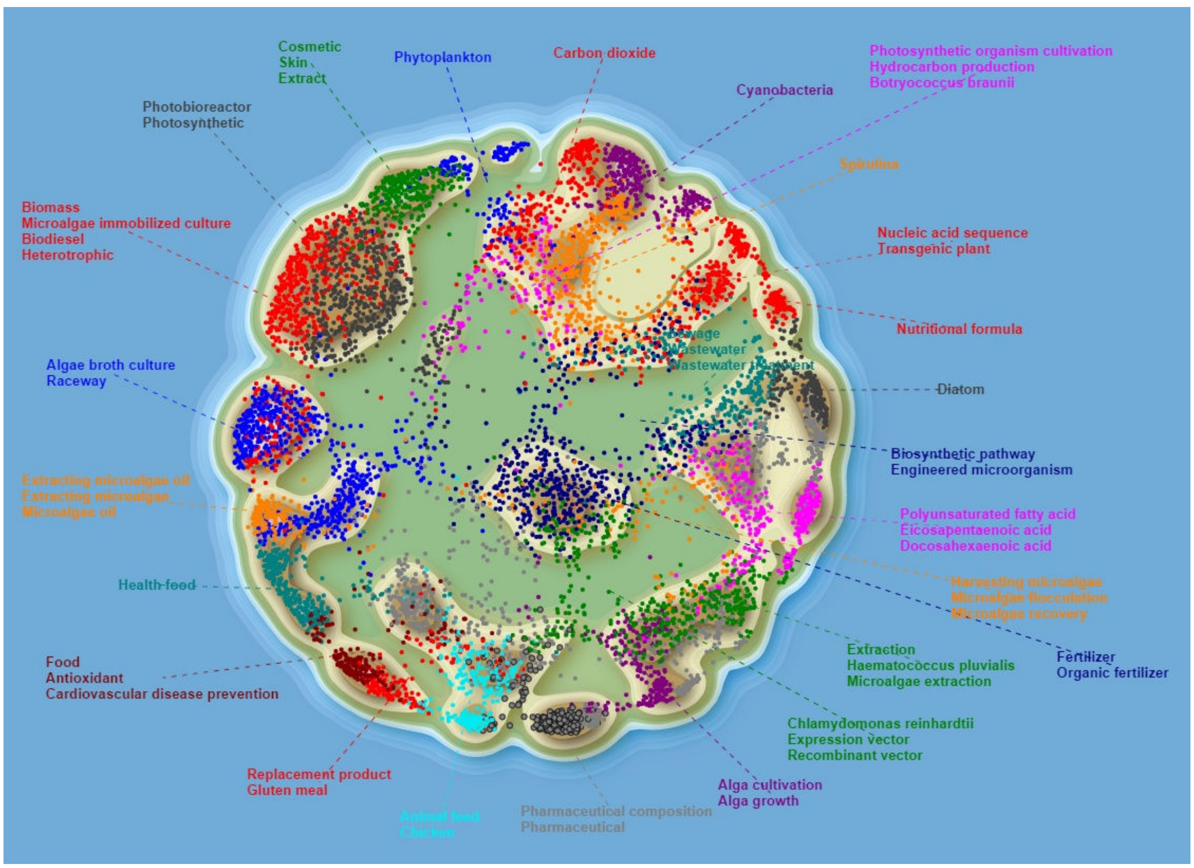


Figure 2 – Map of concepts[4]

[4] This chart shows the patent families, sorted into clusters, depending mainly on the concepts. The IPC codes may also be used to build the map.
The concepts are taken from the full official text in English of the EP applications (without euro-PCT) from 1988 onwards, the PCT applications from middle of 2001, the issued US patents from 1971 to 2000 and the US applications from 15 March 2001, and the UK applications from 1979 onwards, FR applications, CN utility models and CN applications. It is possible to find even older documents, back to 1980 for EP and 2000 for WO. Before everything else, nominal phrases are identified inside the whole of the text, then they are brought to standard according to syntax and semantic rules. Finally, every concept is weighted according to the field in which it has been identified, and the places where it occurs. The concepts are a result of the semantic content of the patent.

Figure 3 - Circular Treemap[5]

The map is built in four stages.

•A vector model is made, mainly with extraction and weighting of concepts.

•Clustering

•Dimension reduction

•Drawing: The main or front page drawing will be displayed with the identified clusters.

In a cluster, you will find families that share concepts and that will have links of proximity and similarity between them.

On the map, each cluster is identified by a different color. Every cluster is represented by several points. Every point stands for a family of patents. If you move the cursor on a point, the title of the family will be shown next to it. Three concepts are shown for every cluster. A family is shown only once on the map: In other words, that family will never be shown in two different clusters.

Every point is so positioned that it respects as best as possible the rules of proportionality and distance.

This map is to be viewed like a topographic map: Different colors mean different levels. Outlines in brown indicate a higher density of families.

[5] The main concepts are shown in a circular tree map format. They are organized in clusters and can be visualized as shades of colors of varying intensity.

An algorithm determines the shortest distance between the concepts and arranges them into clusters. The concepts in a given cluster share the same class codes.

3.2. Geographic analysis

3.2.1. Offices of first filing (OFF)

This analysis looks at the priority filing country, where patent protection was first sought for a given invention. The patent office and country where an application was first filed is referred to as Office of First Filing (OFF).

In many cases, in particular early stages in research and development programs, applicants may be unsure of the potential economic returns that the technology could provide, and therefore they must strike a balance between the costs of filing in many different territories versus their estimate of the potential returns the technology could provide. In practice, most applicants choose to protect their invention in their country of residence first and then, if required, extend later – a process for which they generally have a year to decide upon if they wish to benefit of the provisions of the Paris Convention, or typically 30 months if they file a PCT application.

The practice of filing locally at first has many advantages – the applicant can use their native language for the application, they can use local (likely cheaper) legal counsel for assistance with drafting and filing their application, and they likely have a greater familiarity with the IP laws and culture within their native jurisdiction. The outcome of this is that the office of first filing event (the priority filing event) for any given invention correlates strongly to the physical geographic location of the applicant. This correlation can be exploited to assess where in the world innovation within a given subject matter is emanating from. Still one should bear in mind that the OFF sometimes coincides with the country of location of the legal department which may be different of the R&D location.

Figure 4 summarizes the innovation geography within microalgae at regional level, based on this initial filing location analysis. The vast majority of activity in microalgae is Asian (with almost half of filings coming from China), followed by activity from the United States and then Europe. In figure 4, “Europe” refers to EP applications, while “Taiwan” is an abbreviated description for Taiwan, Province of China.

A detailed look at the chart shows that China is way ahead of all other applicants. Korea, Japan and the USA are all major filing countries in the field, each having filed between 1000 and 1500 patent families. Nonetheless, their filing activity remains well below that of China with 5341 patent families filed. In Europe, despite the first European applicant being in 5th position behind Korea, France represents only 3% of the total number of filings worldwide.

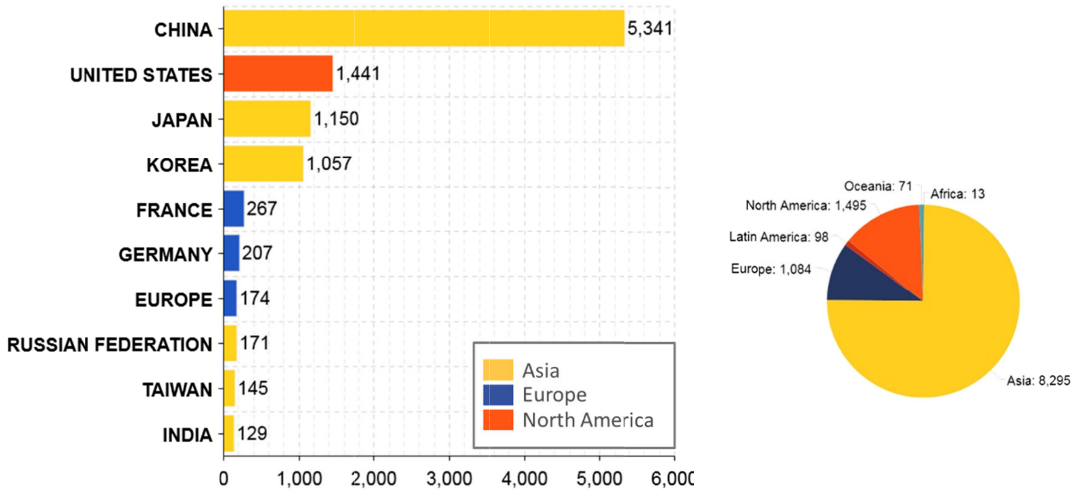


Figure 4 – Major Offices of First Filing (OFF) linked to their Region

Figure 5 confirms these findings whilst giving a broader view with a geographic visualization of the major, minor and medium sources of patent applications and granted patents within the microalgae landscape. Three major geographical areas emerge on top, whilst other parts of the world remain in the margins in term of first filings.

Countries remaining in grey concern offices for which we could not find information regarding filling of microalgae related patent due to a real absence of patent or the inaccessibility of the data within Orbit database.

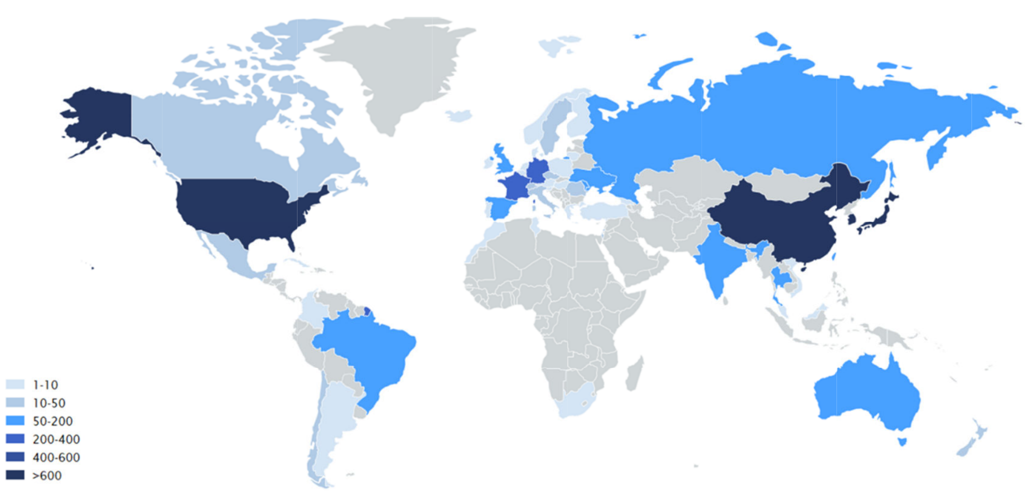


Figure 5 - Geographic map of R&D in the field of Microalgae (Offices of First Filing).

Not included in the figure 5 and table 1 are the number of patent applications for which the OFF was WO or EP.

WO refers to the global number of inventions for which the international procedure (PCT) was the first filed document. (117 documents)
EP refers to the global number of inventions for which the European patent application was the first filed document. (174 documents)

#	Country	95-99	00-04	05-09	10-14	2015	Total
1	CHINA	112	282	897	3450	600	5341
2	UNITED STATES	102	222	568	546	3	1441
3	JAPAN	285	269	352	243	1	1150
4	KOREA	33	137	275	607	5	1057
5	FRANCE	37	45	81	104	0	267
6	GERMANY	36	67	60	44	0	207
7	EUROPE	15	31	65	63	0	174
8	RUSSIAN FEDERATION	33	39	32	65	2	171
9	TAIWAN	0	14	46	85	0	145
10	INDIA	9	26	34	58	2	129
11	THAILAND	28	32	45	13	0	118
12	WORLD	5	15	38	59	0	117
13	MOLDOVA	6	24	42	32	0	104
14	SPAIN	4	18	31	39	0	92
15	UNITED KINGDOM	9	12	28	26	2	77
16	AUSTRALIA	7	12	25	10	0	54
17	UKRAINE	1	10	27	15	0	53
18	BRAZIL	0	0	23	29	0	52
19	ITALY	8	7	13	19	0	47
20	CANADA	10	6	6	11	0	33
21	MEXICO	1	0	7	16	0	24
22	ROMANIA	3	3	1	13	0	20
23	ISRAEL	9	2	4	4	0	19
24	NEW ZEALAND	3	5	5	3	0	16
	SWEDEN	9	4	3	0	0	16

#	Country	95-99	00-04	05-09	10-14	2015	Total
26	CHILE	0	0	4	8	0	12
	CZECH REPUBLIC	1	1	5	5	0	12
28	SWITZERLAND	4	1	3	3	0	11
29	NETHERLANDS	1	1	3	3	0	8
	VIET NAM	0	0	2	6	0	8
31	DENMARK	0	4	1	2	0	7
	NORWAY	0	3	2	2	0	7
	SOUTH AFRICA	0	0	0	7	0	7
34	MALAYSIA	0	0	4	2	0	6
35	POLAND	0	1	2	2	0	5
36	AUSTRIA	1	0	2	1	0	4
	BELGIUM	1	1	0	2	0	4
	FINLAND	0	0	4	0	0	4
	GREECE	1	0	1	2	0	4
40	COLOMBIA	0	0	1	2	0	3
	IRELAND	0	2	0	1	0	3
	LITHUANIA	0	0	2	1	0	3
	TUNISIA	0	1	1	1	0	3
44	CUBA	1	1	0	0	0	2
	HUNGARY	0	0	1	1	0	2
	ICELAND	0	1	1	0	0	2
	MOROCCO	0	0	0	2	0	2
	SINGAPORE	0	0	1	1	0	2
49	ARGENTINA	0	0	1	0	0	1
	GEORGIA	1	0	0	0	0	1
	MONACO	0	1	0	0	0	1
	PORTUGAL	0	0	0	1	0	1
	SLOVENIA	0	0	0	1	0	1
	TURKEY	0	0	0	1	0	1

Table 1 - Number and Evolution of patent families per Office of First Filing - Complete collection

Table 1 presents a breakdown of the number of patent families per Office of First Filing over time and for 55 countries. The table clearly shows that China is the most active and dynamic patent applicant with a CAGR of 24% in the period between 2009 and 2013.

In second place, with an overall CAGR at 13% over the same period, the US however, seem to express a decreasing interest for the field. After a growth spurt at 19% in patent applications in the period between 2005 and 2009, US filings have declined significantly, with the growth rate between 2009 and 2013 being negative at -9%.

At first glance, Japan and Korea, representing respectively 10% and 9% of worldwide filings, seem to have a similar profile, but their situation is quite different. Japan demonstrates regular growth in patent filings, with a CAGR at 8%, while Korea could become a major worldwide player, since its growth rate is the most significant CAGR after China int the period between 2009 and 2013 amounting at 23%.

The table below highlights Japan and other economies of particular interest for this landscape. Japan, in 3rd place overall, naturally dominates with 1150 patent families.
Brazil started filing patent applications related to microalgae in 2005, and seems to continue at a slightly higher rate. Morocco is shown to have filed their first two patents as priority documents over the last period. The Philippines have not yet filed any patents in this field.

#	Country	95-99	00-04	05-09	10-14	2015	Total
3	JAPAN	285	269	352	243	*1*	1150
18	BRAZIL	0	0	23	29	*0*	52
40	MOROCCO	0	0	0	2	*0*	2
-	PHILIPPINES	0	0	0	0	*0*	0

Table 2 – Offices of first filing - Focus on specific countries of interest

3.2.2. Offices of Second Filing (OSF)

Individual inventions that are protected in multiple locations reflect two potential positions of the applicant: a) organizations with existing businesses in multiple territories with a need to protect in multiple locations or with view on potential markets in the jurisdictions they seek protection, and, b) individual technologies of a higher intrinsic value or robustness that warrant broader geographic protection.

As the number of different jurisdictions where an applicant seeks protection closely correlates to a large increase in the cost of protection, patent families filed in more territories could be an indication of a higher intrinsic quality, or at least likely to be used more extensively by their owner.

The office of second filing (OSF) analysis is conducted by determining within the patent family the countries where patent protection was sought subsequently to the initial, priority patent application. While the office of first filing indicates where a technology was developed, the office of second filing can provide an indirect market analysis, giving insight on countries which were considered by applicants as likely to represent a good market, or location for manufacturing, or the products generated from the technology. Therefore, the charts below visualize the market of microalgae from the aggregate view of all applicants´ reach of exclusivity – where they feel protection is required in order to extract maximum value from their inventions.

If Asia remains the dominant country, other areas, such as Australia and Latin America are well represented, indicating that they correspond to potential commercial markets.

PCT applications are the main choice for extending protection internationally (representing 20.4% of the second patent filings), which is not surprising as filing a single PCT application and designating many countries is efficient, relatively inexpensive and straightforward.

The European patent applications represent 10.6% of all second filings (indicated below as "Europe").

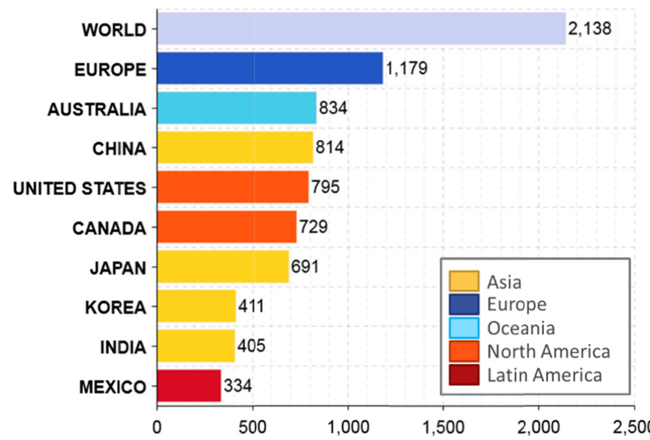


Figure 6 - Major Offices of Second Filing (OSF) linked to their Region

In figure 6, WORLD refers to PCT applications and EUROPE to EP applications.

