CEPIUG
10th Year Anniversary Conference
Milano, Italy, 9-11 September 2018

CO_2 capture and storage technologies: an overview based on patent literature

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Outline

- Background: CO_2 capture and storage technologies
- Issue and Objectives of the analysis
- Patent Search Methodology
- Results
- Preliminary assessment of the maturity level of CO_2 capture and storage technologies
- Conclusions

Background: CO_2 capture and storage technologies (1)

- CO_2 is one of the major greenhouse gases and is related to global warming. Therefore, CO_2 removal is of great importance;
- CO_2 can be also seen as a value-added reagent in organic synthesis;
- Many reviews on this topic have been published in the scientific literature but very few articles on patented innovations on CO_2 capture.

- [1] "*CO_2 capture technologies: an overview with technology assessment based on patents and articles*" (2011): the search was carried out by using keywords and patent classification (B01D 53 code); scholars found that **adsorption and absorption are the most used capture technologies**, while post-combustion is the most used capture process;
- [2] "*Advances in CO_2 capture technology: a patent review*" (2013): more patents on **solvent and solid sorbents** were found, less patents on membranes;
- [3] "*Evolution of CO_2 capture technology between 2007 and 2017 trough the study of patent activity*" (2018): scholars used only CPC codes (Y02C 10+, B01D 2257/504 and B01D 53/62) for their search; most patent activity is related to absorption (Y02C 10/06 ~ 30%) and **adsorption** (Y02C 10/08 ~ 35%).

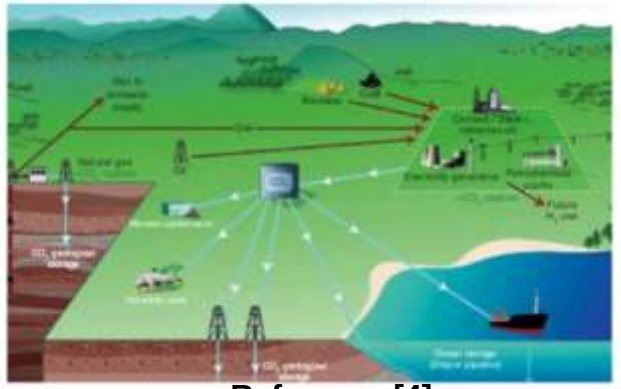
Background: CO_2 capture and storage technologies (2)

CO_2 emissions could be reduced by 80 – 90 % if a modern power plant was equipped with suitable CCS (carbon capture and storage) technologies.
CCS is a three step-step process:

- CO_2 is captured directly from the industrial source, separated from other emissions, concentrated into a nearly pure form and compressed to a pressure of about 100 bar into a liquid state;
- CO_2 is transported through pipelines or ships to a storage location;
- CO_2 is then pumped deep underground (in geological formations or the ocean) for long-term storage.

CO_2 can be captured directly from industrial plants by one of these methods:

- Pre-combustion;
- Oxy-fuel combustion;
- Post-combustion.



Reference [4]

There are three basic technologies for CO_2 separation:

- **Absorption**
- **Adsorption**
- **Membranes**

Issue and Objectives of the analysis (I)

Some papers refers to patent literature to review the state of the art of CO_2 capture and storage

Y02C 10/00	**CO_2 capture or storage** (not used, see subgroups)
Y02C 10/02	• Capture by biological separation
Y02C 10/04	• Capture by chemical separation
Y02C 10/06	• Capture by absorption
Y02C 10/08	• Capture by adsorption
Y02C 10/10	• Capture by membranes or diffusion
Y02C 10/12	• Capture by rectification and condensation
Y02C 10/14	• Subterranean or submarine CO_2 storage

CPC classification codes related to CO_2 capture and storage technologies are well suited!

A total number of ~ 10.000 patent families

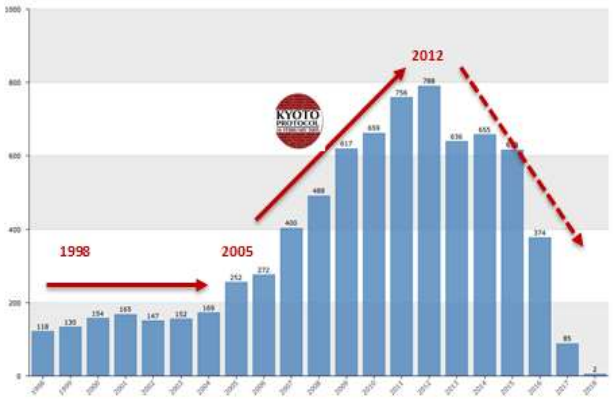
… What about inventions in patents not classified with CPC codes?

Repartition by CPC codes

No. patent families/CPC codes

Repartition by 1° priority year

No. patent families/1° priority years (1998-2017)



Three main periods

The Kyoto Protocol

1997: The Protocol was adopted

2005: It entered into force

2012: End of the 1° commitment period

Issue and Objectives of the analysis (II)

Objectives of the analysis

- Are there any specific IPC codes for CO2 capture?
- What are possible gaps and overlaps between IPC and CPC classification codes for such technologies?
- How to retrieve a pool of worldwide documents as consistent as possible with the topic of the research?

Source: Orbit Intelligence by Questel

Patent Search Methodology (1)

Search criteria:

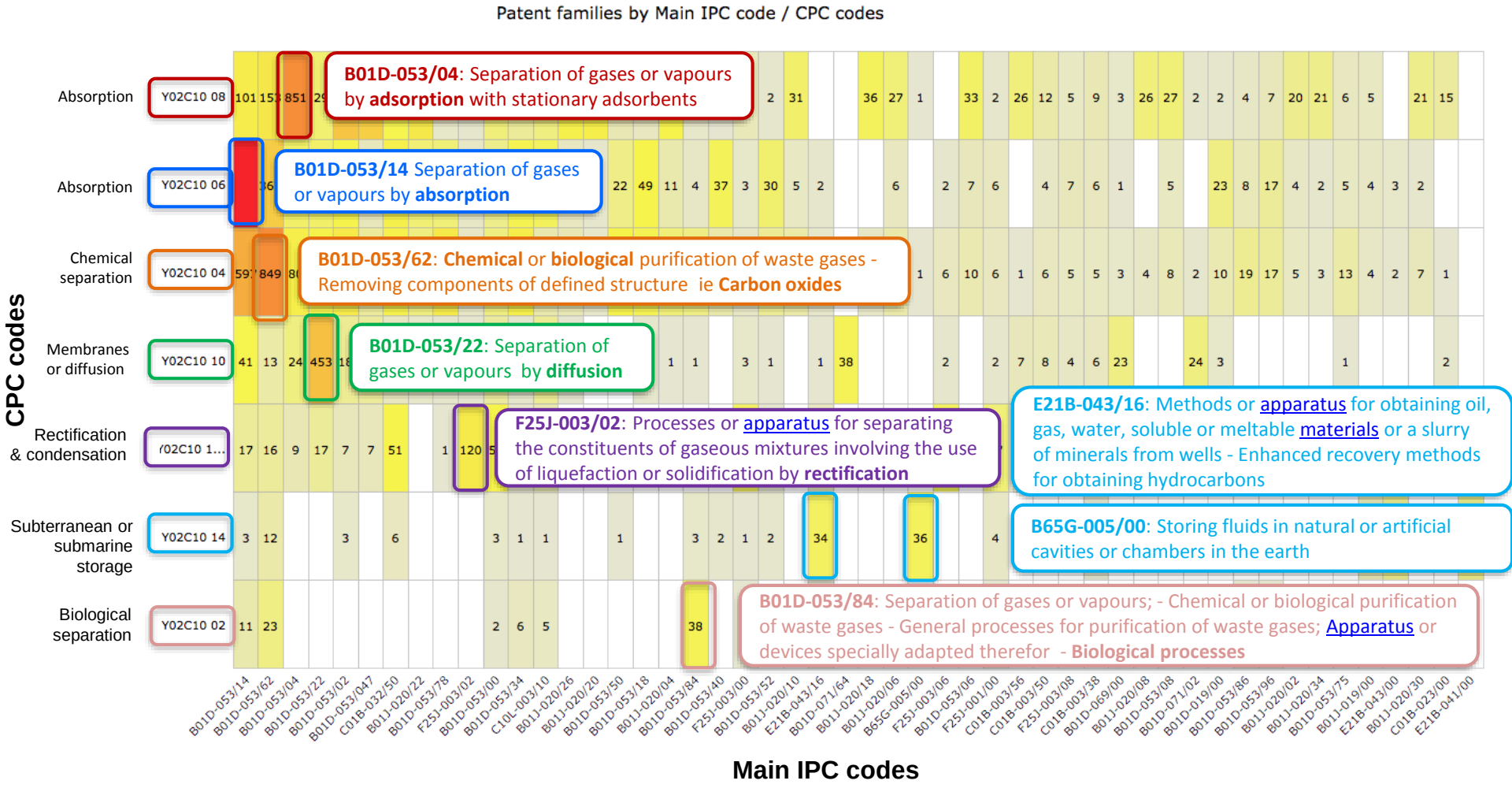
- CPC codes;
- Keywords;
- Date range

Steps:

1. Top 50 IPC codes from the starting CPC pool + graphical analysis;
2. Top Keywords from the starting CPC pool + linked relevant concepts
3. Additional Keywords : *(carbon 1d dioxide) or (CO2) AND (captur? or storage)*
4. Alive patent families
5. Time range: from 2013

Patent Search Methodology (2)

STEP 1: Top 50 IPC codes from the starting CPC pool (95,5%) + **graphical analysis**;



Methodology: Patent Search Strategy (3)

STEP 2: Top Key words from the starting CPC pool + linked relevant concepts

STEP 3: Additional Key words : *(carbon 1d dioxide) or (CO2) AND (captur? or storage)*

CPC codes > 10 011 patent families

(Y02C-010/02+ OR Y02C-010/04+ OR Y02C-010/06+ OR Y02C-010/08+ OR Y02C-010/10+ OR Y02C-010/12+ OR Y02C-010/14+)/**CPC**

OR

Identified IPC codes and Key words > 11 226 patent families

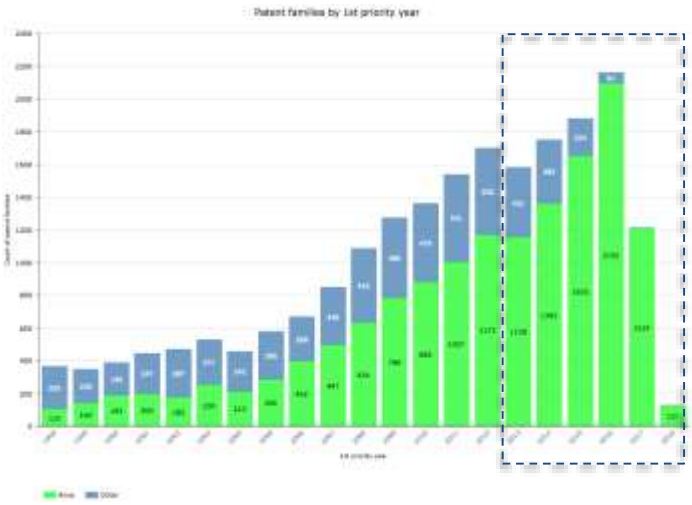
((((CARBON 1D DIOXIDE) OR "CO2")/TI/AB/IW/CLMS/ICLM S ((CAPTUR? OR SEPARATION OR RE_UTILISATION OR STORAGE OR RE_USE)/**TI/AB/IW/CLMS/ICLM**)) AND (B01D-053/62 OR B01D-053/14 OR B01D-053/04 OR C01B-032/50 OR B01D-053/02 OR B01D-053/22 OR B01D-053/047 OR B01D-053/34 OR B01D-053/78 OR C10L-003/10 OR B01J-020/30 OR B01D-053/18 OR B01J-020/22 OR B01D-053/96 OR F25J-003/02 OR B01J-020/28 OR B01D-053/00 OR B01D-053/26 OR B01J-020/34 OR C01B-003/56 OR B01D-053/77 OR B01D-053/52 OR B01D-053/50 OR F25J-003/08 OR B01J-020/18 OR B01J-020/04 OR B01J-020/26 OR B01D-053/86 OR B01J-020/20 OR F25J-003/06 OR B01D-067/00 OR B01D-071/02 OR B01J-020/10 OR B01D-053/75 OR C01B-003/50 OR B01D-053/40 OR B01D-053/56 OR F25J-001/00 OR B01D-069/12 OR B01J-019/00 OR F23J-015/00 OR B01J-020/06 OR B01D-053/84 OR B01J-020/32 OR F25J-003/00 OR F25J-003/04 OR C01B-013/02 OR B01D-069/10 OR C01B-021/04 OR B01J-020/02 OR B01D-019/00 OR C01B-032/40 OR B01D-071/64 OR C01B-003/38 OR C01B-003/52 OR B01D-053/81 OR B01J-020/08 OR H01M-008/06 OR C01B-031/20 OR B01D-053/74 OR B01D-053/48 OR B01D-053/06 OR C01B-023/00 OR C07C-007/11 OR C01F-011/18 OR F23J-015/04 OR C10K-001/12 OR C07C-007/12 OR B01D-053/73 OR C01B-017/16 OR C07C-009/04 OR C12M-001/00 OR F25J-001/02 OR C01B-003/02 OR C01B-003/48 OR B01D-069/00 OR C01B-032/60 OR C10K-001/14 OR B01D-053/46 OR B01D-053/60 OR F23J-015/02 OR C10K-001/00 OR B01D-053/83 OR B01D-069/02 OR B01D-061/00 OR F01N-003/08 OR F17C-011/00 OR B01D-053/92 OR B01D-069/08 OR C01B-003/34 OR B01D-053/32 OR B01D-063/02 OR C10K-001/16 OR B01D-053/72 OR C07C-007/00 OR B01D-047/00 OR B01D-071/06 OR B01D-071/70 OR B01D-069/14 OR C09K-003/00)/**IPC**)

OR

Key words and technological domains > 19 576 patent families

(((CARBON 1D DIOXIDE) OR "CO2")/TI/AB/IW/CLMS/ICLM S (CAPTUR? OR SEPARATION OR RE_UTILISATION OR STORAGE OR RE_USE?)/**TI/AB/IW/CLMS/ICLM)** AND ("ENVIRONMENTAL TECHNOLOGY" OR "CHEMICAL ENGINEERING" OR "BASIC MATERIALS CHEMISTRY" OR "BIOTECHNOLOGY" OR "ORGANIC FINE CHEMISTRY" OR "MACROMOLECULAR CHEMISTRY, POLYMERS")/**TECT**

26,617 patent families



STEP 4. ALIVE legal state

14,737 patent families

STEP 5. Since 2013

Earliest applications date EAPD

7,993 patent families

"COMPLETE" dataset

(*) CPC only + Alive status + since 2013 = 2,200 patent families

Results: Who are the key players?

"CPC only" dataset (*):

1	ExxonMobil 76 |**10,2%**
2	Mitsubishi 52 |**7%**
3	Korea Ins. of Energy research 51 |**6,8%**
4	Air liquide 45 |**6%**
5	Sinopec 41| **5,5%**
6	**UOP Honeywell** 39 |**5,2%**
7	**Korea Electric Power** 32 |**4,3%**
8	Tianjin university 31 |**4,2%**
9	Fujifilm 29 |**3,9%**
10	**Toshiba** 28 |**3,7%**

"Complete" dataset:

1	Sinopec 142 |**10,1%**
2	ExxonMobil 98 |**7%**
3	Mitsubishi 85 |**6%**
4	Air liquide 79 |**5,6%**
5	Korea Ins. of Energy research 72 |**5,1%**
6	Tianjin university 67 |**4,8%**
7	Fujifilm 55 |**3,9%**
8	**Linde** 55 |**3,9%**
9	**Zhejian University** 54 |**3,8%**
10	**General Electric** 49 |**3,5%**

14 UOP | **3,1%**
13 Toshiba |**3,1%**
17 Korea Electric Power |**2,6%**

Influencing Players ?