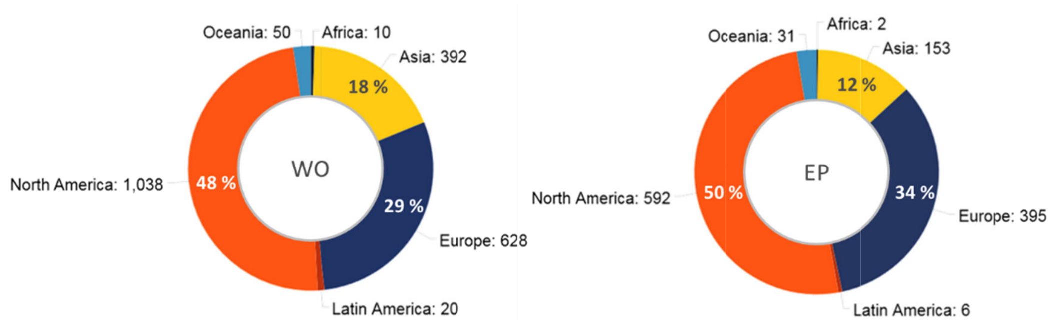


Figure 7 – Origin of PCT and EPO filings

Figure 7 shows the regional distribution for PCT (WO) and EP filings. These two strategies are mainly used by Northern American and European applicants.

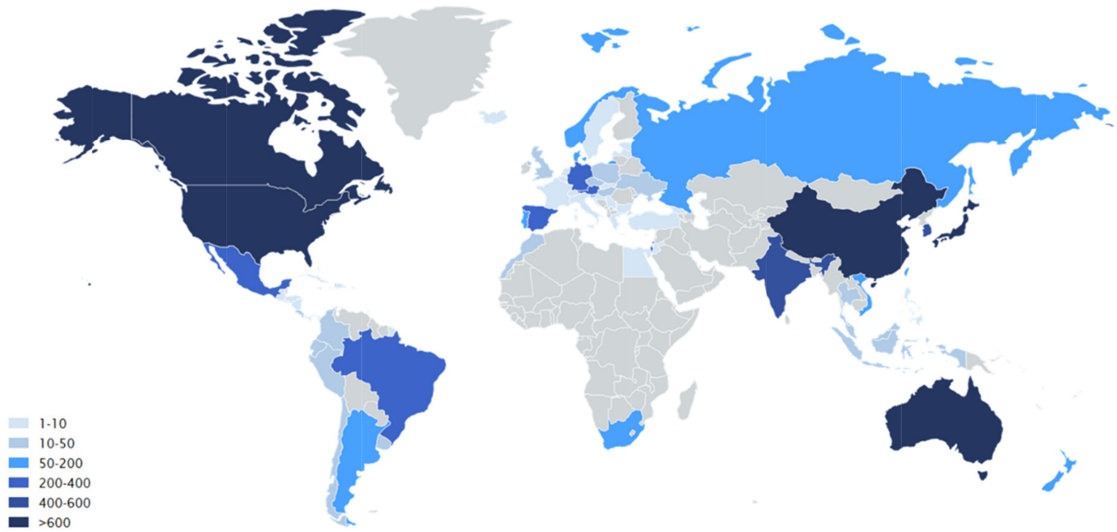


Figure 8 - Geographic map of Market of interest in the field of Microalgae (Offices of Second Filing)

Figure 8 provides a broader view with a geographic visualization of the major, minor and medium sources of OSF within the microalgae landscape.

Countries remaining in grey color concern offices for which we could not find information regarding filling of microalgae related patent due to either a real absence of related patent documents, or the lack of accessibility to the data through Orbit database.

Not included in the figure 8 and table 3 below are the number of patent applications for which the OSF was WO or EP.

WO refers to the global numbers of inventions for which a PCT application was filed as a second filing (2021 documents). EP refers to the global numbers of invention for which the European procedure was filed as a second filing. (1005 documents).

#	Country	95-99	00-04	05-09	10-14	Total
1	WORLD	173	352	753	860	2138
2	EUROPE	160	276	445	298	1179
3	AUSTRALIA	155	226	265	188	834
4	CHINA	73	156	332	253	814
5	UNITED STATES	103	184	275	233	795
6	CANADA	109	171	268	181	729
7	JAPAN	113	179	261	138	691
8	KOREA	45	103	162	101	411
9	INDIA	25	91	203	86	405
10	MEXICO	22	69	153	90	334
11	BRAZIL	45	79	123	10	257
12	SPAIN	64	83	79	9	235
13	ISRAEL	30	51	94	48	223
14	GERMANY	83	87	36	9	215
15	AUSTRIA	68	102	40	0	210
16	TAIWAN	22	36	55	38	151
17	RUSSIAN FEDERATION	9	36	52	29	126
18	NEW ZEALAND	22	29	54	10	115
19	ARGENTINA	16	22	56	18	112
20	DENMARK	33	40	26	1	100
21	SOUTH AFRICA	20	43	24	0	87
22	HONG KONG	16	25	19	19	79
23	VIET NAM	8	12	32	24	76
24	NORWAY	29	39	7	0	75
25	PORTUGAL	19	27	18	1	65
26	SINGAPORE	0	6	24	31	61
27	PERU	3	6	17	15	41
28	POLAND	18	14	3	0	35
29	COLOMBIA	3	1	14	16	34
30	MOROCCO	1	5	16	7	29
31	CHILE	0	1	5	21	27
32	UKRAINE	2	10	12	0	24
33	HUNGARY	15	5	0	0	20
34	SLOVENIA	7	10	2	0	19
35	MALAYSIA	2	3	13	0	18
36	CZECH REPUBLIC	12	5	0	0	17
37	UNITED KINGDOM	3	3	8	2	16
38	ECUADOR	0	5	7	3	15
39	THAILAND	6	5	0	3	14
40	COSTA RICA	0	4	5	3	12
	URUGUAY	0	1	6	5	12
42	INDONESIA	9	2	0	0	11
43	CROATIA	1	5	4	0	10
	CYPRUS	1	8	1	0	10
	TURKEY	8	2	0	0	10
46	PHILIPPINES	0	0	0	7	7
47	DOMINICAN REPUBLIC	0	0	3	3	6
	EGYPT	0	3	3	0	6
	ICELAND	2	3	1	0	6
	SLOVAKIA (Slovak Republic)	5	1	0	0	6

Table 3- Number and Evolution of patent families per Office of Second Filing

On Table 3, 72 different countries are represented in the analysis, along with the evolution of the number of second filings over time. As for the first filings in figure 9 above, the period considered 1995 to 2014, is split into four 5-year intervals. This charts therefore shows whether the interest in this country is growing, stabilizing or declining.

Latin America is an area of growing interest: the number of second filings in Mexico, Argentina, Peru, Colombia and Chile has increased significantly over the last two intervals.

Japan seems to be less important as a country for second filings. Equally Brazil has been less chosen as an OSF on the last period. Whereas, Morocco and the Philippines are ranked higher as OSF than OFF.

#	Country	95-99	00-04	05-09	10-14	Total
7	JAPAN	113	179	261	138	691
11	BRAZIL	45	79	123	10	257
30	MOROCCO	1	5	16	7	29
46	PHILIPPINES	0	0	0	7	7

Table 4 – Offices of Second Filing – Focus on specific countries of interest

3.2.3. Patent filing strategies

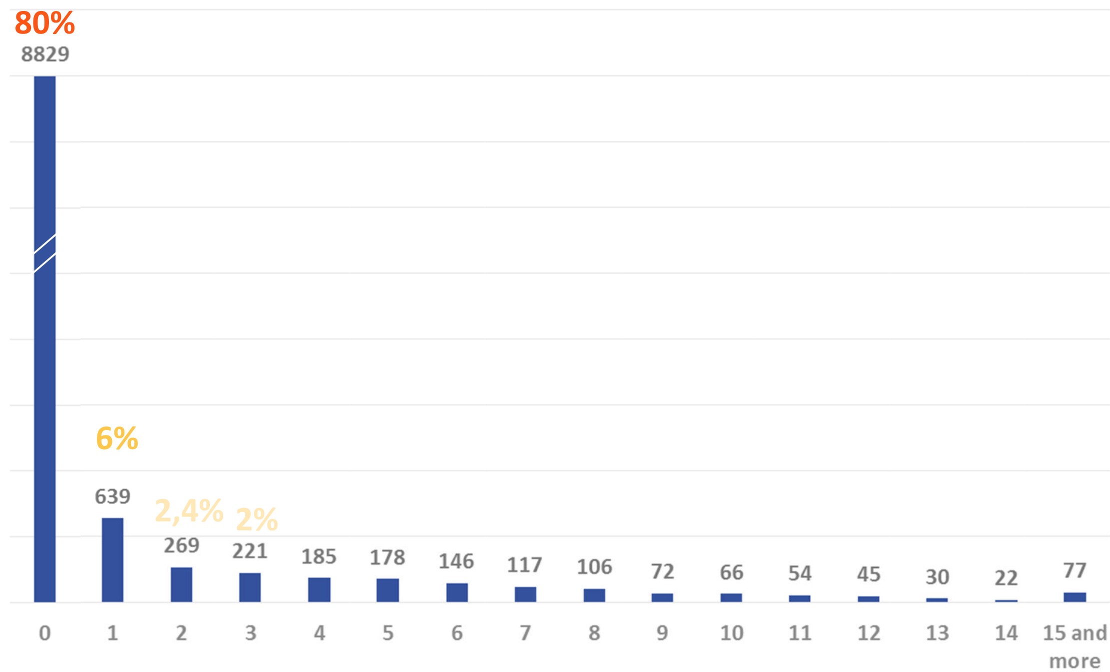


Figure 9 - Distribution of Patent Families by Number of OSF patent applications were filed

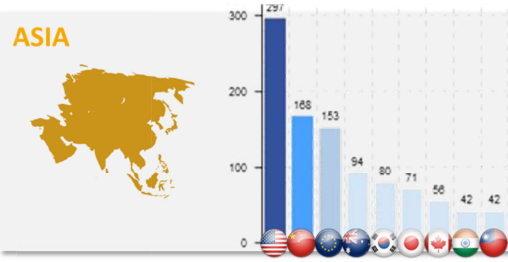
Figure 9 shows the number of patent families, with family members subsequently filed in 1, 2, 3 or more patent jurisdictions (OSF). That type of analysis allows for a better understanding of the type of IP strategy followed in the field of microalgae, as in forms an indirect market analysis and applicants' intention to be active in several countries.

8829 patent families out of the 11056 in total in the microalgae landscape have no subsequent filing outside of their priority country, this predominantly being the profile of the Japanese, as well as Chinese-based entities within the dataset. In other words, 80% of the patent applications included in the search result of this report were only filed in one single jurisdiction, while only 6% were filed in a further patent office, and only 2,5% in a third one. This indicates an intention of the patent applicants to focus on activities in their own country solely, and could translate into a great potential for technology transfer and local use of inventions filed elsewhere.

3.2.4. Analysis of patent filing strategies by region

Figure 10 shows subsequent patent filings (office of second filing) strategies by priority filing regions. The average patent family size or average number of family members per invention, for the entire dataset is 2.25. The size of the largest patent family is 182, while the percentage of patent families with at least one PCT family member is 20.4%.

ASIA

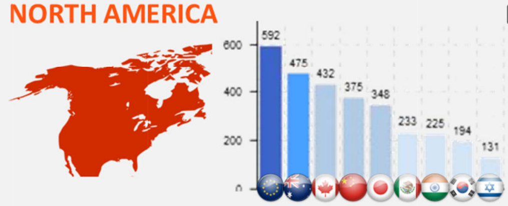


Extension rate 6 % : 8 295 patent families, only 497 extended

Key facts :

- 392 patent families having at least 1 PCT (4%)
- Only 3,6% extended toward USA
- Only 2% extended toward Europe

NORTH AMERICA

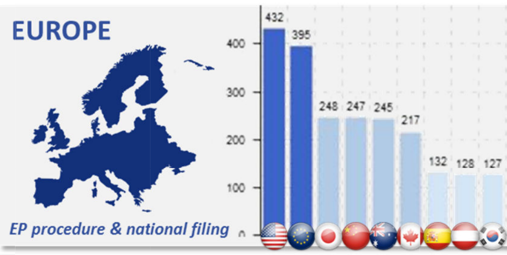


Extension rate 75 % : 1 495 patent families, 1 088 extended

Key facts :

- Almost all extended patent families count at least 1 PCT (95%)
- 40 % extended toward Europe
- 33% extended toward Asia and 20% toward Latin America.

EUROPE

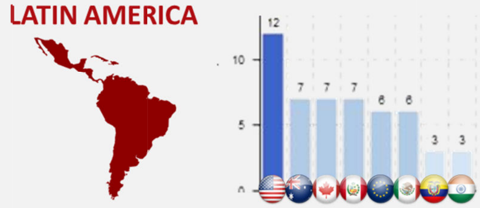


Extension rate 70 % : 1 084 patent families, 756 extended

Key facts :

- 58% of European patent families count at least 1 PCT (628)
- 42 % extended toward North America
- 32% extended toward Asia and 15% toward Latin America.

LATIN AMERICA

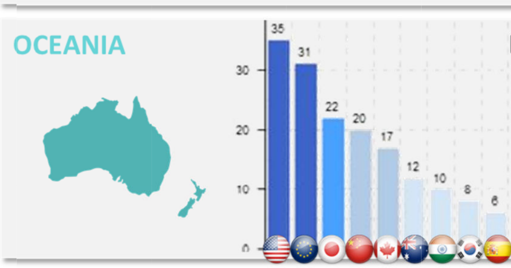


Extension rate 29 % : 98 patent families, only 28 extended

Key facts :

- 20 patent families having at least 1 PCT (20%)
- Only 12 % extended toward USA
- Only 7 % extended toward Europe, 8% toward Asia

OCEANIA

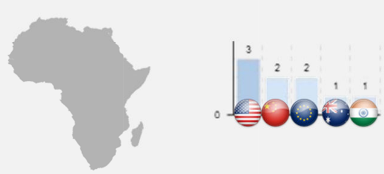


Extension rate 76 % : 71 patent families, 54 extended

Key facts :

- Almost all extended patent families count at least 1 PCT (93%)
- 49 % extended toward USA and 44 % toward Europe
- 45 % extended toward Asia.

AFRICA



Extension rate 85 % : 13 patent families, 11 extended

Key facts :

- 11 patent families count at least 1 PCT (77 %)
- Few patent extended toward USA, China and Europe
- Very young patent portfolio.

Figure 10 – Patent filing strategies by region (sum of National offices data)

3.3. Key Players

Any analysis of patent activity within a given field should exploit the ownership nature of the IP rights.
This section of the study focuses on the nature of the patent activity in microalgae from the patenting organizations.

3.3.1. Key applicants

A primary metric in any landscape analysis is the size of the patent portfolios from the most active entities in the technology, based on their patenting activity, and how the landscape is distributed among them.

Out of the top 20 applicants in the microalgae space, the vast majority are Chinese organizations. Academic research is highly represented with 12 applicants, while there are only 2 companies.

DSM is the leader in the field with 131 patent families. This strong position has been gained through a strong acquisition strategy with the takeovers of Martek (2010) and Ocean Nutrition Canada (2012).

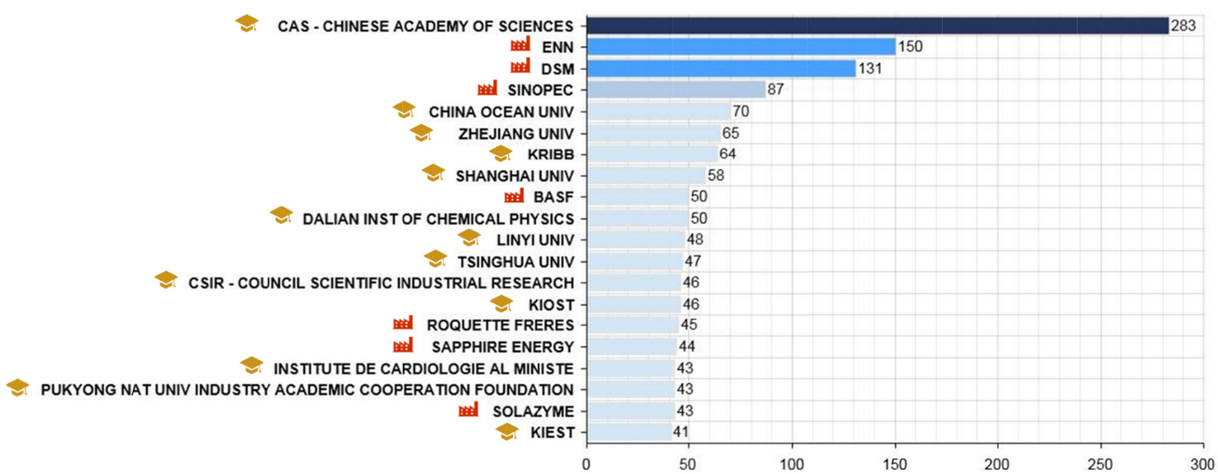


Figure 11 - TOP 20 Applicants

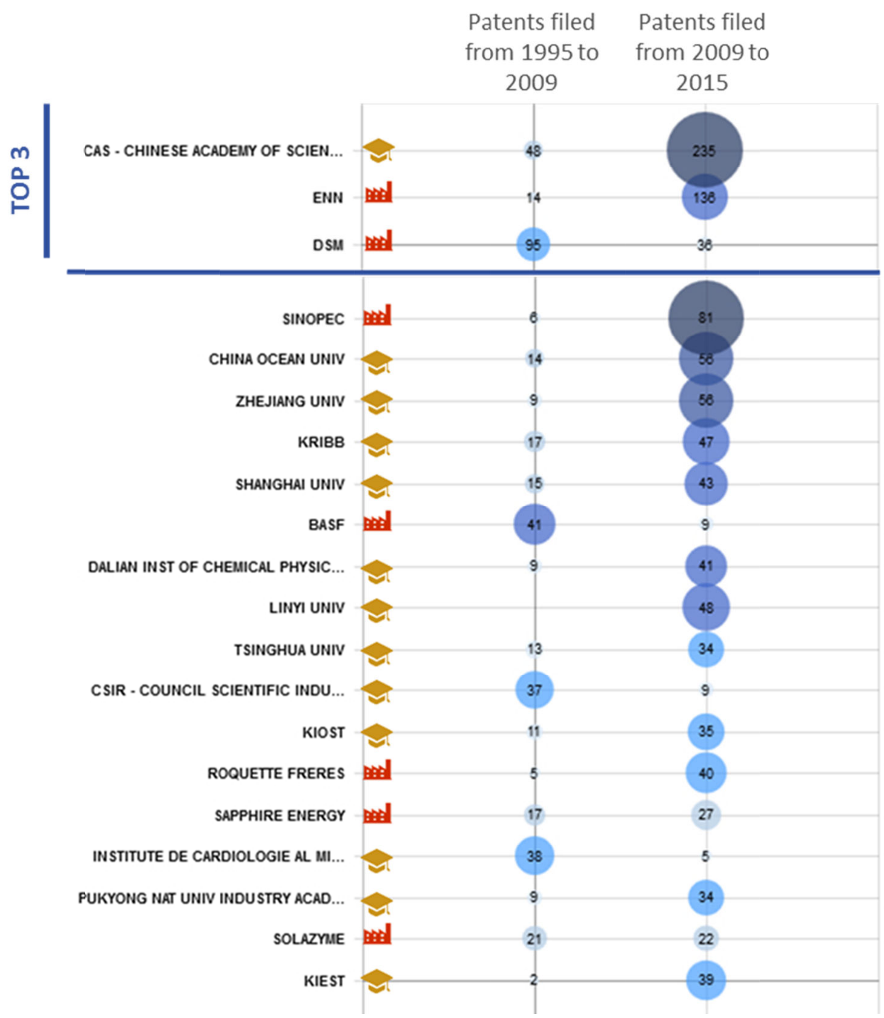


Figure 12 - TOP 20 applicants with the distribution of patents filed before and after 2009

A detailed analysis of the top 20 applicants as shown in figure 12, indicates that Asian applicants are relatively recent newcomers in this field. They were almost absent from the global landscape before 2009. The only non-Asian industrial player, which entered the landscape in the last five years, is Roquette (FR) which filed almost their whole patent portfolio after 2009.

Solazyme (USA) and Sapphire Energy (USA) have maintained a stable development over the years. BASF (Germany), CSIR (India) and the Institute de Cardiologie al Ministe (Moldavia) seem to have slowed down their inventive activity in recent years.

Table 5 lists the top patenting entities in each geographic region (Asia, North America, Europe, Latin America, Oceania and Africa), and lists the total number of patent applications registered, as well as an indication as to whether they are academic (not-for-profit) organizations or corporations.

TOP 10 APPLICANTS - ASIA	Total
CAS - CHINESE ACADEMY OF SCIENCES	282
ENN	150
SINOPEC	87
CHINA OCEAN UNIV	70
ZHEJIANG UNIV	65
KRIBB	64
SHANGHAI UNIV	58
DALIAN INST OF CHEMICAL PHYSICS	50
LINYI UNIV	48
TSINGHUA UNIV	47

TOP 10 APPLICANTS - NORTH AMERICA	Total
DSM	101
SOLAZYME	43
SAPPHIRE ENERGY	39
DU PONT DE NEMOURS	35
JOULE UNLIMITED	30
UNIV OF CALIFORNIA	29
UNIV OF ARIZONA	27
ALGENOL	21
AURORA ALGAE	20
UNIV OF TEXAS	20

TOP 10 APPLICANTS - EUROPE	Total
BASF	42
ROQUETTE FRERES	42
L OREAL	29
DSM	20
CNRS	19
UMWELTTECHNIK	19
FERMENTALG	16
UNIV ALMERIA	14
BAYER AG	13
ENI	11
LONZA	10
SOLVAY	10

TOP 10 APPLICANTS - LATIN AMERICA	Total
OURO FINO	11
UNIV PARANA	8
INST TECN ESTUDIOS SUPERIORES MONTERREY	7
COSTA JORGE ALBERTO VIEIRA	4
PETROBRAS	4
CENTER INVESTIG ESTUDIOS DEL IPN	3
UNIV RIO DE JANEIRO	3
UNIV RIO GRANDE	3
UNIV SAO PAULO	3
AEON BIOGROUP	2
UNIV PERNAMBUCO	2
UNIVERSITY AUTONOMA METROPOLITANA	2
UNIVERSITY OF CHILE	2

TOP 10 APPLICANTS - OCEANIA	Total
PHOTONZ	6
CSIRO	3
NEWSOUTH INNOVATIONS	3
AUSTRALIAN NATIONAL UNIVERSITY	2
CALLAGHAN INNOVATION	2
FLINDERS UNIVERSITY OF SOUTH AUSTRALIA	2
INDUSTRIAL RESEARCH	2
KELVIN WINSTON DUNCAN	2
MBD ENERGY	2
ZERO DISCHARGE	2

TOP 10 APPLICANTS - AFRICA	Total
NELSON MANDELA METROPOLITAN UNIVERSITY	3
MASCIR	2
COUNCEL FOR SCIENTIFIC AND INDUSTRIAL	1
EDGE TO EDGE GLOBAL INVEST	1
PETROTECH FFN	1
UNIVERSITY OF THE WITWATERSRAND	1
VAAL UNIVERSITY OF TECHNOLOGY	1

Table 5 - Major patent applicants by region

In **Asia**, China is enjoying a dominant position mainly through academic research, while the industrial fabric does not seem to be – based on patent data - strongly developed.

North America is mainly represented by the US players. DSM appears in the North American landscape through their Martek acquisition. As opposed to China, the industrial sector is well represented with many specialists of microalgae cultivation and exploitation: Solazyme, Algenol, Aurora Algae, Joule Unlimited and Sapphire Energy.

In **Europe**, the situation is more contrasted. France seems to have developed a network of academic and industrial players: CNRS (academic), Roquette, L'Oréal and Fermentalg are all in the TOP 10.
DSM is present again in third place in the European Top 20. If the recent acquisitions are included, DSM is the undisputed leader in Europe since 2010.
There are very few specialized players: only Fermentalg, and Roquette with a large business unit. The other players are international chemical companies.

Latin America is experiencing a considerable growth mainly through academic research. The microalgae sector seems to be developing, driven by the Brazilian inventive activity, in particular in the animal feed and energy sector.

Oceania is not a strong regional player in the microalgae sector. The first applicant, Photonz, is currently not filing any more patents.

On the **African** continent, all entities hold weak positions, and come almost exclusively from South Africa. Morocco, with Mascir, is in second place. In addition, Egypt seems to be developing their microalgae industrial sector.

TOP 20 INNOVATORS - 2009-2013	Growth factor
DALIAN DETONG BIO TECH DEVELOPMENT	24
ZHEJIANG HEALMING HEALTH SCIENCE	21
ZHEJIANG JINSHANMEI BIOTECHNOLOGY	19
UNIV CHOSUN IACF	17
QINGDAO ZHONGREN PHARMACEUTICAL	17
FEDERAL NOE G BJUDZHETNOE OBRAZOVATEL NOE UCHREZHDENIE VYSSHEGO PROFESSIONAL	16
HARBIN INST OF TECHNOLOGY	14
FERMENTALG	14
EXXONMOBIL	14
DAOHE BIOTECHNOLOGY	14
UNIVERSITY YONSEI	12
CHONGQING UNIV	12
ZHENJIANG LUNENG ENVIRONMENTAL PROT	11
JX NIPPON OIL ENERGY	11
HELIAE DEVELOLPMENT	11
EUGLENA	11
YANG CHENG SHENG	10
FUZHOU UNIV	10
ANHUI JINCAIDI FOOD	10
BEIHANG UNIV	9

TOP 20 INFLUENCERS	Patent portfolio	Citation Velocity
GREENFUEL TECHNOLOGIES	12	5,63
SOLAZYME	40	2,40
CHEVRON	13	2,16
UNIV OF TEXAS	18	1,80
DU PONT DE NEMOURS	38	1,59
JOULE UNLIMITED	28	1,55
UNIVERSITY OF WASHINGTON	14	1,44
DSM	184	1,43
UNIV OF CALIFORNIA	29	1,35
UNIV OF ARIZONA	25	1,16
ALGENOL	19	1,16
SAPPHIRE ENERGY	40	1,12
AURORA ALGAE	19	1,01
ADVANCED BIONUTRITION	11	0,92
ZHEJIANG HEALMING HEALTH SCIENCE	21	0,76
HITACHI	15	0,74
BEIJING UNIV CHEMICAL	11	0,71
ZHEJIANG JINSHANMEI BIOTECH	19	0,71
EXXONMOBIL	15	0,69
NESTLE	12	0,66

Table 6 - Top 20 Innovators and Top 20 Influencers

Table 6 above (entitled "the Top 20 innovators"), lists the top 20 entities experiencing the highest growth in their patent portfolio size between 2009 and 2013.

This analysis confirms the overall Asian dominant position, and reveals the emergence of three companies on each continent: Fermentalg in Europe, Heliae in North America and Euglena in Asia.

The Top 20 Influencers in Table 6 above shows the entities receiving the highest average citation velocity. The velocity represents the average number of forward citations (excluding self-citation of patent applicants) received per year per patent from other parties.

The citation statistic represents the number of occasions a particular patent family member has been referenced by downstream patent applications – either through the patent examination procedure or through applicants putting forward relevant prior art. Patent citation is a common tool for assessing impact, as inventions which gather many such citations are highly likely to be influencing further innovation with the space.

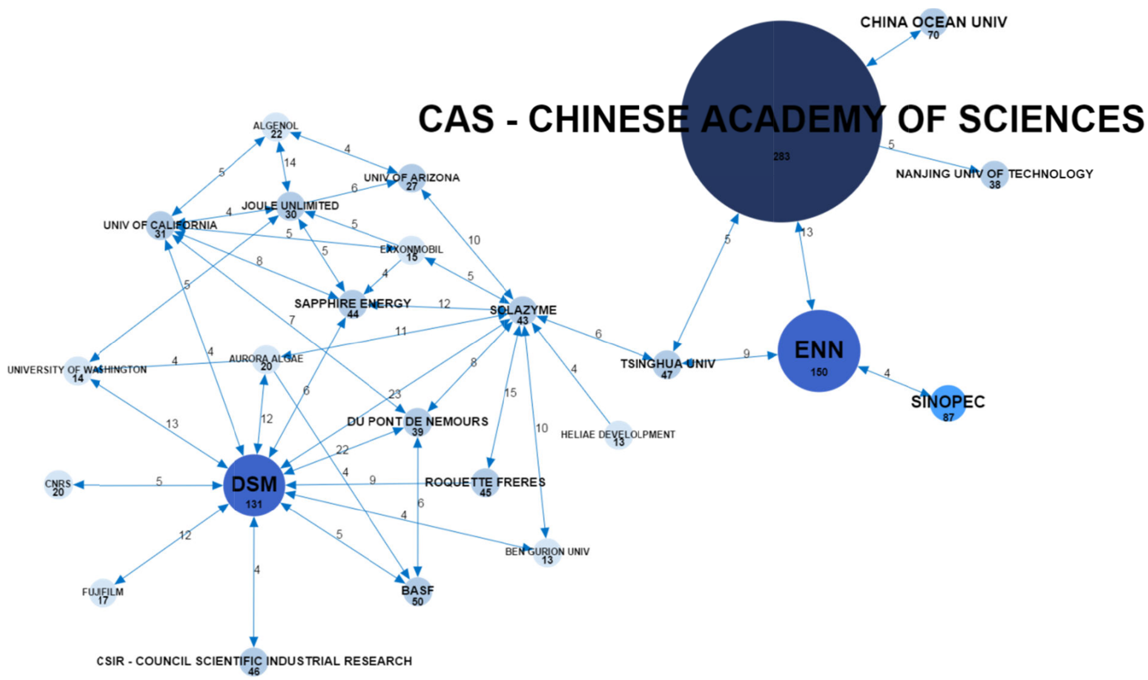


Figure 13 – Citation Network

Figure 13 shows the networks existing between applicants through citations: major cited patent portfolio. DSM and Solazyme are well cited and by many different actors, which demonstrates the strong perceived interest for their technologies by the other players in the field.

3.3.2. Key inventors

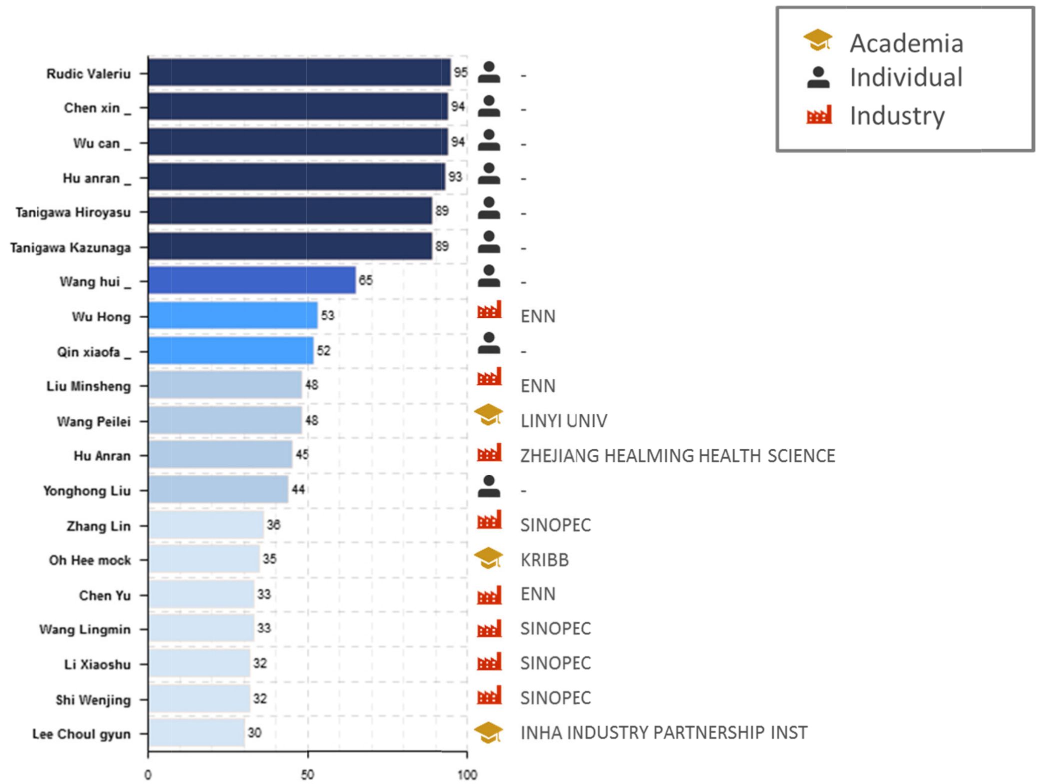


Figure 14 - Main Inventors

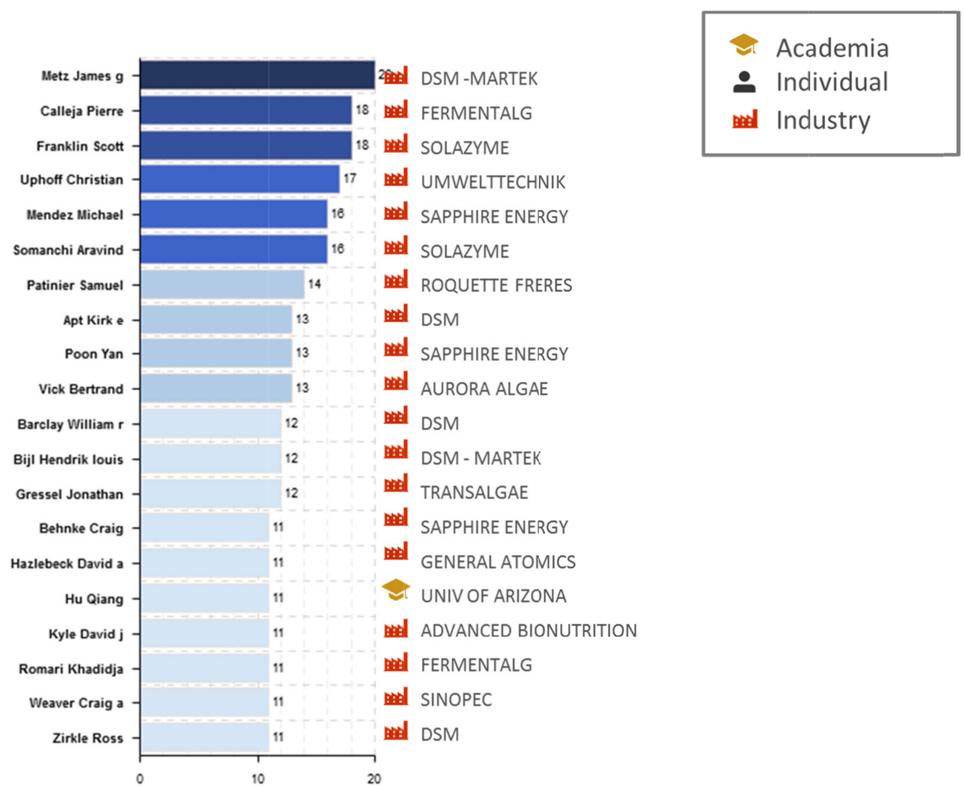


Figure 15 - Main Inventors - Asia Excluded

Most of the top inventors are related to the top Chinese applicants (figure 14). Some inventors are themselves listed as the applicants on their inventions with no company listed (e.g. Rudic Valeriu (Moldavia), Chen Xin (China), Wu can (China). In view of the dominance of China in the results, Figure 15 provides a list of the main inventors outside Asia and gives an insight on other key inventors.

3.3.3. Academic versus corporate patent activity

A further model of the type of organization active in the landscape is to review the patent applicants and identify whether they are academic, government research institutions or corporations.

Figure 16 below shows that 38% of the activity in the landscape comes from academic or government entities, with just over 46 % of the activity in the landscape originating from industry.

A patent can be related to two different types of applicants, academic or industrial, due to collaborations which lead to joint applications. In the microalgae dataset the overall joint application rate is at 12.6%. Joint application rate amongst industrial companies is at 5.5% and amongst academics (or not-for-profit) is at 4%.

Synergies between academia and industry are rather low; the joint application rate in this instance being at 2.1% (Thus, in figure 16, one patent family may be counted twice if it involves an academic and an industrial player).