ExxonMobil, Sinopec and Fujifilm

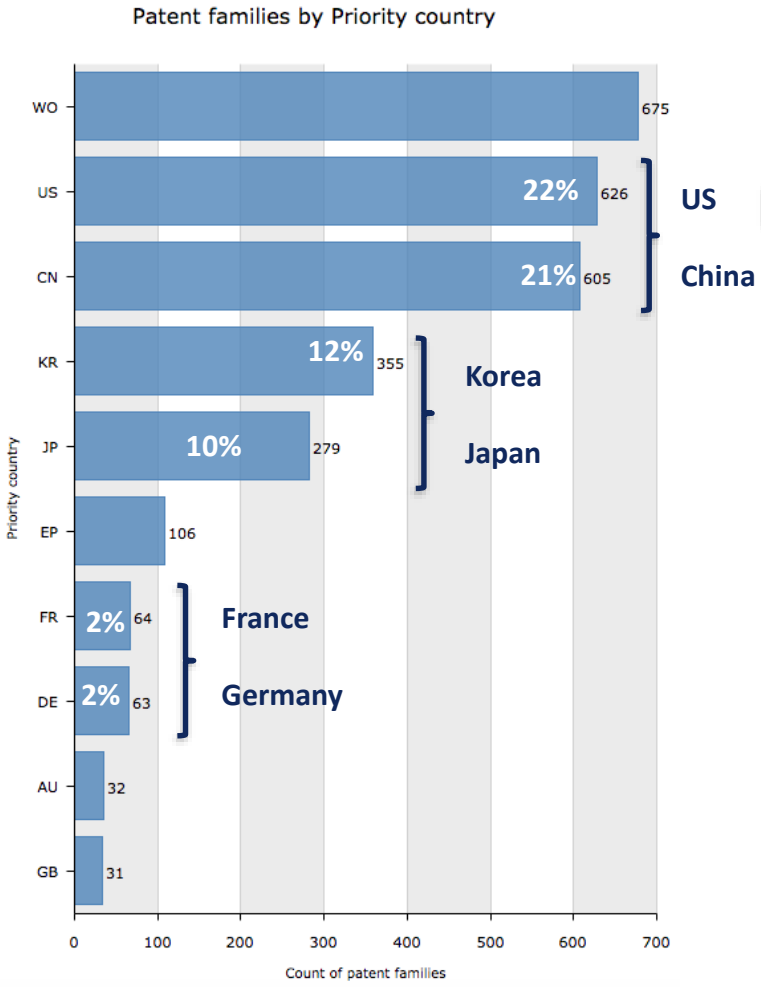
ExxonMobil, Sinopec and Fujifilm

- Mainly Oil & gas companies
- Academic players in Korea and China
- Leaders: ExxonMobil and Sinopec

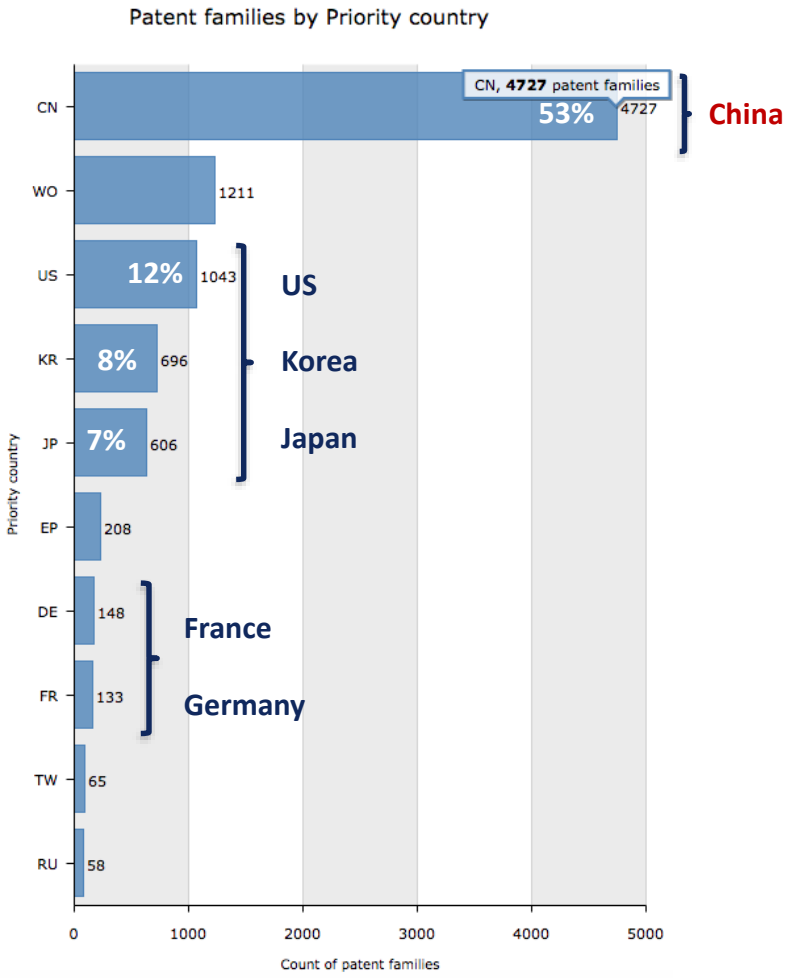
- !! Assignee grouping influence the ranking
- Adding IPC codes > more Chinese actors in the analysis

Results: Research & Development location?

"CPC only" dataset:



"Complete" dataset:

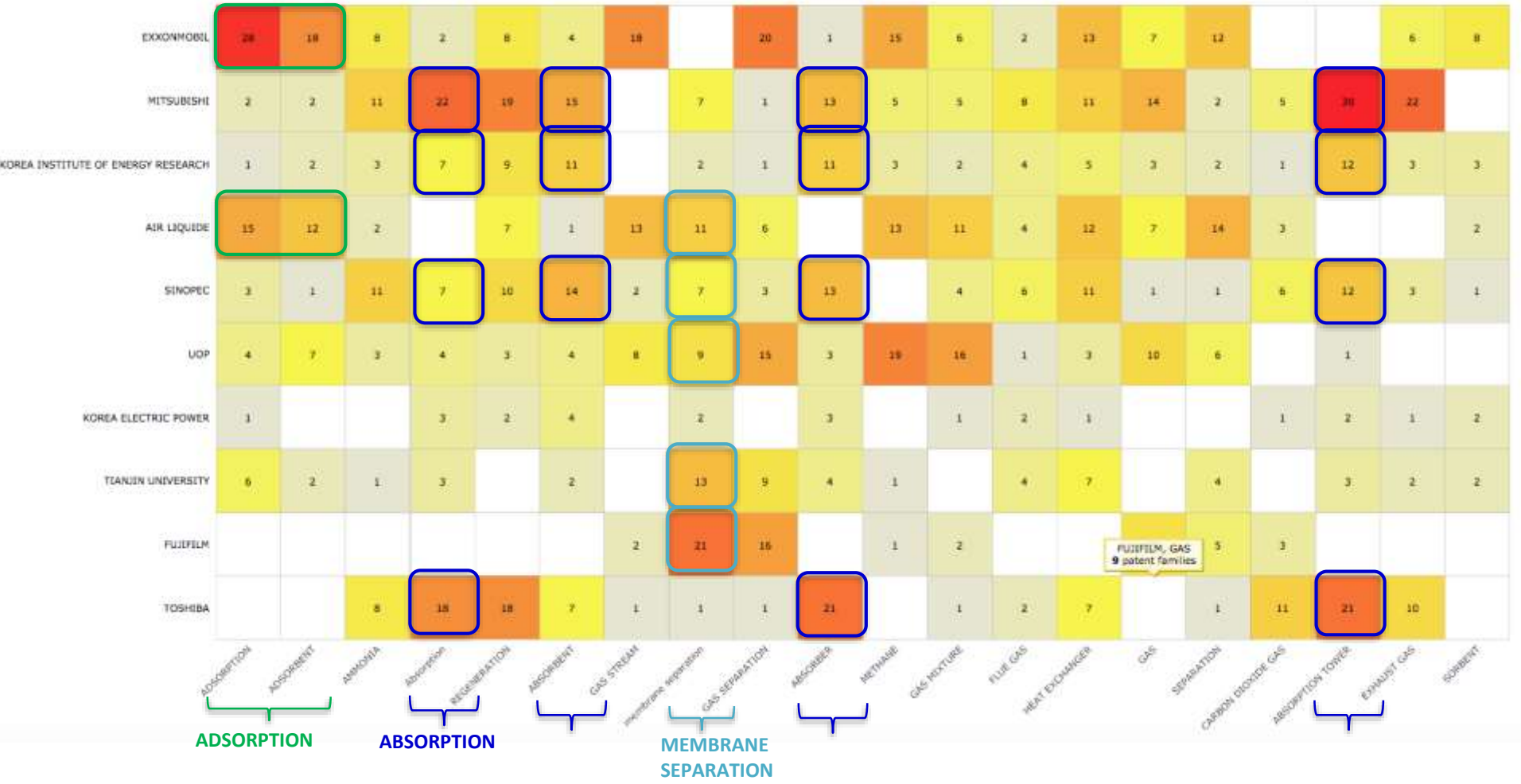


- **China**, US,
- Korea, Japan
- Germany, France

- Adding IPC codes > more Chinese patents in the analysis

Results: Top players positioning by process (1)

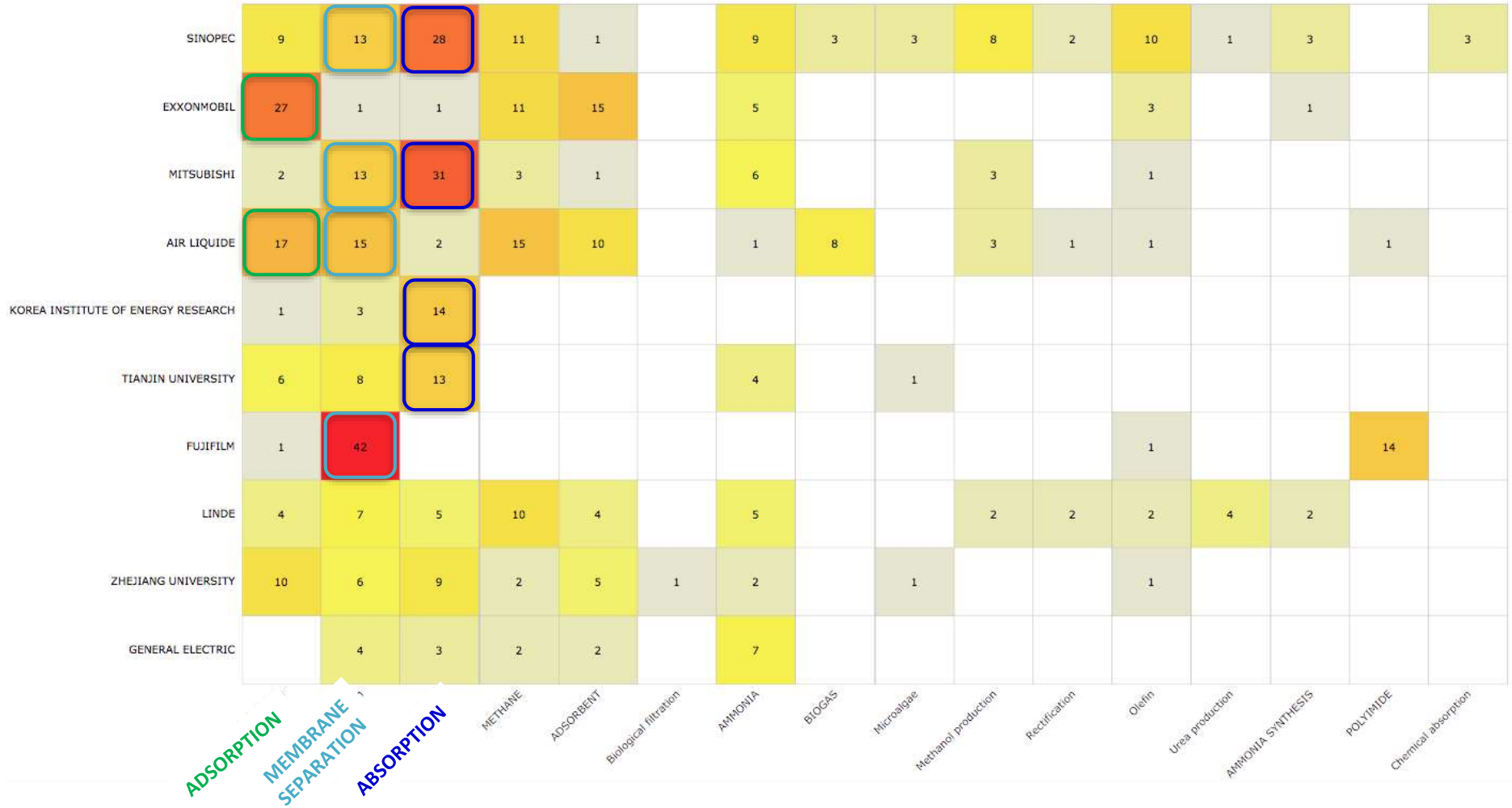
“CPC only“ dataset:



- Exxonmobil: Adsorption
- Mitsubishi: Absorption
- Fujifilm: Membranes
- Korea Institute of technology: Absorption
- Air Liquide: Adsorption and Membranes
- Sinopec: Absorption and Membranes

Results: Top players positioning by process (2)

“Complete“ dataset:



- Exxonmobil: Adsorption
- Mitsubishi: Absorption and **Membranes**
- Fujifilm: Membranes
- Korea Institute of technology: Absorption
- Air Liquide: Adsorption and Membranes
- Sinopec: Absorption and Membranes

Results: Key & emerging technologies(1)

Patent value Index

- Nb of **forward citations** corrected with **age** and **technical domain**
- **GDP** of the **countries** where the analyzed patent families are granted or pending.

"CPC only" dataset:

Title	Applicant/Assignee	Publication number	1st Publ. date	Patent value	Market cov.	Non-self fwd cit.	Radicalness	Originality	Generality
Synthesis of zsm-58 crystals with improved morphology	EXXONMOBIL*	EP2928579	2014-06-12	5.14	2.8	3	0.99	0.87	0.9
Material itq-55 and method for preparation	EXXONMOBIL*	EP3157869	2015-12-22	5.04	3.01	2	0.99	0.93	0.86
A method for upgrading a gas	RE N TECHNOLOGY*	EP2794062	2013-07-18	4.95	3.1	3	0.99	0.89	0.85
Apparatus and method for oxy-combustion of fuels in internal combustion engines	SAUDI ARABIAN OIL*	EP2828502	2013-09-26	4.92	2.65	6	0.99	0.94	0.9
Integration of pressure swing adsorption with a power plant for co2 capture/utilization and n2 production	EXXONMOBIL RESEARCH & ENGINEERING*	EP2861325	2013-12-19	4.9	2.47	5	0.99	0.95	0.92
Anhydrous, amorphous and porous magnesium carbonates and methods of production thereof	DISRUPTIVE MAT*	EP2928830	2014-06-12	4.77	2.58	4	0.99	0.91	0.92
Purification of air	AIR PRODUCTS & CHEMICALS*	EP2803401	2014-11-19	4.74	2.29	10	1	0.8	0.77
System and method for carbon dioxide capture and sequestration	CHICHILNISKY GRACIELA*	EP2867600	2013-11-07	4.7	2.28	3	0.99	0.94	0.89
Zeolitic imidazolate framework material, methods for making same, and uses thereof	EXXONMOBIL*	EP2831087	2013-10-03	4.54	2.25	7	0.99	0.9	0.87
Mitigating leaks in membranes	KING FAHD UNIVERSITY OF PETROLEUM & MINE MIT - MASSACHUSETTS INSTITUTE OF TECHNOL	EP3062914	2015-05-07	4.54	1.71	16	0.97	0.94	0.9
Control of gas composition of a gas separation system having membranes	EVONIK FIBRES*	EP2919888	2014-05-22	4.48	2.38	4	0.99	0.84	0.89
Magnetic activated carbon and methods for preparing and regenerating such materials	BIOKOL LILLIESTRÄ**LE*	EP2885076	2014-02-20	4.39	1.93	15	1	0.88	0.84
Low-pressure drop structure of particle adsorbent bed for gas adsorption separation process	CLIMEWORKS*	EP2986357	2014-10-23	4.38	2.11	4	0.99	0.89	0.87
Mixed matrix polymer compositions	CSIRO COMMONWEALTH SCIENTIFIC & INDUSTRI UNIVERSITY OF COLORADO*	EP2922618	2014-05-30	4.37	2	8	0.98	0.92	0.88
Aqueous solution which efficiently absorbs and recovers carbon dioxide in exhaust gas, and method for recovering carbon dioxide using same	NIPPON STEEL & SUMITOMO METAL*	EP2813277	2013-08-15	4.35	2.5	3	0.96	0.88	0.84
Integrated method of driving a co2 compressor of a co2-capture system using waste heat from an internal combustion engine on board a mobile source	SAUDI ARABIAN OIL*	EP2888460	2014-02-27	4.32	2.52	2	0.99	0.94	0.86
Operation of a gas turbine power plant with carbon dioxide separation	ANSALDO ENERGIA*	EP2837778	2015-02-18	4.26	2.34	4	0.99	0.89	0.95
Carbon sequestration methods and systems, and compositions produced thereby	BLUE PLANET*	EP2892635	2014-03-13	4.21	1.75	9	0.99	0.94	0.91
Removal of hydrogen and carbon monoxide impurities from gas streams using a copper and manganese based catalyst	AIR PRODUCTS & CHEMICALS*	EP2789376	2014-08-31	4.21	2.64	2	0.99	0.87	0
Dry processes, apparatus, compositions and systems for reducing sulfur oxides and hcl	FUEL TECH*	EP2833989	2013-10-03	4.21	2.19	4	0.99	0.9	0.82
Acidic gas separation module, acidic gas separation device, and telescope prevention plate	FUJIFILM*	EP2902090	2014-04-03	4.2	2.05	3	0.97	0.8	0.83
System and method for concentrating gas by adsorption	INVACARE*	EP2822671	2013-09-12	4.19	1.96	6	0.99	0.86	0.8
Carbon dioxide capturing system and method of operating same	TOSHIBA* TOSHIBA PLANT SYSTEMS & SERVICES*	EP2668993	2013-12-04	4.13	2.32	4	0.99	0.85	0.72
Separation membranes formed from perforated graphene	LOCKHEED MARTIN*	EP3116625	2015-09-17	4.12	1.83	3	0.98	0.98	0.91
Manufacturing method for composite membrane for acid gas separation, and membrane module for acid gas separation	FUJIFILM*	EP2979749	2014-10-02	4.1	2.1	2	0.98	0.95	0.83

- ExxonMobil+++
- Identification of key actors:

- Technologies regarding zeolitic compounds, membranes ++, pressure swing adsorption, …

Results: Key & emerging technologies (2)

"Complete" dataset:

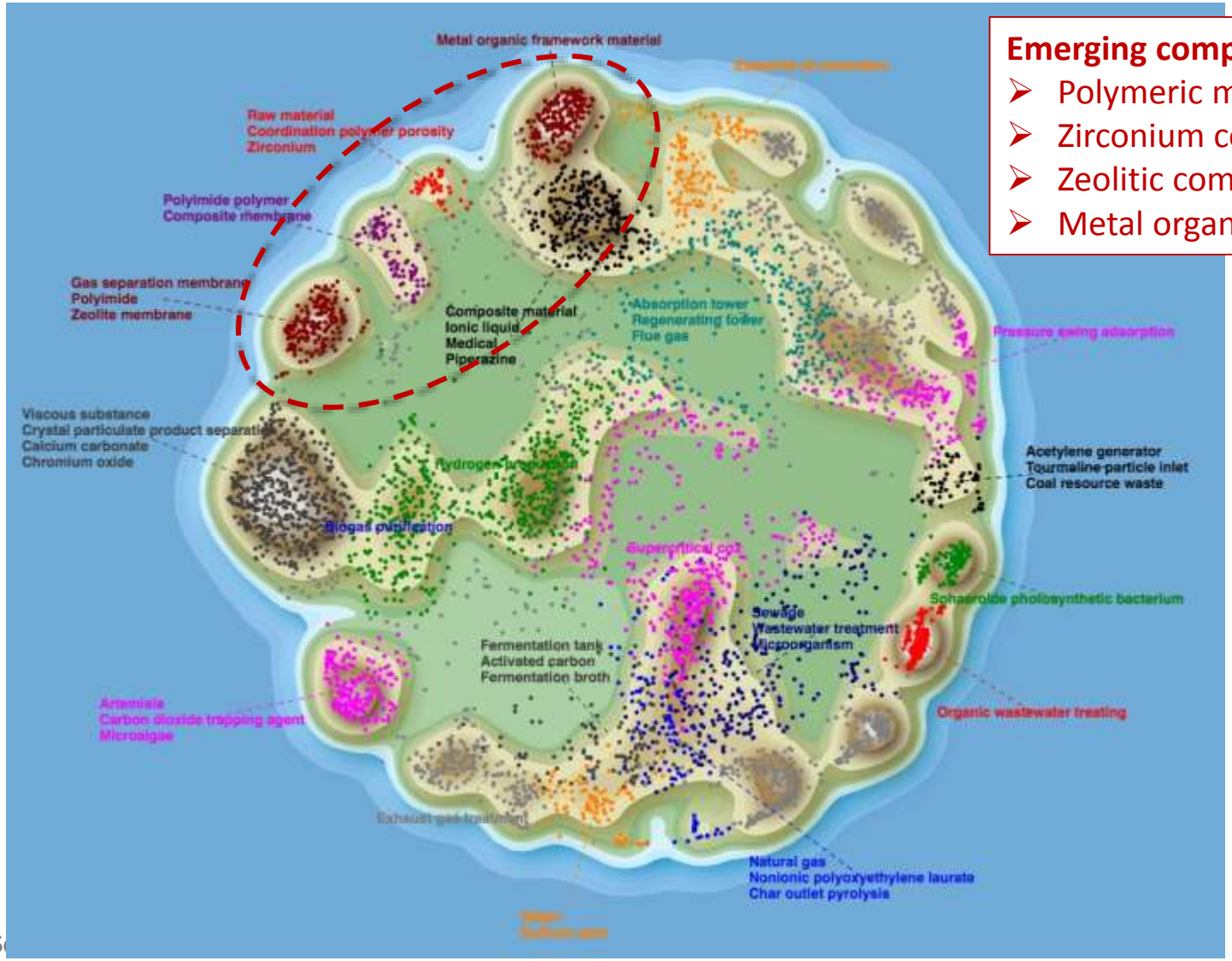
Patent value Index

Title	Applicant/Assignee	Publication number	1st Publ. date	Patent value	Market cov.	Non-self fwd cit.	Radicalness	Originality	Generality
Fuel cell integration within a heat recovery steam generator	EXXONMOBIL*	EP2973819	2014-09-18	5.97	2.86	10	1	0.9	0.96
Electrolyte formulations for use in biocompatible energization elements	JOHNSON & JOHNSON VISION CAR	EP2988358	2015-09-01	5.41	2.57	8	0.99	0.92	0.93
Synthesis of zsm-58 crystals with improved morphology ⬅	EXXONMOBIL*	EP2928579	2014-06-12	5.1	2.78	3	0.99	0.87	0.9
Material itq-55 and method for preparation ⬅	EXXONMOBIL*	EP3157869	2015-12-22	4.99	2.97	2	0.99	0.93	0.86
Carbon dioxide conversion to hydrocarbon fuel via syngas production cell harnessed from solar radiation	SAUDI ARABIAN OIL*	EP2941475	2014-07-10	4.97	2.18	15	0.99	0.95	0.92
A method for upgrading a gas ⬅	RE N TECHNOLOGY*	EP2794062	2013-07-18	4.96	3.11	3	0.99	0.89	0.85
Substituted oxopyridine derivatives and their use in the treatment of cardiovascular diseases	BAYER PHARMA*	EP2978756	2014-10-02	4.95	2.52	5	0.99	0.76	0.74
Integration of pressure swing adsorption with a power plant for co2 capture/utilization and n2 production ⬅	EXXONMOBIL RESEARCH & ENGIN	EP2861325	2013-12-19	4.9	2.47	2	0.99	0.95	0.92
Apparatus and method for oxy-combustion of fuels in internal combustion engines ⬅	SAUDI ARABIAN OIL*	EP2828502	2013-09-26	4.89	2.62	6	0.99	0.94	0.9
System and method for diffusion combustion with fuel-diluent mixing in a stoichiometric exhaust gas recirculation gas turbine system	EXXONMOBIL UPSTREAM RESEAR	EP2914828	2014-05-08	4.85	1.99	9	1	0.93	0.92
Anhydrous, amorphous and porous magnesium carbonates and methods of production thereof ⬅	DISRUPTIVE MAT*	EP2928830	2014-06-12	4.73	2.55	4	0.99	0.91	0.92
Partial oxidation reaction with closed cycle quench	8 RIVERS CAPITAL* PALMER LABS*	EP2812417	2013-08-15	4.71	2.7	2	0.99	0.95	0.92
Beverage dispensing apparatus with a carbonation system	STRAUSS WATER*	EP2861521	2014-03-12	4.71	2.54	3	0.97	0.89	0.85
System and method for carbon dioxide capture and sequestration ⬅	CHICHILNISKY GRACIELA*	EP2867600	2013-11-07	4.7	2.28	3	0.99	0.94	0.89
Redox flow battery for hydrogen generation	EOS HOLDING ENERGIE OUEST SU	EP2823528	2013-09-12	4.64	2.55	6	0.99	0.76	0.73
Water treatment process and water treatment system	TOSHIBA* TOSHIBA ELECTRONIC DEVICES &	EP3002260	2015-01-08	4.62	2.43	5	1	0.87	0.92
Purification of air ⬅	AIR PRODUCTS & CHEMICALS*	EP2803401	2014-11-19	4.55	2.23	8	1	0.8	0.76
Zeolitic imidazolate framework material, methods for making same, and uses thereof ⬅	EXXONMOBIL*	EP2831087	2013-10-03	4.54	2.25	7	0.99	0.9	0.87
Mitigating leaks in membranes ⬅	KING FAHD UNIVERSITY OF PETRC MIT - MASSACHUSETTS INSTITUTE	EP3062914	2015-05-07	4.54	1.71	16	0.97	0.94	0.9
Process for the production of chemical compounds from carbon dioxide	HALDOR TOPSOE*	EP2844614	2013-11-07	4.49	2.88	2	0.97	0.91	0
Integrated hydroprocessing, steam pyrolysis catalytic cracking process to produce petrochemicals from crude oil	SAUDI ARABIAN OIL*	EP2828361	2013-09-26	4.48	2.14	8	0.95	0.78	0.83
Removing carbon nanotubes from a continuous reactor effluent	EXXONMOBIL UPSTREAM RESEAR SOLID CARBON PRODUCTS*	EP2838840	2013-10-24	4.48	1.91	16	0.98	0.93	0.9
Control of gas composition of a gas separation system having membranes ⬅	EVONIK FIBRES*	EP2919888	2014-05-22	4.48	2.38	4	0.99	0.84	0.9
Refrigerator equipped with apparatus for producing carbonated water	SAMSUNG ELECTRONICS*	EP2772714	2014-08-28	4.44	2.42	3	0.95	0.86	0.86
Flexibly operable power plant and method for the operation thereof	MITSUBISHI HITACHI POWER SYST	EP3019581	2015-01-15	4.44	2.82	1	0.99	0.95	0

- 11 patent families already identify using the CPC classification only (⬅)
- Remaining families > not relevant?

Results: Key & emerging technologies (3)

- Landscape map limited to the last 3 years – 5500 families
- Concept grouping & exclusion (CO2, capture, separation, storage)



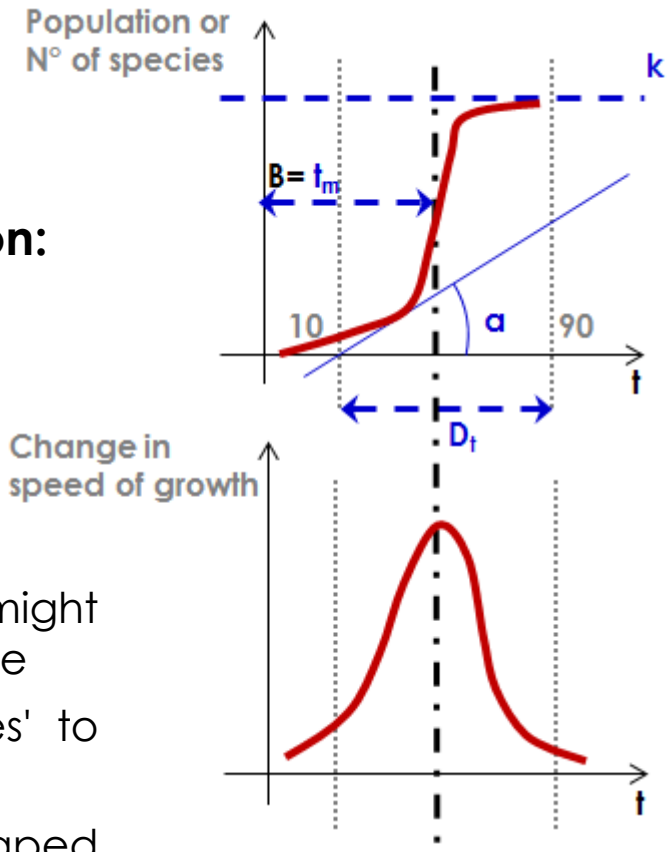
Emerging compounds:

- Polymeric membranes, polyimide
- Zirconium compounds
- Zeolitic compounds
- Metal organic framework (MOF)

Preliminary assessment of the maturity level of CO2 capture technologies (I)

Technology Forecasting based on trend extrapolation: logistic curve

$$N(t) = \frac{K}{1 + e^{-\alpha t - \beta}}$$



Growth under competition

- Natural growth of autonomous systems in competition might be described by LOGISTIC EQUATION and logistic S-curve
- Natural growth is defined as the ability of a 'species' to multiply in finite 'niche capacity'
- For socio-technical systems the 3-parameter S-shaped growth model is applied for describing "trajectories" of growth or decline in time.

The logistic growth model has proved useful in modeling a wide range of phenomena in economic, social, technological and environmental context and can be applied for technological forecasting.

Parameters and their meaning on the chart:

a growth rate parameter ➔ slope of the curve;

β location parameter ➔ it shifts the function in time;

K carrying capacity (or saturation parameter) ➔ the asymptotic limit of growth.