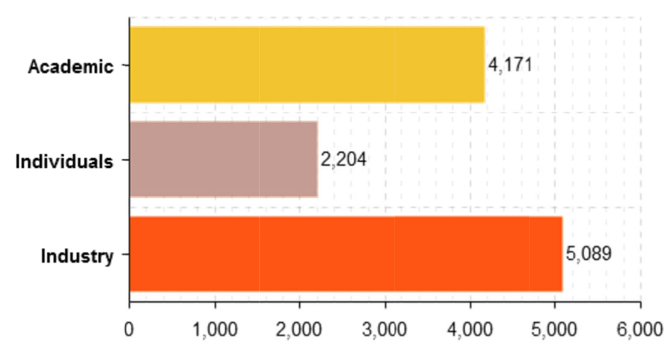


Figure 16 – Analysis of patent applicant profile

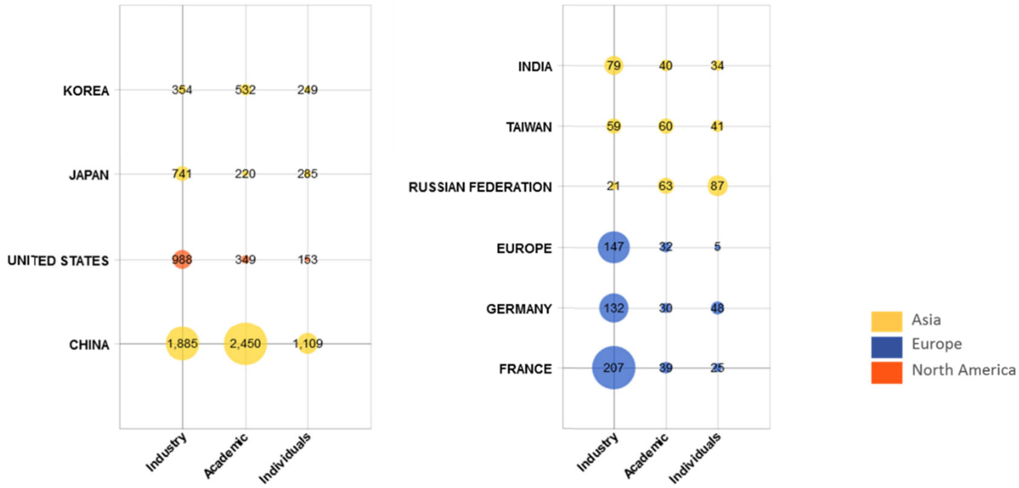


Figure 17 - Applicant type per Office of First Filing

As shown in Figure 17, Europe and North America exhibit a higher industrial maturity in the field. Asia is characterized by a predominance of academic research, except for Japan which has an industrial fabric similar to that of Europe or the USA.

3.3.4. Collaboration Networks

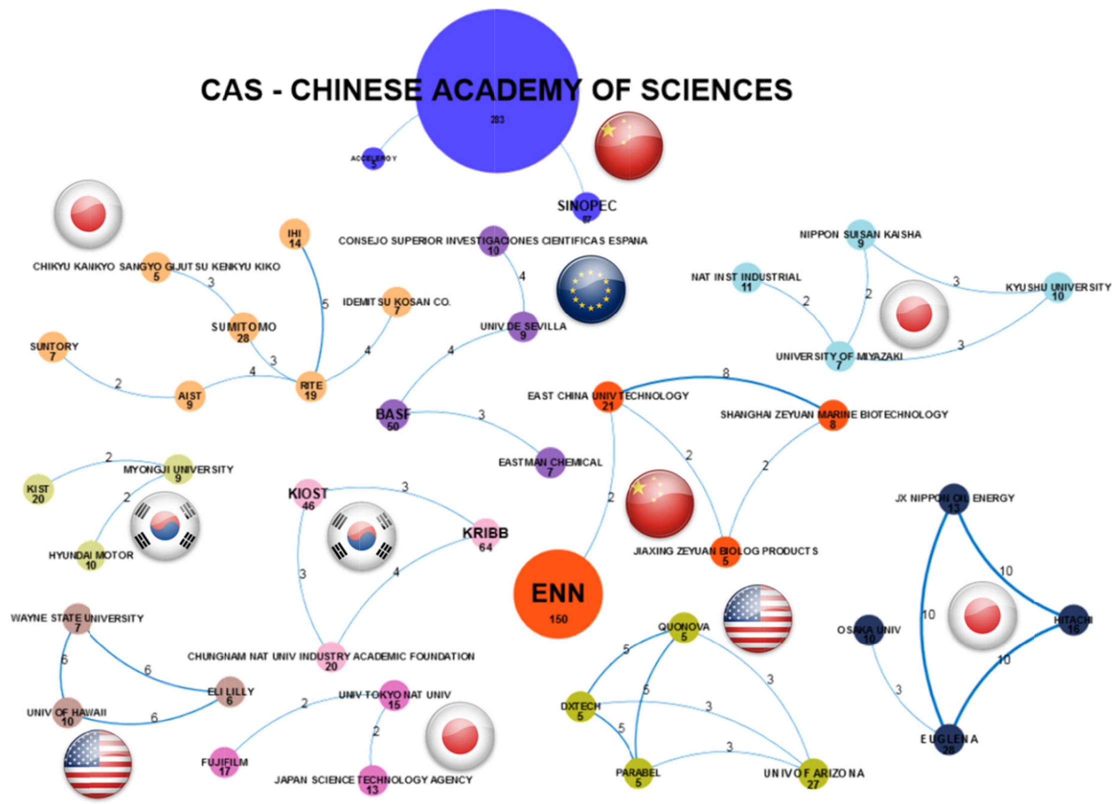


Figure 18 - Collaboration Networks - Co-assignment

Figure 18 shows the relationships among players trough co-patenting. High connectivity, based on co-patenting, may be closely linked to collaborative working environments. The patent-based applicant network map is based on applicants' joint filings of at least 2 patents between applicants with a patent portfolio of more than 5 patent families (reducing the complexity of a very rich network map). The map indicates strong regional synergies between the players. No major international collaborations can be identified through the patent analysis.

4. TECHNICAL ANALYSIS OF THE MICROALGAE PATENT LANDSCAPE

The data collection of 11 056 patent families was mined in detail for further technical analysis with the objective to provide further analytical details on the innovation trends and activity within the field of Microalgae. This section turns therefore to the detailed categories of technology, application, products and others, into which the microalgae landscape was segmented.

Note that individual families can be categorized into multiple fields if warranted. For example, an individual patent family mentioning the cultivation of Spirulina would be clustered in both categories, namely cultivation mode and strain.

The section below provides first a technical overview explaining in detail the segmentation and showing specialization of microalgae innovation by geography, and is then followed by an in-depth analysis of all segments, giving insight into the microalgae players and the market trends.

4.1. Technical Overview

4.1.1. Technical segmentation

4.1.1.1. Microalgae strains

Spirulina and Chlorella were the first strains used commercially. Dunaliella followed, out of which is extracted beta carotene, Haematococcus which provides Astaxanthin, Nannochloropsis / Phaeodactylum and Nitzschia for EPA and Schizochytrium / Cryptecodinium for DHA . These geni represent a major interest for the industry, but many others are also investigated. This evolution and the increasing number of geni of interest is related to the increase of knowledge and know-how in microalgae cultivation. As the scientific community gathers knowledge on the metabolism and the control of culture conditions, more and more geni can be grown and moved from lab to pilot scale and then industrial scale.

Genetic modification of microalgae has been described in the early 1970s in Synechocystis. In 1989, Chlamydomonas was genetically modified, and has since become a study model. Since then, over thirty strains have been the subject of genetic improvements for antibiotic resistance, mutation complementation reporter genes, etc.

4.1.1.2. Cultivation modes

Microalgae can either grow under autotrophic, heterotrophic or mixotrophic conditions. However, all microalgae are photoautotrophic, which means that they can use light and CO2 as their only source of energy[6]. Under heterotrophic conditions (fermentation), microalgae grow using organic carbon, such as glucose, in the dark.

Mixotrophic condition concerns the use of light together with organic carbon. Therefore, both light and the carbon source are critical parameters to be controlled for the optimum cultivation of microalgae under this mode.

4.1.1.3. Up and Down Stream processes

Growing

Two main types of microalgae farming systems can be distinguished: Open systems, in the open air, and Closed systems, allowing sterility in the culture medium. In the latter, either a level of light can be allowed (photobioreactors or PBR), or no light at all (fermenter).

Open culture systems fall into two major subcategories: open circular pond and raceway. These are heavily dependent on a set of environmental stress: water resources, climate / sunshine , etc. Therefore, the photobioreactors have been designed to overcome these difficulties. They work as a closed system enabling controlled culture of photosynthetic organisms. Their designs are varied: flat, tubular, helical and can be made out of plexiglas, glass or plastic. The light input can be natural or artificial.

Harvesting/Dewatering[7]

When the crop reaches maturity, biomass is harvested. At this stage the biomass is very rich in water, which, depending on the desired product, will imply the need for a subsequent drying stage. Many researchers believe that the mastery of this step is the key to successful large-scale production and commercialization (in particular for biofuels). Harvesting microalgae currently involves techniques which can be mechanical, physical (acoustic methods and / or electric), chemical or biological. It is common to combine different methods to obtain higher separation rates at a lower cost.

Representing up to 20-30 % of the production cost, harvesting is a step which is complex, as it depends on the variety of the strains, whose size can vary between 1 and 50, and up to 100 microns, and on very diluted suspensions: 0.1 to 10g per liter. These characteristics therefore influence the

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[6] Mata, T. M., Martins, A. A., Caetano, N. S., Microalgae for biodiesel production and other applications: A review. Renew. Sust. Energ. Rev. 2010, 14, 217–232.

[7] Renewable and Sustainable Energy Reviews, 2015, vol. 41, issue C, pages 1489-1500

choice of adequate technology, but have also an impact on the techniques downstream in the value chain.

According to the desired final water content we distinguish different techniques:

- Very wet biomass , <5% DW: floatation , flocculation;
- Wet biomass 5-30 % DW: filtration techniques, centrifugation ; and
- Dry biomass: harvesting completed by a drying step

There are special cases where the microalgae biomass is not physically harvested, but the substances of interest are retrieved directly in the culture medium (e.g.: Exopolysaccharides).

Extraction

Extraction processes are based on the identification of the organic compounds of interest and depend on the species, the growth state and the water content of the biomass. Many techniques require a completely dried biomass prior to extraction. Two main processes can be distinguished: mechanical and physical extraction methods, and non-mechanical extraction (chemical and biological).

Conversion

In the context of biofuel production, the extraction of oil can result in the production of biofuel per transesterification or hydrotreatment. Biomass residues may be also converted into biofuel through thermal or biochemical conversion processes such as fermentation, anaerobic digestion, gasification, pyrolysis or liquefaction.

4.1.1.4. Products and applications from microalgae

Microalgae are natural sources of lipids, proteins and polysaccharides which form the basis of many food chains.

The main lipids present in microalgae are the essential fatty acids (omega 3 and 6), non- essential fatty acids (omega 7 and 9), sterols and phytosterols, as well as VLCFA (Very Long Chain Fatty Acids). Microalgae's polysaccharides are species specific, or even sometimes strains specific. They are also different, depending on the culture mode, or even the substrates used. A multitude of possible combinations can be produced by the cellular machinery of the microalgae. Some are relatively well known, such as paramylon produced by Euglena. Others, more specific, haven been commercialized such as the Alguronic acid® of Solazyme, or the Alguard product, a polysaccharide extracted from the porphyridium, from Frutarom.

There are also many exopolysaccharides secreted by the cell in its environment. Like many marine organisms, polysaccharides have the distinctive characteristic of having high sulfate levels, giving them particular biological properties, such as antimicrobial, pro-activator of cell growth, etc.

Being rich protein sources, microalgae are used as substitutes for animal or vegetable protein feed. They are also contemplated for the production of essential amino acids, or even the production of recombinant proteins, especially for the pr of complex eukaryotic proteins.

Microalgae are also a rich source of pigments, the first biological function of which is the protection of the microalgae from sunlight. Their anti-oxidant quality is of interest for the nutrition, health and cosmetics industry. Many carotenoids can be extracted from microalgae. Being a result of photosynthesis, microalgae are also a source of chlorophyll pigments, and of another class of pigments, phycobilliproteins, mainly identified in cyanobacteria and rhodophytes.

Finally, microalgae can produce biofuels such as bioethanol (by fermentation) but also oil, processed into biodiesel, and gases, especially bio-hydrogen.

All these products address the food, feed and aquaculture markets, as well as the cosmetics, health, energy and bioremediation markets, making microalgae a cultivation with a high diversity and commercial exploitation potential.

4.1.2. Specialization of microalgae innovation by geography

A cross-analysis of the offices of first filing (OFF) and the technology segments provides an understanding of the focus of applicants in different territories on specific segments of microalgae.

Figure 19 shows the absolute number of patent families per Office of First Filing and for each Technical category.

	CHINA	UNITED STATES	JAPAN	KOREA	FRANCE	GERMANY	RUSSIAN FEDERATION	INDIA	TAIWAN	SPAIN	UNITED KINGDOM
Process: Bioengineering	581	413	58	59	14	25	10	8	8	2	14
Process: Conversion	236	170	38	40	14	19	17	1	6	10	2
Process: Extraction	1168	220	166	185	50	18	27	25	31	26	14
Process: Growing technologies	750	212	34	106	29	33	8	20	16	22	11
Process: Harvesting Dewatering	1468	312	96	134	57	25	12	23	20	27	15
Products: Fuels	808	517	162	188	47	44	32	16	22	27	20
Products: Lipids	535	334	72	99	54	25	3	24	10	10	13
Products: Other products	76	13	10	12	4	2	6	0	1	0	0
Products: Pigments	820	315	216	160	53	28	21	44	20	23	10
Products: Polysaccharides	518	167	98	36	62	27	3	9	13	6	8
Products: Proteins	1058	245	94	80	42	27	10	9	15	6	9
Application: Cosmetic	232	115	132	90	110	36	14	3	6	13	9
Application: Animal Nutrition - Feed	907	157	128	97	26	28	31	9	13	12	13
Application: Aquaculture	538	81	11	23	9	5	4	3	6	5	4
Application: Bioremediation	712	163	97	71	19	25	24	4	15	19	6
Application: Energy	757	511	140	182	42	38	28	21	19	27	21
Application: Human Nutrition - Food	1180	289	315	207	69	37	15	24	19	16	7
Application: Pharmaceutical	1358	474	330	181	106	57	47	36	39	16	24

Figure 19 - Analysis of major Technical Categories by major Offices of First Filing

Major findings from this analysis include:

- Chinese entities focus on nutritional and medical applications. This is linked to their historical use of microalgal biomass.
- The United States focus majorly on biofuel applications, they have been funding huge projects in this area. With regards to processes, Bioengineering is particularly developed in the United States.
- Japan and Korea are focused more on extraction of pigments for applications in the food industry. Korea has also a strong focus on pharmaceutical applications.

4.2. Major Microalgae strains

The choice of strain is an essential step in the value chain. It is mainly related to the targeted product and the cultivation method.

Only 6017 patent families (55%) out of the 11 056 in the dataset mention at least one of the 500 strains that were screened. This means that other patents only mention microalgae without specifying the microalgae strain (5039 – 45%). Amongst the patents mentioning at least one of the 500 strains, 48% are related to processes.

Figure 20 provides a ranking of the strains which were most frequently mentioned in the patent documents. Spirulina and Chlorella are the major strains, way ahead of the other strains. Both cover 36% of the patent dataset in the field of microalgae. These strains are well known, particularly in Asia, for their nutritional properties, and have recently gained importance as food supplements in the global market.

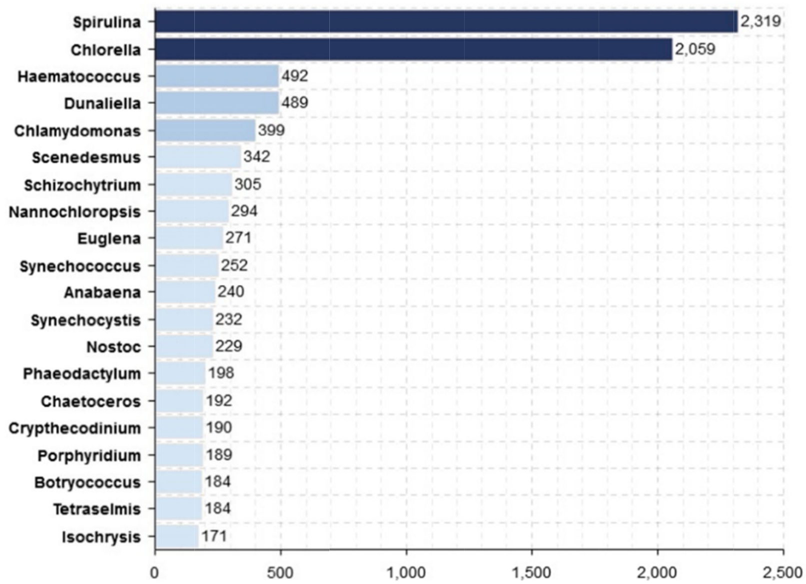

Figure 20 –TOP 20 Microalgae strains – Number of patent families per Microalgae strain.

Haematococcus and Dunaliella are also of great interest for the industry. From these strains, two pigments can be extracted: Astaxanthin and Beta-carotene. These two products are amongst the first extracts of microalgae that found a place on the market.

Astaxanthin, extracted from Haematoccus, represented a production volume of 300 tons a year and a value of US$10M (2014) whilst Beta-carotene, 1 200 tons a year (2010) and US$285M (2012)[8].

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[8] Microalgae-based products for the food and feed sector: an outlook for Europe, JRC - Scientific and Technical Research Reports, 2014.

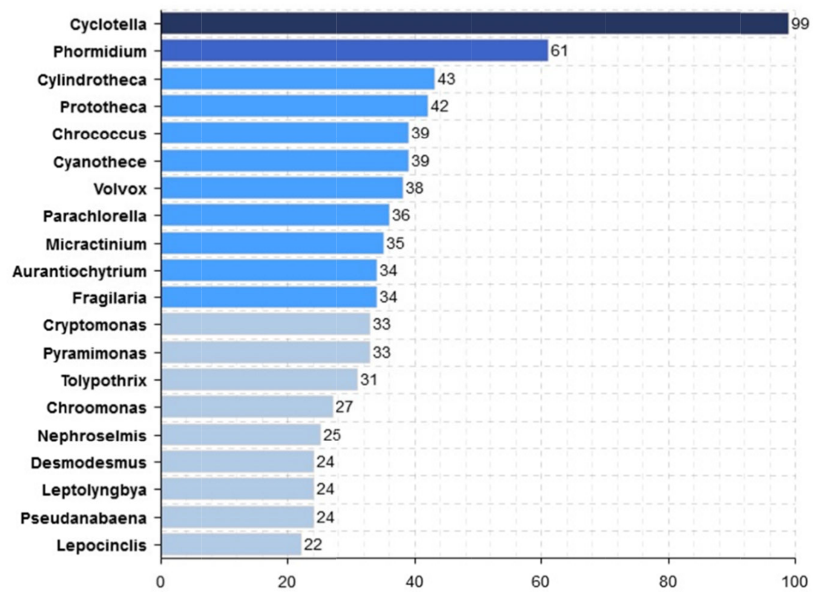

Figure 21 - TOP 20 Microalgae emerging strains

A deeper analysis of the strains looks at emerging strains. Emerging strains are defined as strains for which at least 70% of the patent documents mentioning them were published after 2009 or for which at least 3 times more documents mentioning the strain were filed between 2009-2014, than between 2004-2008.

Cyclotella appears as the first emerging strain of the last 5 years. It is close to the major strains as it is in 29th position in the global ranking. Phormidium, the second emerging strain, is the 37th most represented strain in the landscape.

Certain organizations are sometimes responsible for the rise of some of the strains: Solazyme with 18 patent families claiming patent protection related to Prothoteca and 10 patent families related to Parachlorella; SINOPEC finally has 18 patent families claiming patent protection related to Cyclotella.

4.3. Cultivation Modes

There are three major types of organisms that define the corresponding modes of cultivation:

- Autotroph: An organism that is able to form nutritional organic substances from simple inorganic substances such as carbon dioxide;
- Heterotroph: An organism deriving its nutritional requirements from complex organic substances (for instance: glucose);
- Mixotroph : A mixotroph is an organism that can use a mix of different sources of energy and carbon.

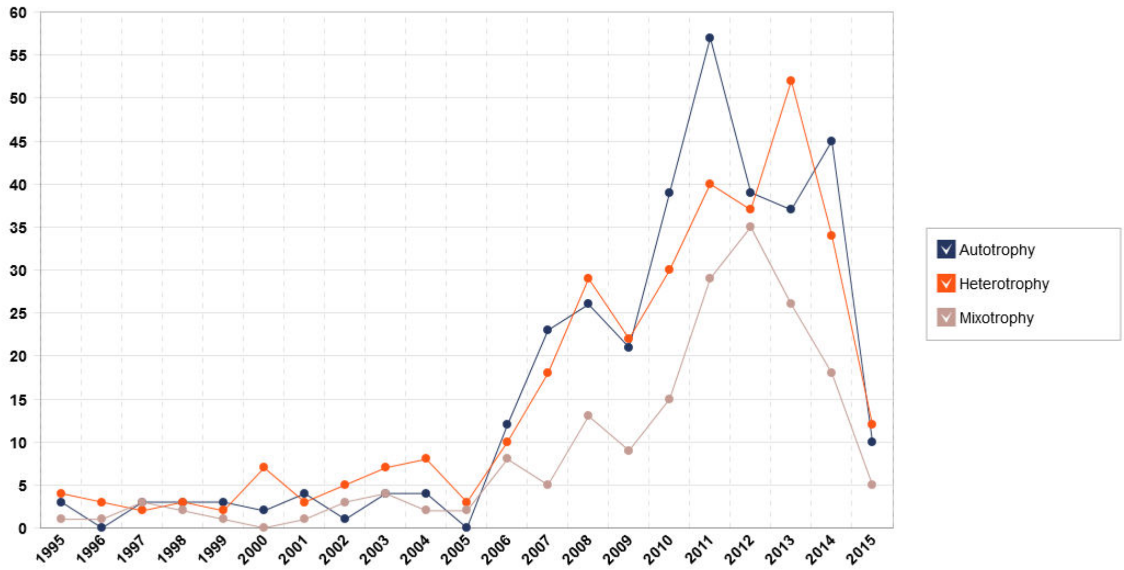

Figure 22 –Timeline of activity in specific trophic modes

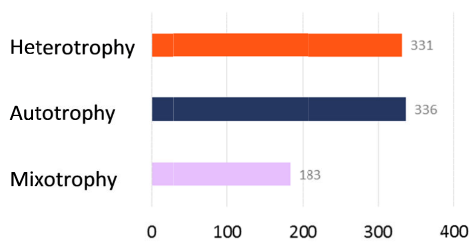

Figure 23 - Number of patent families mentioning a trophic mode

Just over 5% of the patent documents mention clearly the trophic mode they are using. These patents were segmented according to the cultivation modes described above, as shown in Figure 23.

The optimization of cultivation modes in order to improve production yields have started to be covered by patents from the mid-2000s.

Autotrophy is the most widespread mode as it is the "classical" cultivation method, corresponding to the metabolism of many microalgae. However, autotrophy has very quickly been challenged by new modes: Heterotrophy, Mixotrophy, mostly in order to increase yields. Mixotrophy developed later, with a significant rise from 2010.

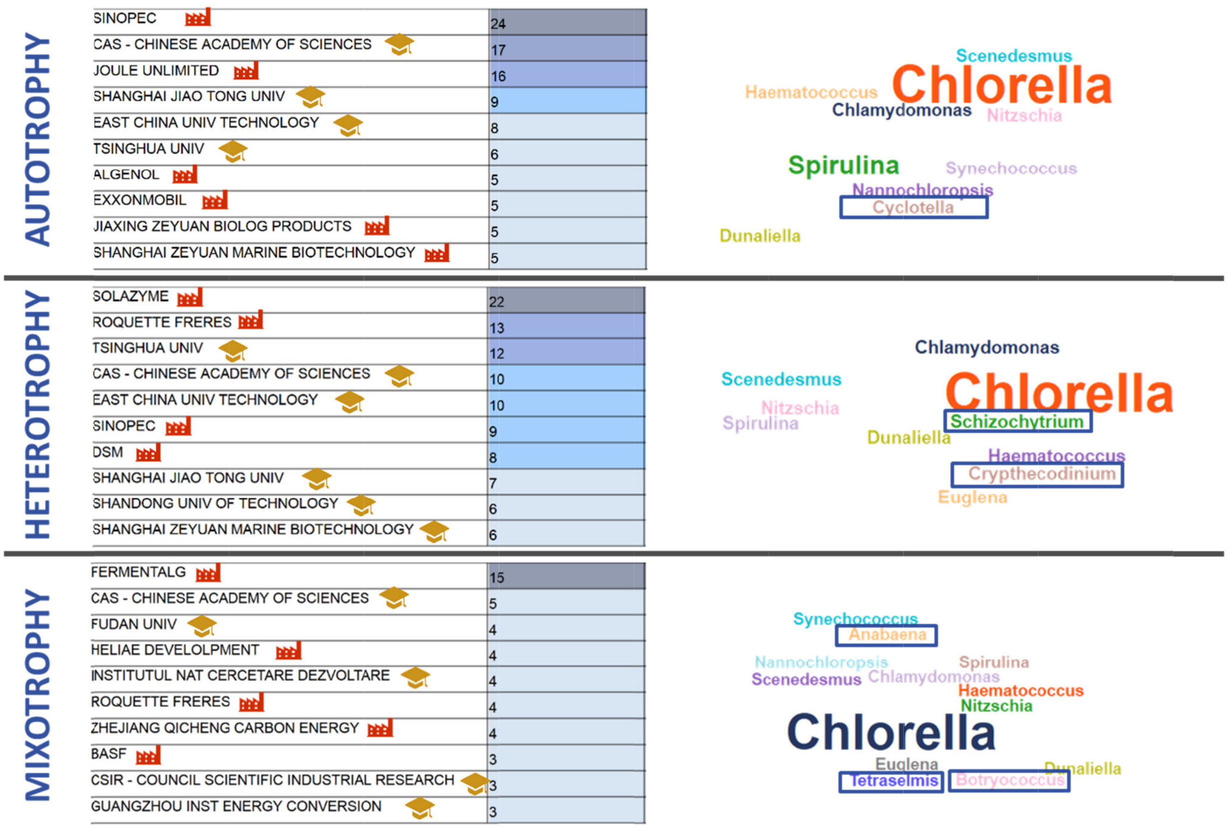

Figure 24 - Major Players per Trophic Mode and associated Strains of Microalgae

According to the trophic mode used, the emergence of different companies may be observed. Autotrophy, the best known mode, is related to a diversified player panel: academic / industry / end users / companies specialized in microalgae.
While Heterotrophy seems to be better mastered by specialized players, such as Solazyme, Roquette and DSM, Mixotrophy is mainly developed by Fermentalg and Heliae.

It can be observed that some strains can be grown under different trophic modes, for example Chlorella, Spirulina, Chlamydomonas and Scenedesmus.

However, other strains seem to be addressed specifically by a particular trophic mode (boxed strains on figure 24). These are the most cited strains for the given mode. For example, for Heterotrophy the most cited strains are Schizochytrium, Crypthecodinium, for Mixotrophy, Anabaena, Tetraselmis Botryococcus, and for Autotrophy, Cyclotella.

4.4. Up and Downstream processes

5 647 patent families, representing 51% of the dataset, are related to upstream and downstream processes.

For more than 10 years, major research and development has been devoted to the optimization of Cultivation modes and systems; nevertheless, now Harvesting and Extraction represent the main challenges. Harvesting and Extraction account for the segments with the strongest growth over the last 5 years (2009-2013). The difference with the other processes is even stronger if we focus on the last 3 years. For that period, Harvesting has a CAGR of 19% and Extraction, 15%.

Harvesting and Extraction are the key enabling steps for microalgae production scale-up and cost reduction. They still represent a technical challenge in terms of development.

The very recent slowdown observed for processes such as Conversion and Growing, may be partly due to the slowdown in the biofuel research in general.

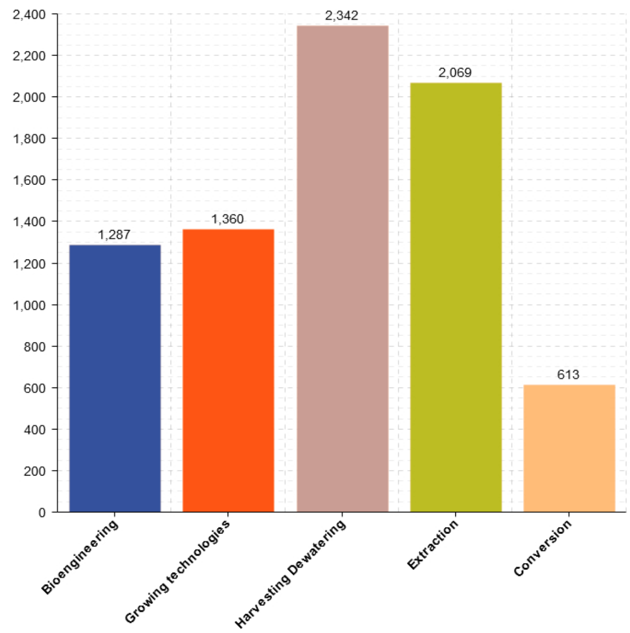

Figure 25 - Analysis of the value chain - Up and downstream processes

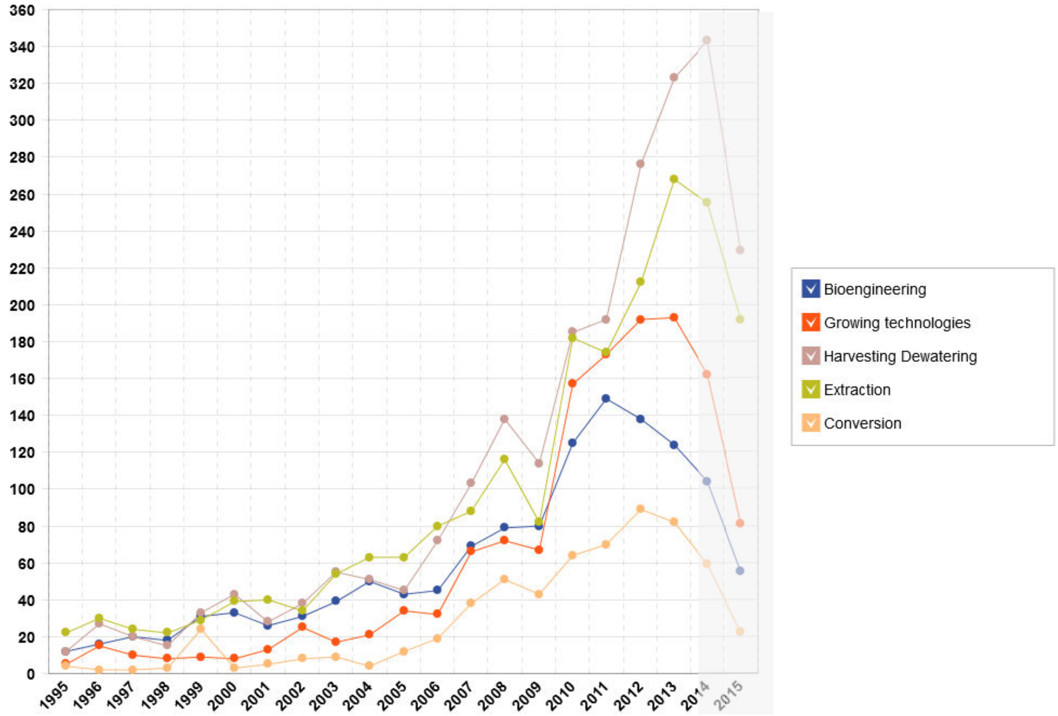

Figure 26 - Timeline of activity in Up and downstream processes

4.4.1. Growing Technologies

There are several types of growing technologies which can be divided into two main categories: Open and Closed systems.

The systems experiencing the strongest growth today mainly concern Closed systems, whether dedicated to cultivation in auto- hetero-, or mixotrophy. These systems have the significant advantage of protecting the culture from risk of unwanted microbial contamination in the production.

Figure 30 shows that Photobioreactors are much more developed than Open systems today: 1 163 patent families for the Photobioreactors against 449 for Open systems. In the category of Open systems, only the Raceway type still seems to be the subject of developments with a growth rate of 18%.

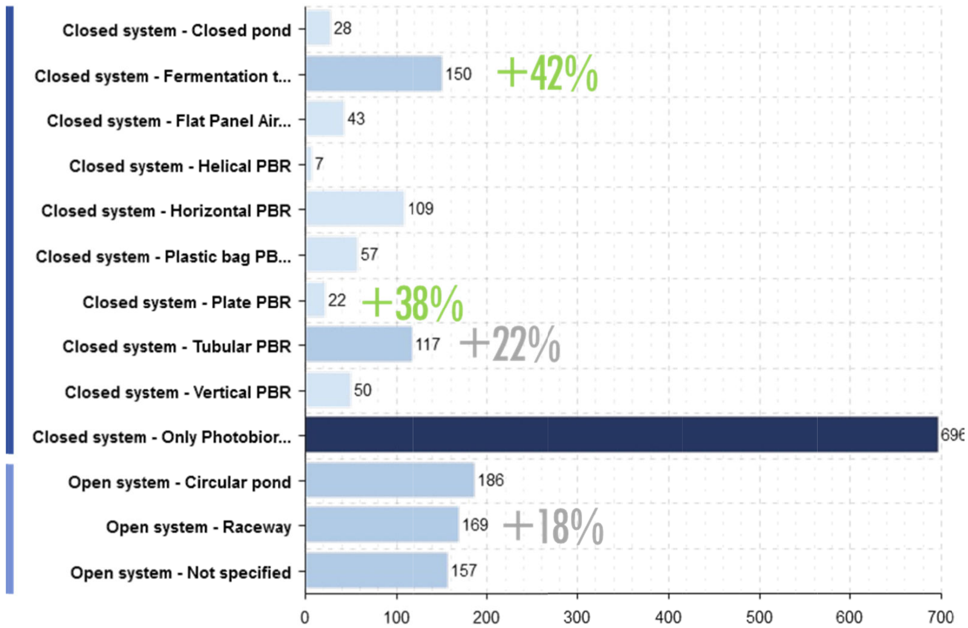

Figure 27 – Analysis of Growing technologies[9]

TOP 10 Industrials	
ENN	53
SINOPEC	24
GREENFUEL TECHNOLOGIES	11
SAPPHIRE ENERGY	11
JOULE UNLIMITED	10
ALPHY BIOTECH	8
AURORA ALGAE	8
BASF	8
HELIAE DEVELOLPMENT	6
SFN BIOSYSTEMS	6

TOP 10 Academics	
CAS - CHINESE ACADEMY OF SCIENCES	56
INHA INDUSTRY PARTNERSHIP INST	22
LINYI UNIV	19
CHINA ENGINEERING DESIGN INST	14
SDIC STATE DEVELOPMENT INVEST	13
CHINA OCEAN UNIV	12
DALIAN INST OF CHEMICAL PHYSICS	12
KIEST	11
KRIBB	11
JINAN UNIV	10

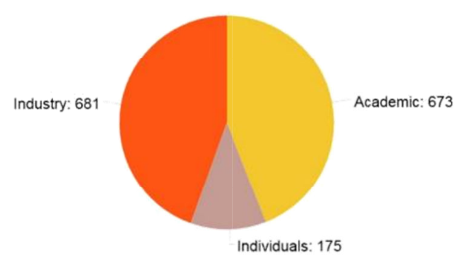

Figure 28 – Analysis of Top Players and Academic versus corporate patent activity

[9] CAGR are always calculated between 2009 and 2013, which correspond to the recent 5-year period for which we have all the data (2014 and 2015 are incomplete due to delays between the submission and publication of patents)
CAGR in green indicate a higher growth of the given technology compared to the average CAGR of this step in the value chain.
CAGR in grey indicate a growth more or less equal to the average value.
Non displayed: no marked trend in growth, i.e below the average area or of no interest for the study

Among the major industrial players present in this segment, worthy of mention are:

- Sapphire Energy, using Raceway, a low cost growing system for biofuel production;
- Joule, working on an axenic system of the Closed Photobioreactor type, which is a hybrid system between an open pool and a plastic bag[10];
- Aurora Algae, focusing on an Open Pound technology, filed for bankruptcy in 2015[11]. The choice of production site: water availability / sunshine / labor cost are essential factors in the development of this solution); and
- Heliae, developing both a closed raceway usable whatever the trophic culture mode, and a tubular Photobioreactor, in partnership with Schott[12].

Also worth mentioning is the patent drafting strategy which consists of choosing the term of Photobioreactor in its broadest sense (Figure 27), which represents 51 % (696 patent families) of all patents in the Growing category.