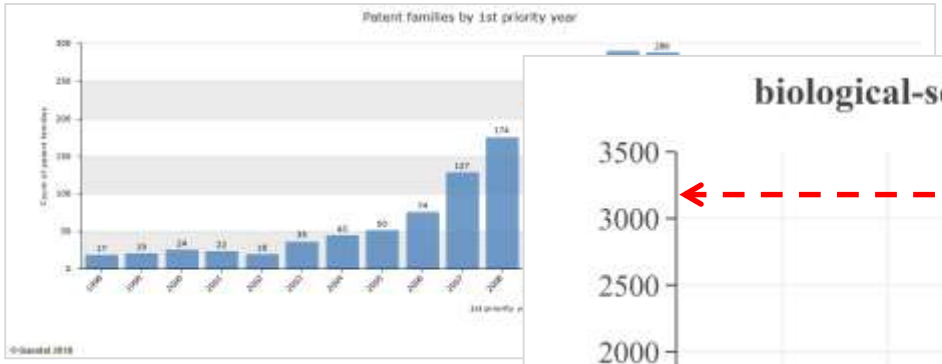
tm midpoint of the growth process N(tm) = k/2;

Dt time interval required for the growth process to grow from 10 to 90 percent of the saturation level k; Dt =(ln81)/a

Preliminary assessment of the maturity level of CO2 capture and storage technologies (II)

❑ Technology: Biological separation

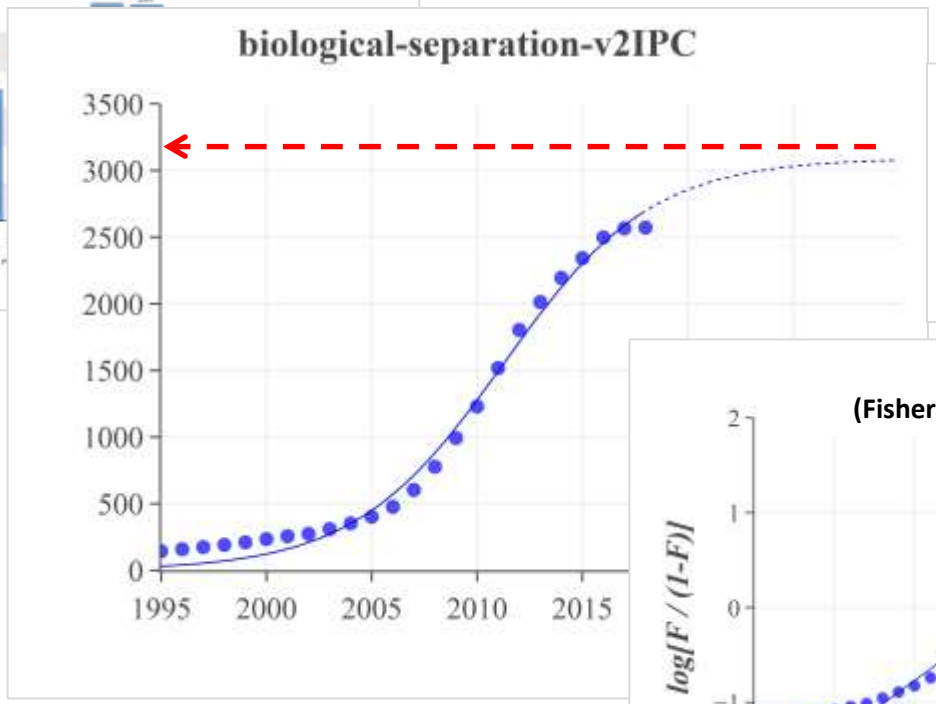
Search Strategy. Keywords + CPC Code + corresponding IPC codes *(see slide 8)*



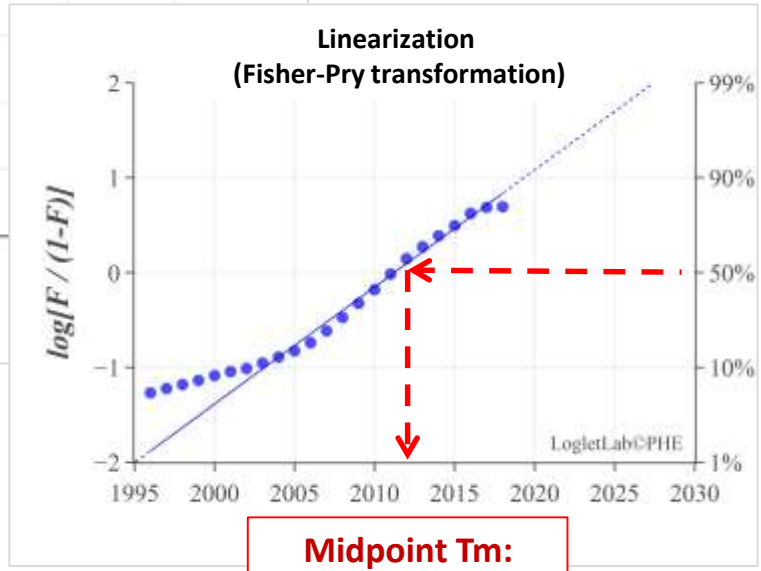
2,575 patent families

Trend Extrapolation through Logistic Curve*

Loglet Lab 4



Parameters :
Saturation (K): 3091
Midpoint Tm: year 2011
Time Δt: 15 years.
Year for 99%: 2027



Midpoint Tm: *year 2011*

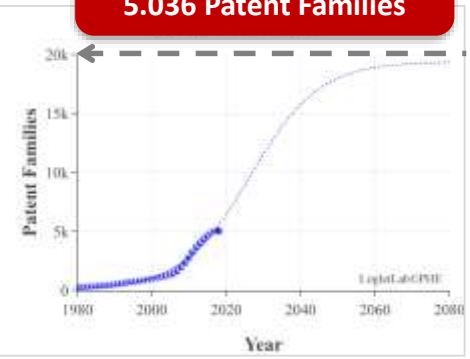
➔**Result: Biological separation technology seems to have exceeded the midpoint of its growth process** (Tm: 2011) and is going to reach its maximum level of development in the next ten years (Saturation Time: 2028)!

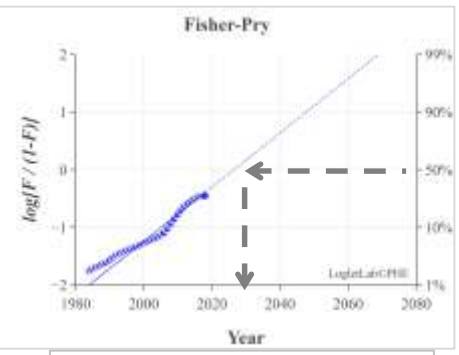
arbieri, A. Dayon, F. Silipigni

(*) LogletLab 4.0

Preliminary assessment of the maturity level of CO2 capture technologies (III)

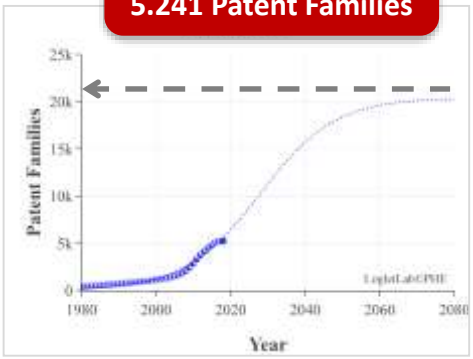
Chemical-separation
5.036 Patent Families

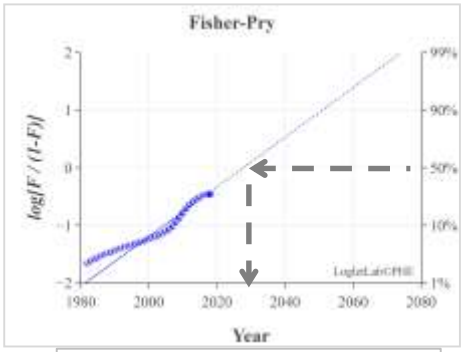




Saturation (K): 18400
Midpoint Tm: *year 2026*
Time Δt: 40 years
Saturation Time (99%)= *2070*