4.4.2. Harvesting technologies

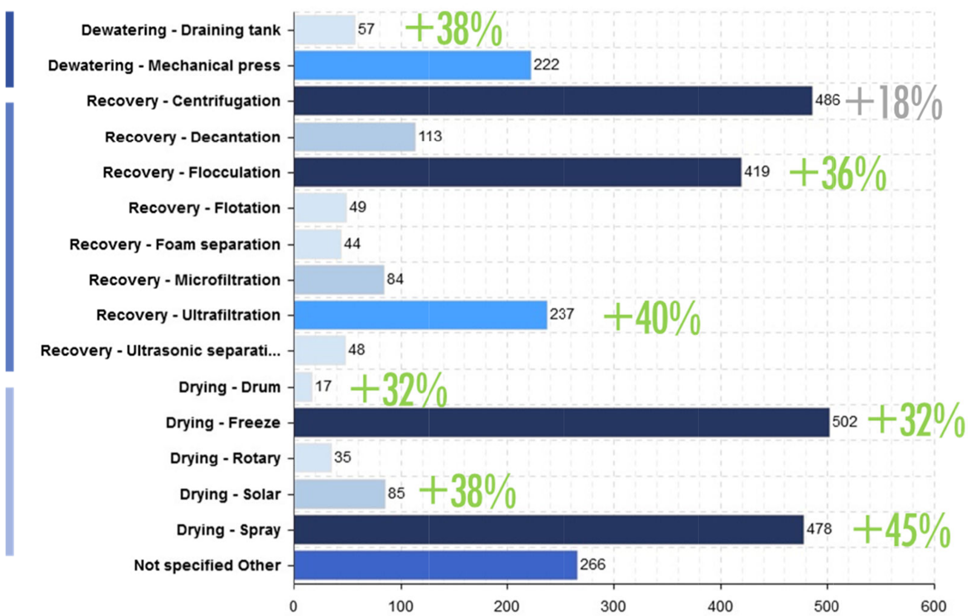

Figure 29 – Analysis of harvesting technologies[13]

[10] http://www.jouleunlimited.com/blog/joules-take-photobioreactor-design-anything-ordinary

[11] http://www.biofuelsdigest.com/bdigest/2015/07/22/rip-aurora-algae-algae-and-the-never- never /

[12] http://www.us.schott.com/english/news/press.html?NID=us592.

[13] CAGR are always calculated between 2009 and 2013, which correspond to the recent 5-year period for which we have all the data (2014 and 2015 are incomplete due to delays between the submission and publication of patents)
CAGR in green indicate a higher growth of the given technology compared to the average CAGR of this step in the value chain.
CAGR in grey indicate a growth more or less equal to the average value
Non displayed: no marked trend in growth, i.e. below the average area or of no interest for the study

TOP 10 Industrials	
SINOPEC	33
DSM	25
ENN	18
ROQUETTE FRERES	14
ANHUI JINCAIDI FOOD	10
SAPPHIRE ENERGY	10
BFS BIO FUEL SYSTEMS	9
HELIAE DEVELOLPMENT	8
QINGDAO ZHONGREN PHARMACEUTICAL	7
SOLAZYME	7

TOP 10 Academics	
CAS - CHINESE ACADEMY OF SCIENCES	70
CHINA OCEAN UNIV	20
TSINGHUA UNIV	18
LINYI UNIV	16
SHANDONG UNIV	16
CSIR - COUNCIL SCIENTIFIC INDUSTRIAL RESEARCH	15
SOUTH CHINA UNIV OF TECHNOLOGY	15
FUZHOU UNIV	13
JIANGNAN OF UNIV	13
BEIJING FORESTRY UNIV	12

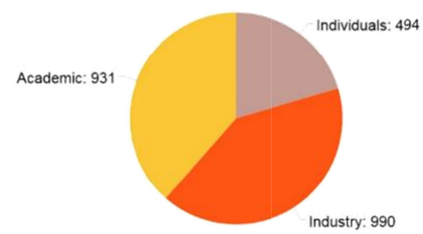

Figure 30 – Analysis of Top Players and Academic versus corporate patent activity

Harvesting of the biomass and the need for water removal are intimately associated with the stages upstream and downstream of the process. Except for cultures in heterotrophy, algal biomass can contain up to 99% water, which will need to be reduced depending on the extraction method and / or the downstream conversion.

Among the main applicants, there are no specialized player in the Harvesting process and no technology provider.

With regards to the different technologies:

- Spray drying and freeze drying are used in particular for products sold as dry biomass. Dry biomass is used in particular for food, animal feed and aquaculture applications. This technique provides the finished product directly;
- Flocculation is a technique mainly deployed for the treatment of wastewater / bioremediation.

4.4.3. Extraction

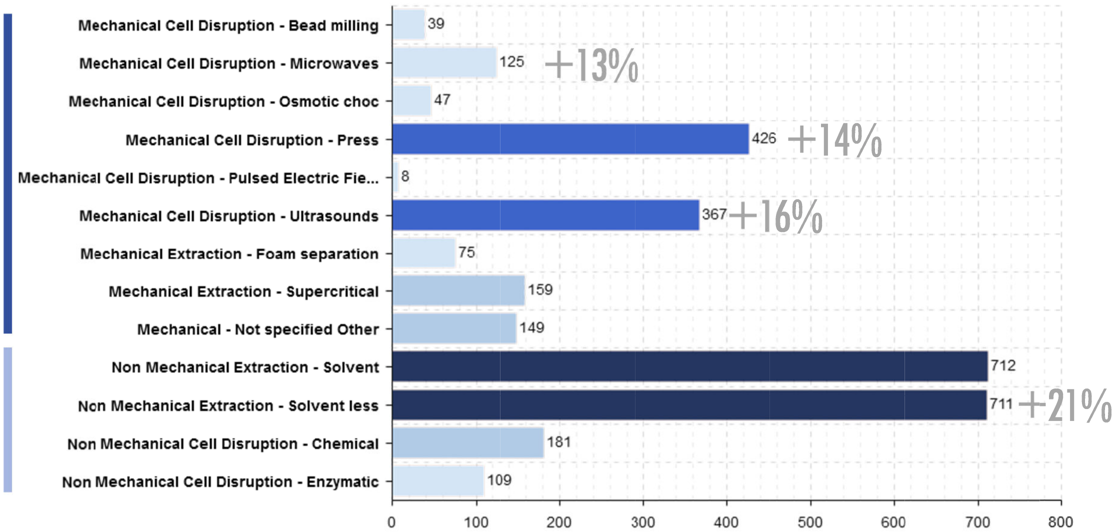

Figure 31 – Analysis of extracting technologies[14]

TOP 10 Industrials	
DSM	29
CHENGDU PENGXIANG BIOTECHNOLOGY	18
SINOPEC	18
ENN	14
SOLAZYME	8
BASF	7
DAOHE BIOTECHNOLOGY	7
PEGASUS	7
ROQUETTE FRERES	7
BFS BIO FUEL SYSTEMS	6

TOP 10 Academics	
CAS - CHINESE ACADEMY OF SCIENCES	63
ZHEJIANG UNIV	23
CSIR - COUNCIL SCIENTIFIC INDUSTRIAL RESEARCH	16
SHANDONG UNIV	15
TSINGHUA UNIV	15
SOUTH CHINA UNIV OF TECHNOLOGY	13
CHINA OCEAN UNIV	10
SHANGHAI UNIV	10
BEIJING FORESTRY UNIV	9
NAT CHUNG HSING UNIV	9

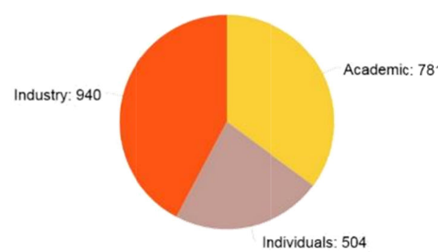

Figure 32 – Extraction: Analysis of Top Players and Academic versus corporate patent activity

Despite a wide range of existing techniques, few have managed to gain a foothold over the base solvent extraction techniques or techniques without organic solvent (extraction claimed without solvent and aqueous extraction or hydrolysis). There is a genuine desire to develop methods for extracting the compounds of interest smoothly, and to reduce the need for removing traces of

[14] CAGR are always calculated between 2009 and 2013, which correspond to the recent 5-year period for which we have all the data (2014 and 2015 are incomplete due to delays between the submission and publication of patents)
CAGR in green indicate a higher growth of the given technology compared to the average CAGR of this step in the value chain.
CAGR in grey indicate a growth more or less equal to the average value
Non displayed: no marked trend in growth, i.e below the average area or of no interest for the study.

residual solvent. This is one of the most pronounced trends in the field (+ 21% between 2009 and 2013).
Mechanical techniques with the strongest growth are the press and cell disruption by ultrasound, respectively +14% and +16% between 2009 and 2013.

As for the players present in the Growing technologies, downstream processes are here again primarily developed by the producers of microalgae. In fact, there are very few companies specialized in specific extraction solutions.

Not indicated on the graph (figure 32) but worthy of mention, in 10th position, tied with BFS Biofuels system, are also present Heliae, DuPont and Dainippon Ink.

4.4.4. Conversion

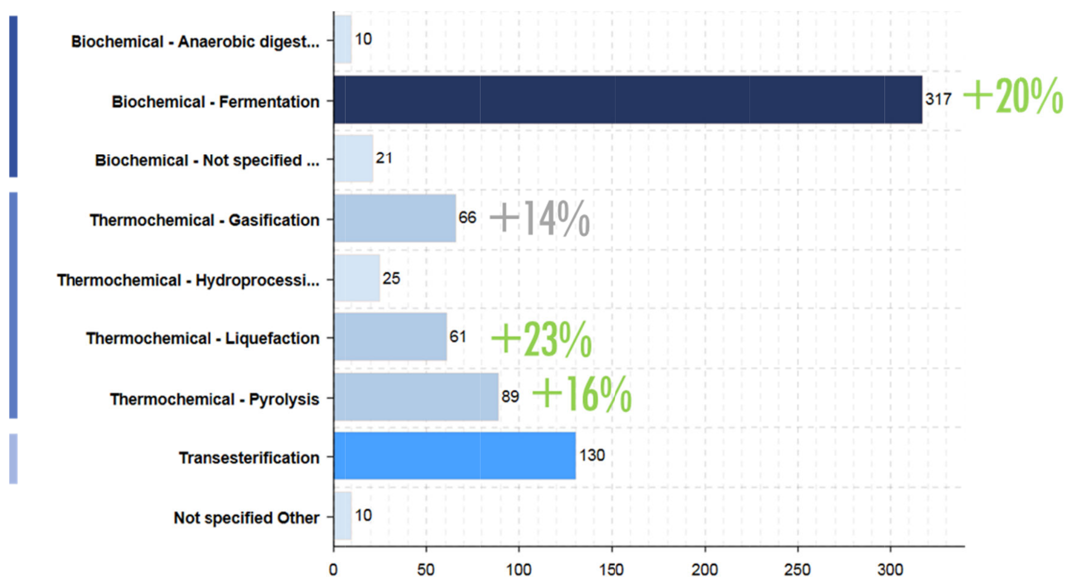

Figure 33 – Analysis of Conversion technologies[15]

Conversion is the step of the value chain with the lowest growth and with the smallest number of patents, which seems to show that the interest in the development of these processes is low. Conversion is a step that has so far been mainly developed by the biofuel sector, which also explains the low number of patents involved and the presence of specialist companies such as CNOOC (China National Offshore Oil Corporation), ENI, Butamax , Chevron and BFS.

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[15] CAGR are always calculated between 2009 and 2013, which correspond to the recent 5-year period for which we have all the data (2014 and 2015 are incomplete due to delays between the submission and publication of patents)
CAGR in green indicate a higher growth of the given technology compared to the average CAGR of this step in the value chain.
CAGR in grey indicate a growth more or less equal to the average value
Non displayed : no marked trend in growth, i.e below the average area or of no interest for the study

Major findings from Figure 33 and 34 include:

- Solazyme is part of the microalgae specialists having invested heavily towards biofuels;
- Fermentation which is used in particular for the production of alcohols, is the most claimed technology and experiences sustained growth; and
- Liquefaction is the 2nd fastest growing conversion technology.

TOP 10 Industrials	
BUTAMAX ADVANCED BIOFUELS	12
CHEVRON	12
SOLAZYME	10
ENN	8
OURO FINO	8
DU PONT DE NEMOURS	5
BFS BIO FUEL SYSTEMS	4
CNOOC	4
ENI	4
KIVERDI	4

TOP 10 Academics	
TSINGHUA UNIV	18
CAS - CHINESE ACADEMY OF SCIENCES	14
FUDAN UNIV	12
GUANGZHOU INST ENERGY CONVERSION	10
SHANGHAIJIAO TONG UNIV	10
UNIV OF TEXAS	9
CHINA AGRICULTURAL UNIV	6
KIST	6
SHENYANG UNIVERSITY	5
HARBIN INST OF TECHNOLOGY	4

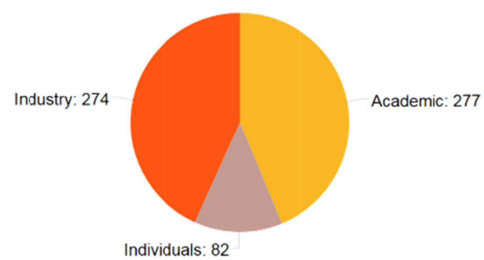


Figure 34 –Conversion: Analysis of Top Players and Academic versus Corporate patent activity

4.5. Products from microalgae and their applications

4.5.1. Products from microalgae

Expected to be the 3rd generation biofuel solution, microalgae have quickly been developed for the biofuel industry with a marked inflection point in 2006. Although this is the product category with the most patents, its growth has waned to become stagnant over the last 5 years.

Lipids and pigments, which are the second metabolites of interest, also developed early on, still continue to see a steady growth over recent years.

Since 2010, new categories of products are emerging, proteins and polysaccharides, in response to new challenges in the food and animal feed markets, as well as in the cosmetics field.

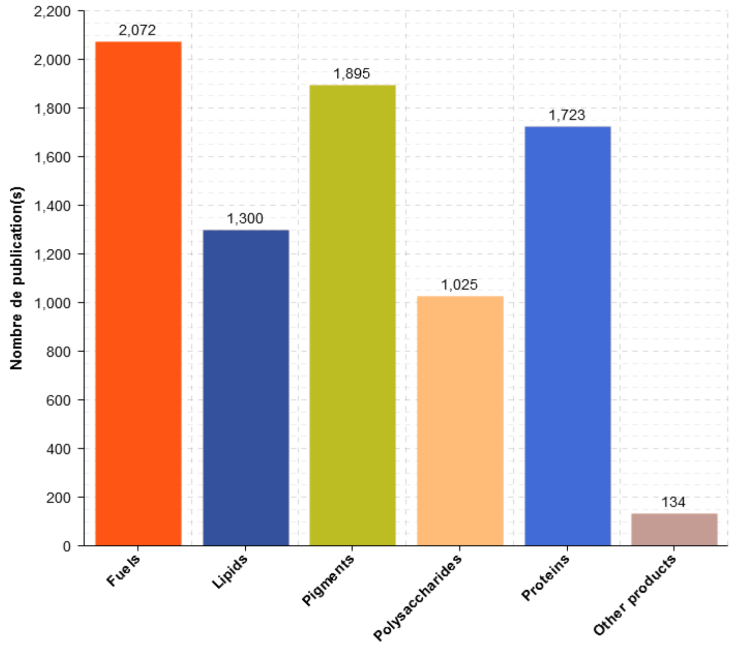


Figure 35 – Analysis of the products

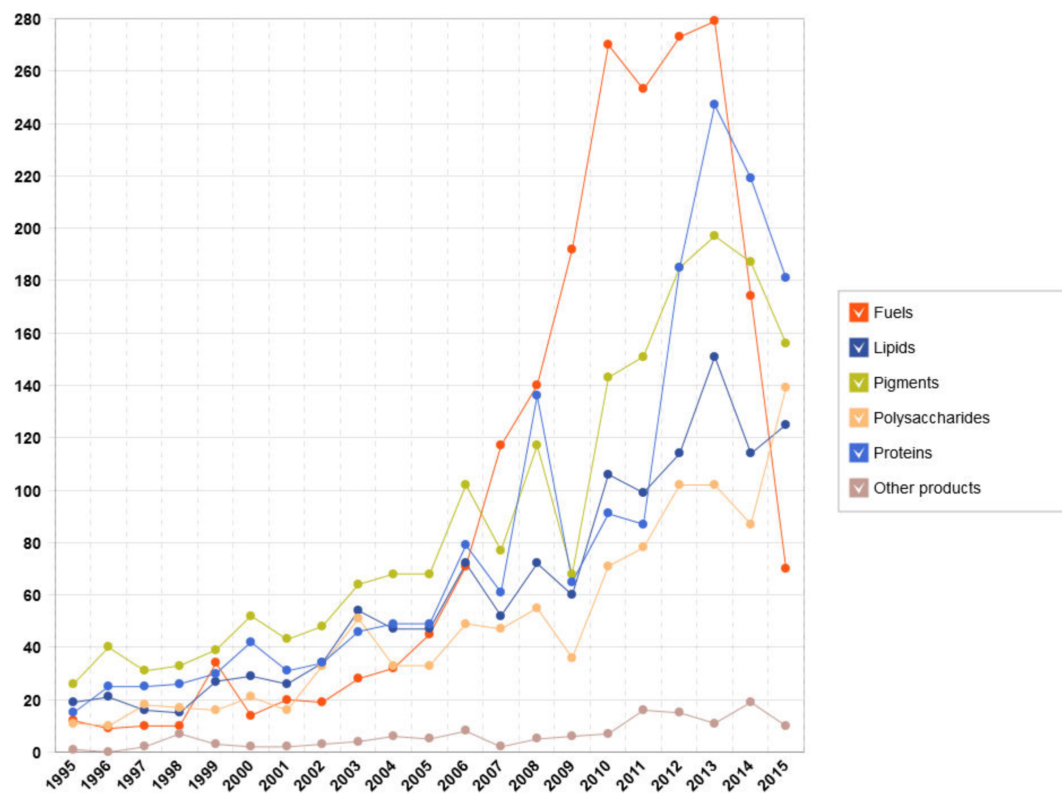


Figure 36 – Timeline of activity in products from microalgae

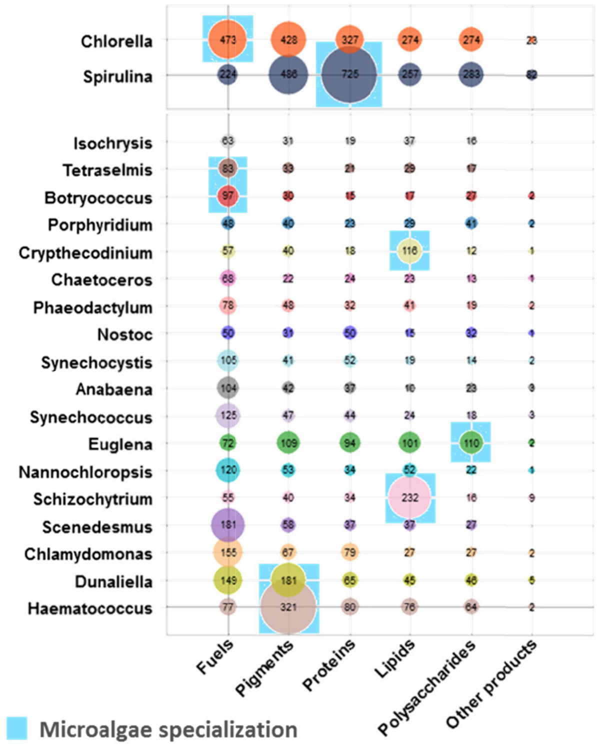


Figure 37 - Major and emerging strains cross-linked to the products

There is a high transversality among the main microalgae strains. This can be explained first of all by the method of cultivation which can influence the production of certain metabolites. Secondly, genetic engineering may also be used to alter the metabolism of a strain to enable the production of a specific metabolite. Some species, such as Chlorella, can be grown in auto-, hetero- or mixo-trophy, and each of these modes can be used to direct the microalgae metabolism.

Nevertheless, some strains are more specialized as shown on figure 37 above:

- Chlorella for biofuel production;
- Spirulina for protein production and protein animal feed, but also for the production of pigments, in particular Phycocyanin (pycobiliproteins);
- Tetraselmis Botryococcus, Scenedesmus, Nannochloropsis, Anabaena, Snechococcus, Synechocystis for biofuels;
- Chlamydomonas for biofuels, especially biohydrogen;
- Crypthecodinium, and Schyzochytrium for the production of lipids. These strains, Thraustochytrium (Top 30) and Auranthiochytrium (emerging strain) are the preferred sources of lipids. Schyzochytrium, Thraustochytrium and Aurantiochytrium belong to the same taxonomic families: Thraustochydrides;
- Euglena for the production of polysaccharides (including paramylon, a molecule specific to this strain);
- Duanliella and Haematococcus especially for pigment. The first is for the production of beta carotene while the latter is a source of Astaxanthin.

This mapping also shows how the high degree of interest for biofuels has slowed the deployment of these strains for other products and applications. Half of them have mainly been developed for the biofuels industry but very few exploited to obtain other products.

4.5.2. Applications of microalgae

Health, energy and human nutrition are the three main applications for products from microalgae. Animal feed and aquaculture have gained interest over the last five years.

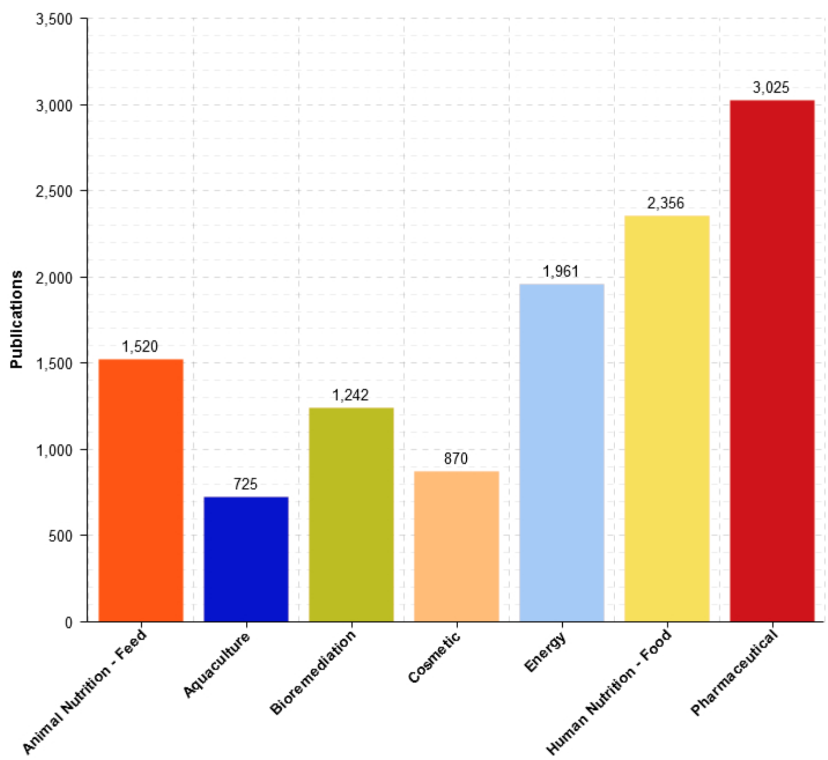
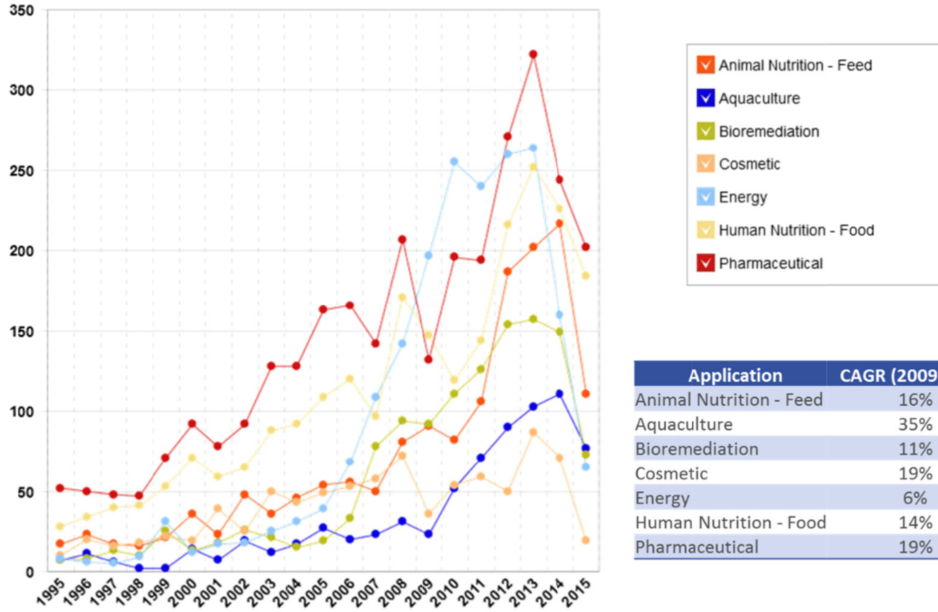


Figure 38 – Analysis of the applications



Application	CAGR (2009-2013)
Animal Nutrition - Feed	16%
Aquaculture	35%
Bioremediation	11%
Cosmetic	19%
Energy	6%
Human Nutrition - Food	14%
Pharmaceutical	19%

Figure 39 – Timeline of activity in applications of microalgae

The "Animal Nutrition - Feed" sector is growing rapidly, especially with protein meals, because there is a real challenge today find alternatives to proteins from animal origin. It covers 1,520 patent families, 8% out of which mention the use of genetic engineering.

The objective for the Animal Nutrition sector is to improve eggs, meat and milk quality and boost animal growth. Pigments derived from microalgae, such as carotenoids, for example, are of interest for eggs, as they allow natural coloring.

The "Aquaculture" sector is experiencing a growth well above the microalgae landscape average growth. It concerns 725 patent families, out of which 6% report the use of genetic engineering. The objective for this application sector is to capitalize on the active ingredients produced naturally by the microalgae, by optimizing the cultivation conditions.

Established for over 40 years in that application, microalgae’s role is well known, and includes the ability to:

- Improve nutritional qualities: management of the lipid profile of fish;
- Provide antioxidants: Astaxanthin-rich fish;
- Improve organoleptic qualities: Astaxanthin can be used as a natural dye;
- Supplement fish with EPA DHA; and
- Improve fish growth through the use of protein meals of microalgae as an alternative to fish meal.

The sector includes fish, mussel and shellfish, shrimp, crayfish farming, and seaweed farming. Given the identified descriptors, crayfish and mussel farming seem to be the sector's most innovative (based on patent data) areas.

	Animal Nutrition - Feed	Aquaculture	Bioremediation	Cosmetic	Energy	Human Nutrition - Food	Pharmaceutical
DSM	40	7	1	27	11	79	79
CAS - CHINESE ACADEMY OF SCIENCES	24	13	30	4	62	18	33
ENN	16	24	18	5	35	12	14
LINYI UNIV	9	28	2	1	5	18	18
BASF	12	5	2	13	3	12	19
ROQUETTE FRERES	9	0	0	8	2	35	15
SOLAZYME	6	4	2	10	16	16	12
INSTITUTE DE CARDIOLOGIE AL MINISTE	0	0	0	17	0	10	40
CHINA OCEAN UNIV	10	4	4	2	13	11	9
TSINGHUA UNIV	2	1	14	1	30	3	2
L OREAL	2	0	0	30	5	2	13
SINOPEC	2	6	14	0	23	2	1
ZHEJIANG UNIV	5	6	5	0	23	2	5
DALIAN DETONG BIO TECH DEVELOPMENT	24	15	0	0	0	0	11
CSIR - COUNCIL SCIENTIFIC INDUSTRIAL RESEARCH	4	0	6	0	13	15	9
SHANGHAI JIAO TONG UNIV	2	3	17	1	14	3	4
JOULE UNLIMITED	0	0	1	0	24	2	17
KRIBB	1	0	4	2	25	1	7
GUANGDONG OCEAN UNIV	18	18	1	0	1	1	5
ZHEJIANG HEALMING HEALTH SCIENCE	0	0	0	1	0	21	21
ZHEJIANG JINSHANMEI BIOTECHNOLOGY	2	0	0	1	0	19	19
PUKYONG NAT UNIV INDUSTRY ACADEMIC COOPERATION FOUNDATION	6	6	1	1	3	11	12
CHINESE ACADEMY OF FISHERY SCIENCES	13	13	8	0	0	1	3
FUDAN UNIV	3	2	13	0	15	1	3
JIANGNAN OF UNIV	1	1	10	3	14	3	4
SOUTH CHINA UNIV OF TECHNOLOGY	2	2	5	0	6	8	14
DU PONT DE NEMOURS	7	1	0	1	10	8	4
SHANDONG UNIV	1	0	8	0	10	5	9
FUJI CHEMICAL INDUSTRIAL	4	0	0	5	0	10	15
NINGBO UNIV	8	7	1	0	2	5	8
UNIV OF CALIFORNIA	4	0	2	0	16	2	8
SHANGHAI UNIV	3	4	1	2	8	3	7
HARBIN INST OF TECHNOLOGY	1	1	11	0	16	1	2
DALIAN INST OF CHEMICAL PHYSICS	1	2	1	0	11	2	12
UNIV OF TEXAS	0	0	3	2	12	5	9
SOUTH CHINA SEA INST OCEANOLOGY	7	3	3	3	2	6	7
SAPPHIRE ENERGY	1	0	1	0	20	1	4

Figure 40 – Products: Analysis of Top 35 Players

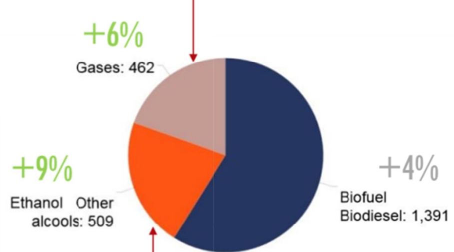
The "Cosmetics" sector is largely industrial, with a strong European presence, in particular in France, with players such as L'Oréal. This sector covers 870 patent families, out of which 5% report the use of genetic engineering.

Among the smaller portfolios there are players, such as Symrise, with Symhair and Symbronze products, Codif with Phormiskin and Dermochlorella products or Soliance with Costalane, Megassane and Porphyraline.

In this sector, Pigments (31%) together with Proteins (43%) are the products experiencing the strongest growth. In the Proteins segment, peptide-type active ingredients, represent a major share. Examples are Dépolutine and Grevilline extracts of Soliance.

The "Energy" sector refers to 1961 patent families, out of which 17% report the use of genetic engineering. The use of genetic engineering is particularly high in this sector. The objectives are to improve lipid productivity, increase productivity of the strain, optimize metabolic consumption of the strain, etc. All these efforts aim at solving the most notable disadvantage of microalgae, being that their cell division cycle is much longer than that of bacteria.

This sector is experiencing a relatively slow growth compared to other segments. The interest is no longer the same than in the past, mainly because of production costs, which are still too high, and the sometimes too complicated scale-up.



	2009	2010	2011	2012	2013	2014	2015	Total
LINYI UNIV	0	0	0	0	0	5	0	5
SHOWA DENKO	0	0	0	0	3	0	0	3
ZHEJIANG UNIV	0	0	0	0	3	2	2	7
BEIJING TIAN AN BIOLOG TECHNOLOGY	0	0	0	6	0	0	0	6
HARBIN INST OF TECHNOLOGY	0	0	0	1	1	0	2	4
SHANGHAI JIAO TONG UNIV	0	0	1	2	2	0	0	5
FUDAN UNIV	0	0	2	6	0	0	0	8
CNOOC	0	0	1	3	0	0	0	4
CALYSTA	0	0	1	3	0	0	0	4
CAS - CHINESE ACADEMY OF SCIENCES	0	2	3	0	1	2	2	10

	2009	2010	2011	2012	2013	2014	2015	Total
HENAN UNIVERSITY	0	0	0	2	1	1	0	4
ZHEJIANG QICHENG CARBON ENERGY	0	0	5	0	0	0	0	5
BEIJING UNIV CHEMICAL	0	0	2	1	0	1	1	5
HARBIN INST OF TECHNOLOGY	0	2	0	0	3	0	1	6
SINOPEC	1	1	0	0	3	0	0	5
TSINGHUA UNIV	1	1	2	3	1	0	0	11
JOULE UNLIMITED	1	3	2	0	0	0	0	9
ENN	1	0	0	5	1	0	0	10
UNIV OF CALIFORNIA	1	1	1	0	0	0	0	5
CAS - CHINESE ACADEMY OF SCIENCES	0	2	2	2	3	1	0	12

	2009	2010	2011	2012	2013	2014	2015	Total
ZHEJIANG UNIV	0	0	1	2	4	4	2	13
SHELL	0	10	1	0	0	0	0	11
KRIBB	0	9	0	6	5	1	0	21
SINOPEC	2	1	2	2	9	0	0	16
KIEST	1	5	4	5	1	0	0	16
HARBIN INST OF TECHNOLOGY	1	2	0	5	6	0	1	15
GUANGZHOU INST ENERGY CONVERSION	1	1	2	0	1	7	1	13
JOULE UNLIMITED	6	2	4	1	2	0	0	18
ENN	1	4	3	9	2	2	1	28
CAS - CHINESE ACADEMY OF SCIENCES	1	7	10	5	13	6	3	46

Figure 41 – Detailed analysis of patenting activity in biofuels

The "Human Nutrition" sector concerns 2356 patent families, 9% out of which mention the use of genetic engineering.
The use of microalgal biomass as a source of protein in the human diet is one of the first line of development that has been achieved, especially in Asia. Nevertheless, with players such as Roquette Freres, this segment has regained interest in the last four years. The development of new microalgae as food protein sources has clearly become a strong driver of innovation in the microalgae industry.

Pigment production comes second: for example, with the BASF Group (Cognis) for beta-carotene, and Cyanotech, Astareal (Fuji chemical) or Valensa for astaxanthin. Many opportunities still exist given microalgae strong potential and other pigments of interest for human nutrition, such as Lutein and Fucoxanthin.

In the third place, and experiencing continued interest and growth for over the last 10 years, is the production of lipids. In particular, the identification of new sources of omega 3 and omega-6 (essential fatty acids) remains an important area of development. Many players have positioned themselves on the field, but the presence of the leader DSM / Martek group seems to stifle the development of other companies. There is a noticeable trend of patents covering sterols and microalgal phytosterols.

A significant fraction of patent documents, nearly 50% are for medicinal preparations, often from traditional Chinese medicine. Many players are positioning their product at the interface of nutrition and health, by protecting treatment methods (DHA) against Alzheimer's, or using Lutein to fight against eye disease, or protecting dermatological benefits of polysaccharides.

Other field of applications might be investigated for microalgae: Agronomy & Agriculture as an example, or also New Biomaterials. Those niche applications are only still emerging and concern a few hundreds of patent documents. No meaningful analysis could be conducted on those applications for this PLR.

4.5.3. Products and applications

Figure 42 shows the links between products and applications. In this figure, the green areas correspond to intersections for which there is a growth of at least three times the average of the overall microalgae landscape (CAGR 2009-2013: 10%). Given the large number of products that can be obtained from microalgae, the number of applications that can be addressed is very high. Although the "Biofuels" application was initially one of the main drivers of the development of microalgae, there are now many newer “product/ applications” couples that are attracting the interest of industrial and academic research for microalgae. Protein production, regardless of the targeted application, is now one of the new drivers. The utilization of pigments for cosmetics (+ 31%) and aquaculture (+ 35%) is also experiencing strong growth. The use of polysaccharides for cosmetics is also an area of interest as shown by Solazyme with the alguronic acid which is the flagship ingredient of the Algenist cosmetics range.

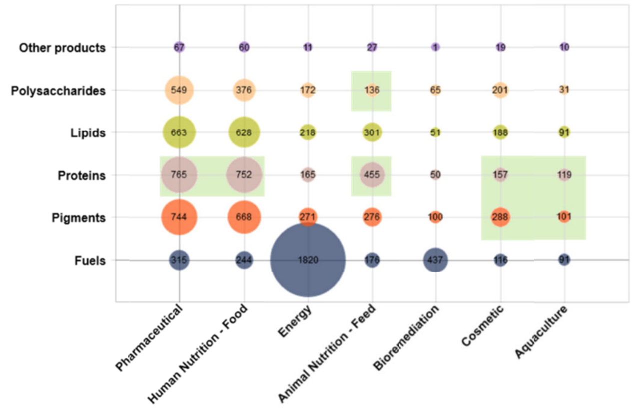


Figure 42 – Product-Applications: Cross-analysis matrix[16]

[16]CAGR in green correspond to the sectors for which the growth is at least three times higher compared to the average CAGR of the overall microalgae (CAGR 2009-2013: 10%)

ANNEX A – PATENT LANDSCAPE KEY WORDS

Microalgae

microalg+; microo-rganism / microbe photosynthetic+; phytoplankton; chlorella; porphyridium; haematococcus; monodus; botryococcus; isochrysis; gyrodinium; chlamydomonas; cyanospira; schizochytrium; pavlova; chaetoceros; thalassiosira; galdieria; thraustochytrium; odontella; spirulin+; phaeodactylum; euglena; nanochlor+; arthrospira; tetraselmis; scenedesmus; nannochlor+; navicula; nostoc; dunaliella; aphanizomenon; chrysophyc+; monochry+; crypthecodinium; skeletonema; nannochloropsis; cyanophy+; ochromonas; nitzschia; platymonas; cyanobact+; rhodophy+; xanthophyc+; haptophyc+; euglenophyc+; bacillariophy+; chlorophyc+; chlorophyt+; prasinophy+; prochlorophy+; diatomophy+; cryptophy+; eustigmatophy+; prymnesiophy+; dinophy+; thraustochy+; diatom

Cultivation

heterotroph+; mixotroph+; autotroph+; photo_autotroph+; cultiv*; culture*; grow*

Closed; open; Tubular?; Plastic?; bag?; Plate?; Horizontal; Circul+; raceway?; FPA; helical; vertical; PBR?; +reactor?; pond?; cultivation system+; photobioreactor?; ferment+ tank?; indoor / outdoor system+

Harvesting / Dewatering

+floccula+; flo?ta+; centrifug+; microfiltra+; ultrafiltra+; foam; ultrason+ 2d separa+; decant+; draining 2d tank?; mechanical 2d press; dryer?; drying; recov+; harvest+; dewater+

Extraction

solvent+; supercritical; enzymatic; osmotic shock; sonicat+; bead mill+; press+; microwave; PEF; pulsed electric field; ultrason+; mechanical; hydroly+; enzymolysis; membrane AND extraction; extracted; extracting; treatment; process

Conversion

+chemical+ 2d conversion; transesterification; liquefaction; pyroly?is; hydroprocess+; ga?ification; anaerobic; aerobic 2d digestion; methani?ation; fermentation; conversion 3d process+; refining and hydrogen; methane; glycerol; biodiesel; FAME; greenfuel; jetfuel; butanol

Lipids

OMEGA9; OLEIC; GADOLEIC; ERUCIC; NERVONIC; +OCTADECENOIC; GONDOIC; +EICOSENOIC; ELAIDIC; +EICOSATRIENOIC; +DOCOSENOIC; +TETRACOSENOIC; Omega3; linolenic; eicosapentaenoic; EPA; icosapenta*; timnodonic; docosahexaenoic; DHA; cervonic; Doconexent; stearidonic; eicosatrienoic; eicosatetraenoic; heneicosapentaenoic; docosapentaenoic; DPA; clupanodonic; tetracosapentaenoic; tetracosahexaenoic; Omega6; linoleic; GLA; calendic; eicosadienoic; DGLA; arachidonic; ARA; docosadienoic; docosapentaenoic; tetracosatetraenoic; omega7; palmitoleic; vaccenic; paullinic; ALA; PUFA?; MUFA?; fatty 2d acid?; lipid*; VLCFA;

Polysaccharides

polysaccha; disacchar*; algin*; *chito*; pullul*; hyaluro*; dermatan*; keratan*; *gl?can*; starch; polyoside?; polyholoside?; *dextran*; xanthan*; carbohydrat*; fructan; galactan; *mannan; *cellulo*; *pectin?; glycoge*; inulin; cellob*; EPS; fucoid*; gl?cosamine*; agar*or carraghen*; paramylon; Alguronic

Proteins

Prote*; aminoacid?; hydroly?ate?; farina; farine; flour; *peptide?; antibod*; chemok*; cytokine*; factor*

Pigments

xanthophy; Betalain?; *Flavonoid?; Betacyanin? pigment?; *caroten*; *Lutein*; *Lycope*; *xanthin*; *xanthophyl*; *Chlorophyl*; phycobil*; *Phycoerythrin; *Phycocyanin; Actinioerythrin; Astacein; Astacene; Azafrinaldehyde; Bacterioruberin; Bixin; Capsanthin; Capsorubin; *Chlorobactene; Crocetin*; Crocin; Cryptocapsin; Eschscholtzxan*; Flexixanthin; Foliachrome ; Hydroxyspheriodenone; Neochrome; Nonaprenoxanthin; Okenone; Paracentrone; Pectenolone; Peridinin; Phoeniconone; Phoenicopterone; Physalien; Phytofluene; Rhodopin*; Rhodovibrin; Rubixanthone; Siphonein; Spheroidene; Torularhodin*; Torulene; Trollichrome; Warmingone

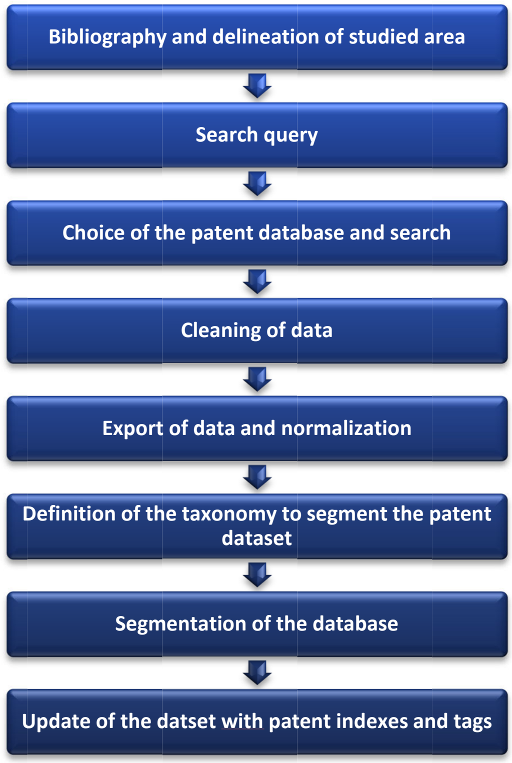
Fuels

fuel; *diesel*; *ethanol; *butanol; *propanol; *methan*; Hydrogen

Other valuable compounds

buildingblock?; *diacid?; succinic; fumaric; malic; FDCA; *furandicarbox*; hydroxypropionic; *HPA; aspartic; glucaric; glutamic; itaconic; levulinic; *butyrolac*; glycerol; sorbitol; xylitol; arabinitol; *oil?; *TOCOPHEROL*; *TOCOTRIENOL*; VITAMINE; retinol*; retinal; retinoic; retinyl; VITAMINA; *ascorbic; ascorbate; VITAMINc

ANNEX B – SEARCH STRATEGY



Search queries

For this study, the approach that was used is based on keywords exclusively. In fact, using IPC codes or particular CPC codes fails to improve the queries due the constraints inherent to the microalgae field, including:

- Too little use of the only IPC class which includes microalgae: less than 30% of the identified families are connected to the classes C12N-001, C12R -001, such classes being also not specific to microalgae.
- The cultivation and downstream processes for biomass treatment are transverse and apply, for some, to any type of microorganisms (bacteria, yeasts ...).
- For example, “C12M -001 apparatus for enzymology & microbiology”, “A01G -033 Cultivation of seaweed” are both major IPC classes that can be used among other things to describe photo-bioreactors implemented for cultivation of microalgae. These same systems can more rarely be described by the IPC relating to aquaponic system or wastewater ... all remote classes and not specific to the domain.

The following steps were used to create and refine the search methodology:

1. Creation of a query « microalgae »:

This query consists of scientific terms (taxonomy) and trivial words (common names).

- The scientific terms used, are based on the most represented geni and classes of the biological organisms taxonomy, within the scientific literature. The classes being a dominant level on the types, it allows the identification of types similar to those already known to have application and industrial interest.
- Trivial words correspond to: microalgae, photosynthetic organisms and phytoplankton. We know that some companies working in the area describe their microalgae products as "algal biomass" or "blue algae" or "red algae". These terms also being used to refer to macro-algae should not be used to avoid damaging the quality and relevance of the patent database.

2. Creation of queries in relation to up and downstream processes.

There are three main cultivation modes to grow microalgae using various growing systems. Microalgae may be genetically modified or not, harvested in different ways, and their molecules of interest extracted by different techniques depending on the molecule and its final use. These various processes therefore draw that a plurality of value chains can be implemented. Hence the strategy employed aims to create a query for each of these blocks, each containing different possible technological alternative. This is done through a literature review.

3. Creation of queries in relation to products.

Similarly to processes, microalgae are sources of many possible products (lipids, proteins, polysaccharides, biofuels and other molecules and extracts with high added value). Depending on the chosen IP strategy, we can either identify patents based only on processes, upstream and downstream of the value chain, or patents on very specific products derived from microalgae. Here again, requests are created with the help of a literature review and designed to encompass all feasible alternatives for the same product category.

Using this multi-pronged strategy, a search in the Fampat patent database (Questel Orbit), is performed using the specified keywords with Boolean operators (AND, OR and NOT) and also more complex search operators such as word truncation (in the middle or the end of a word), series of terms or searching for words in the same paragraph or within n words of each other. Searches are performed on title, abstract and first claim.

The patent searches were conducted in November 2015.

Patent dataset development: normalization

The patent dataset for analysis was created in Orbit, and then exported onto Questel’s Intellixir analytics platform, on which the dataset refinement and analysis was performed. Intellixir is a web application, running SaaS (Server as a Service), which analytical features make it then possible to measure, detect and highlight high-value information with the chosen, dynamic and interactive graphical representations.

This dataset was segmented as described in section 2.3. The dataset and segmentation process then underwent iterative process of expert review based on title and abstract screening, during which various classes of false positives were identified and eliminated where possible.

The applicant names were normalized. Indeed, the name of the applicant varies considerably both within a single entity and over time. For example, 3M can patent both under the acronym and as Minnesota Mining and Manufacturing Company. Even within these two distinctions, variations in syntax, spelling and formatting can create problems with formal accurate analysis of entity names. In addition, the acquisition of a company, or indeed the divestiture of subsidiaries can create issues with proper identification of patent ownership. Therefore, there is a requirement for grouping the various name variants that exist within the dataset, as well as research into mergers, acquisitions and subsidiaries to provide an accurate reflection of the ownership of patent rights within the landscape.

ANNEX C – TAXONOMY

Up and downstream processes

Cultivation mode → Growing technology → Harvesting / Dewatering → Extraction → Conversion

Cultivation mode

Autotrophy
Heterotrophy
Mixotrophy

Growing technology

Open System:
Circular Ponds
Raceway
...

Closed System
Closed ponds
Plastic bag PBR
Tubular PBR
Plate PBR
Horizontal PBR
Vertical PBR
Helical PBR
Fermentation Tank
...

Other Systems
...

Harvesting / Dewatering

Recovery :
Flocculation
Flottation
Centrifugation
Décantation
Microfiltration
Ultrafiltration
Ultrasonic sep.
Foam sep.
...

Dewatering
Draining tank
Mech. Press
...

Drying
Drum
Freeze
Rotary
Solar
Spray
...

Extraction

Mechanical:
Supercritical
PEF
Sonication
Bead milling
Press
Microwaves
Ultrasonic sep.
Foam sep.
Osmotic
...

Non-Mechanical
Solvent
Enzymatic
Hydrolysis
...

Conversion

Biochemical:
Anaerobic Dig..
Fermentation
...

Thermochemical
Liquefaction
Pyrolysis
Hydroprocessing
Gasification
...

Transesterification

Products

Products	
Lipids	Essential fatty acids, Non essentials fatty acids, Sterols and Phytosterols, Others
Proteins	Peptides, Amino acids, Hydrolysates and Flour, Enzymes
Pigments	Carotenoids, Phycobiliproteins, Chlorophyls
Polysaccharides	-
Fuels	Biofuel & Biodiesel; Ethanol & other alcohols; Gases
Others	Vitamins, Caarboxylic acids, Chemical bulding blocks

Application

- Human Nutrition
- Animal Nutrition
- Aquaculture
- Cosmetics
- Bioremediation
- Energy
- Pharmaceuticals

ANNEX D – GLOSSARY

Fampat patent family: defined as an “invention-based family”, the family definition (from Questel) incorporates the EPO’s strict family rule (same priority application(s)) with additional rules (Applications falling outside the 12 month filing limit; Links between EP and PCT publications…)

Patent application: To obtain a patent, an application must be filed in the appropriate Patent Office with all the necessary documents and fees. The patent office will conduct an examination to decide whether to grant or reject the application. Patent applications are generally published 18 months after the earliest priority date of the application. Prior to that publication, the application remains confidential.

Granted patent: once examined by the patent office, an application becomes a granted patent or is rejected. If granted, the patent gives to his owner a temporary right for a limited time period (normally 20 years) to prevent unauthorized use of the technology outlined in the patent. Procedure for granting patents varies widely between countries according to national laws and international agreements in a same patent family, an application can be granted in a country and rejected in an other.

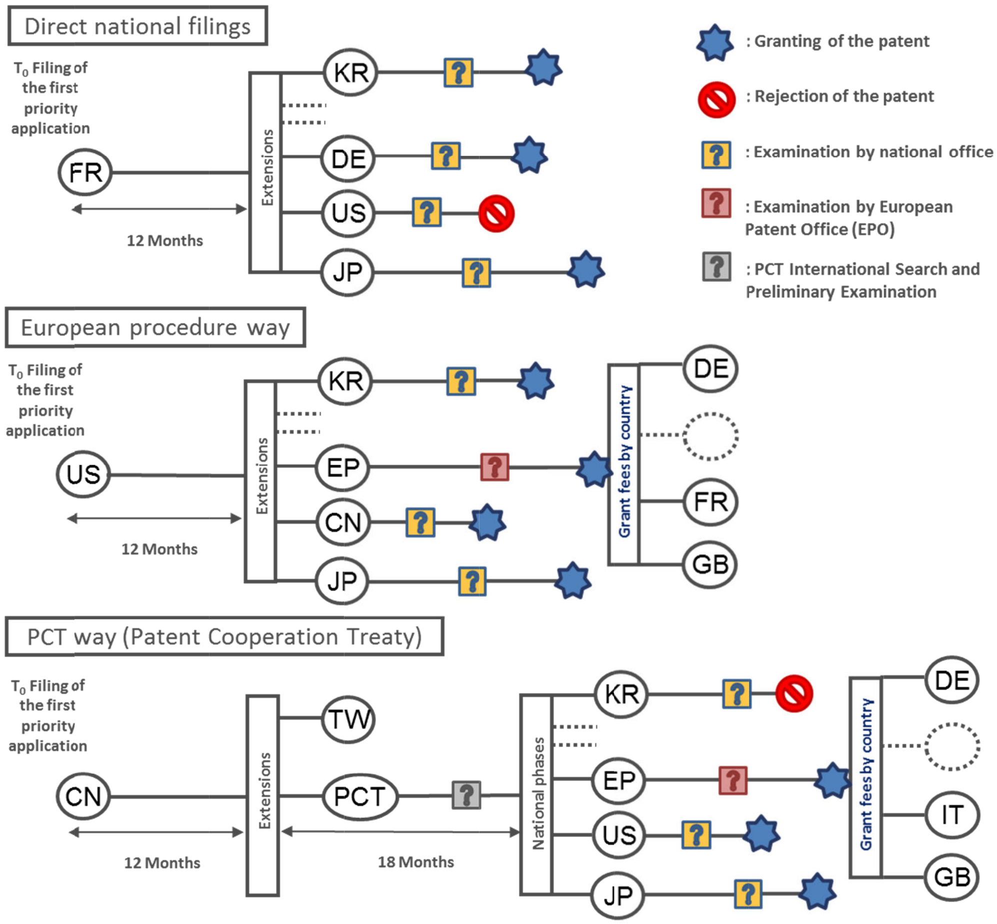
PCT (WO): The Patent Cooperation Treaty (PCT) is an international patent law treaty concluded in 1970, administered by the World Intellectual Property Organization (WIPO), between more than 140 Paris Convention countries. The PCT makes it possible to seek patent protection for an invention simultaneously in each of a large number of countries by filing a single “international” patent application instead of filing several separate national or regional patent applications. The granting of patents remains under the control of the national or regional patent Offices in what is called the “national phase”.

European patent (EP): A European patent can be obtained for all the EPC countries by filing a single application at the EPO in one of the three official languages (English, French or German). European patents granted by the EPO have the same legal rights and are subject to the same conditions as national patents (granted by the national patent office). A granted European patent is a “bundle” of national patents, which must be validated at the national patent office to be effective in member countries. The validation process could include submission of a translation of the specification, payment of fees and other formalities at the national patent office. Once a European patent is granted, competence is transferred to the national patent offices.
Other regional patents or procedures also exist: the Eurasian patent (EA), ARIPO patent (AP) for English-speaking Africa and OAPI patent (OA) for French-speaking Africa.

Office of first filing (OFF): The country where the first application was filed – this is taken to be the earlier priority country.

Office of second filing (OSF): This is the jurisdictions where subsequent family members of a patent were filed. Here each application/patenting country in a family of counted only once, even when more than one patent from that family is filed in the country. The office of first filing is also not included here.

Patent filing procedures:



Patent Applicant: The organization to which a patent is assigned ownership; typically, the inventor's employer.

Patent Citation: During patent examination/filing procedures, the examiner and/or the applicant will reference relevant patents or patent applications that currently exist in the public domain. Reversing this process allows for the analysis of the number these downstream citations an individual patent family has obtained over the course of its publication period. Patents with greater numbers of citation events are generally thought to be more impactful in their field, though individual data artifacts (such as citation bias) can occur and need to be accounted for.

Patent Claims: The section of a patent specification that contains the claimed invention by the inventor. Patent Search The process of collating a dataset containing patent records of relevance.

Priority Filing: The first location in which a particular invention has a patent application filed. Also known as Office of First Filing (OFF).

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