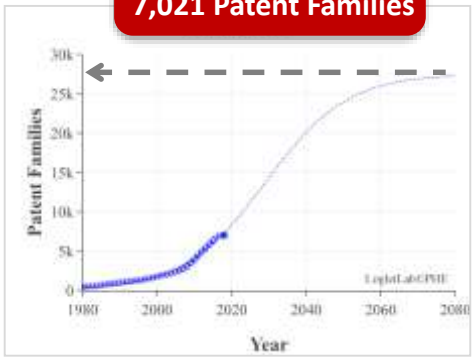
Absorption
5.241 Patent Families

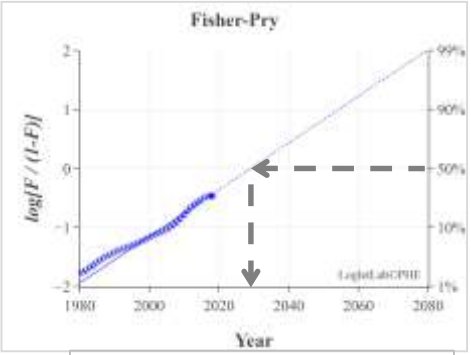




Saturation (K): 20400
Midpoint Tm: *year 2028*
Time Δt: 44 years
Saturation Time (99%)= *2075*

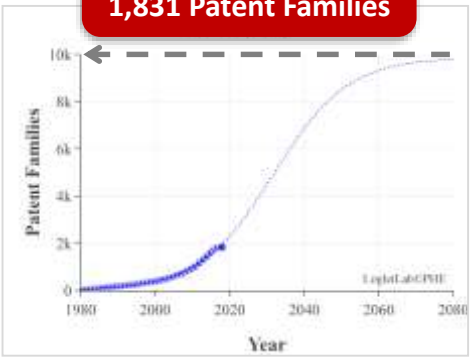
Adsorption
7,021 Patent Families

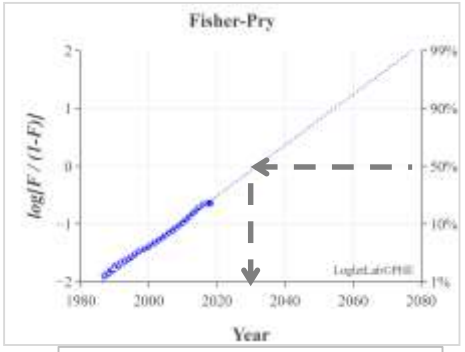




Saturation (K):27600
Midpoint Tm: *year 2029*
Time Δt: 48 years
Saturation Time (99%)= *2080*

Membranes
1,831 Patent Families





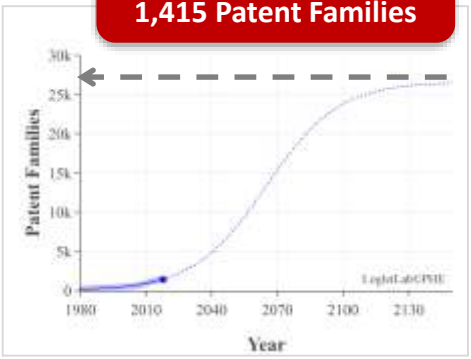
Saturation (K):9800
Midpoint Tm: *year 2027*
Time Δt: 44 years
Saturation Time (99%)= *2071*

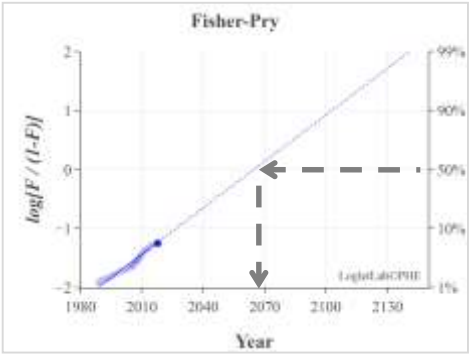
➔**Result: Chemical Separation, Absorption, Adsorbtion and Membranes technologies appear to be younger technologies, that have still not reach the midpoint of their growth process** (Tm year: ≈2027) with still much time to further develop and reach their maximum level of capabilities (Saturation Time: ≈2075)*!

(*) LogletLab 4.0

Preliminary assessment of the maturity level of CO2 capture technologies (IV)

Rectification
1,415 Patent Families





Saturation (K): 26600
Midpoint Tm: *year 2065*
Time Δt: 73 years
Saturation Time (99%)= *2141*

Comments

- **Preliminary results**, a validation by experts of the sector is needed!
- Existing CO2 capture technologies have still room to further develop and enhance their capabilities;
- They show different processes of growth:
  - **Biological Separation (BS)** shows a limited time to future growth;
  - **Chemical Separation, Absorption, Adsorbtion and Membranes technologies** forecast a longer time to growth (more than double of BS technoloy);
  - **Rectification technology** appear to be at its infancy and the forecasted time to growth is much longer (more than four times of BS technology)
- Forecasted times to reach the saturation level are different;

➔**Result: Rectification and condensation technology appears to be in its infancy, far from the midpoint of its growth process** (Tm year: ≈2065) and with a long road before reaching its maximum level of development (Saturation Time: ≈2140)!

(*) LogletLab 4.0

Conclusions

◈ Patent Search Methodology & Analysis:

- Professionals tools for records analysis (Advanced Graphs and Key concepts analysis) support concretely the identification of correlations between CPC and IPC codes - **over 95%**;
- CPC analysis is very relevant but not complete – **almost 25%**. CPC not used in Japan and Chinese patents backlog has not been updated.
- Need to introduce keywords in the search strategy

◈ CO2 capture and storage technologies

- Professional tools to analyze patent results support to highlight an **overview of the main technologies** and applicants **according to different criteria**;
- Researchers and investors should **take into account the forecasted evolution process** of these technologies, in order to support efficiently their R&D decisions;

CEPIUG
10th Year Anniversary Conference
Milano, Italy, 9-11 September 2018

CO_2 capture and storage technologies: an overview based on patent literature

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- Audrey Dayon – Questel; adayon@questel.com
- Filippo Silipigni – Politecnico di Milano, Dept. of Mechanical Engineering, filippo.silipigni@polimi.it

References

[1] C. M. Quintella et al., "***CO_2 capture technologies: an overview with technology assessment based on patents and articles***", Energy Procedia 4 (2011), 2050 – 2057

[2] B. Li et al. "***Advances in CO_2 capture technology: a patent review***", Applied Energy 102 (2013), 1349 - 1447

[3] J. L. Mìguez et al. "***Evolution of CO_2 capture technology between 2007 and 2017 trough the study of patent activity***", Applied Energy 211 (2018), 1282 – 1296

[4] S. Benson, F. M. Orr, "***Carbon Dioxide Capture and Storage***", MRS Bulletin, Volume 33, Issue 4 (Harnessing Materials for Energy), April 2008, 303 – 305

[5] Meyer, P.S., Yung, J.W. and Ausubel, J.H. (1999**) A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software**. Technological Forecasting and Social Change, 61(3), 247-271.

[6] **Loglet Lab 4.0** The Rockefeller University, New York, www.logletlab.com

[7] Grübler, A., 2003. **Technology and Global Change**, Cambridge: International Institute of Applied System Analysis-IIASA.

[8] Kucharavy, D., 2008. **Technological forecasting**. (prediction of technology change). 4 days seminar. June 26-29, Vinci, Italy, http://www.seecore.org/id2.htm.


thank you
danke
謝謝
gracias
merci
teşekkür ederim
ngiyabonga
شكراً جزيلاً
спасибо
obrigado
dziękuję
bedankt
go raibh maith agat
kop khun krap
sukriya
terima kasih
arigatô
dakujem
grazie
takk
tapadh leat
mochchakkeram
dank je
mauruuru
hvala
sagolun
taiku
merci
рахмат
Баярлалаа
faafetai lava
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bayarlalaa
enkosi
sobodi
dėkuji
mėsi
didi madhoba
kam sah hamnida
তোমাকে ধন্যবাদ
najis tuke
rahmat
ありがとう
감사합니다
ευχαριστώ
tanemirt
rahmet
diolch
xiexie
dhanyavadagalu
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хвала
asante
manana
obrigada
djiere dieuf
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spas
welalin
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vinaka
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blagodaram
misaotra
matondo
paldies
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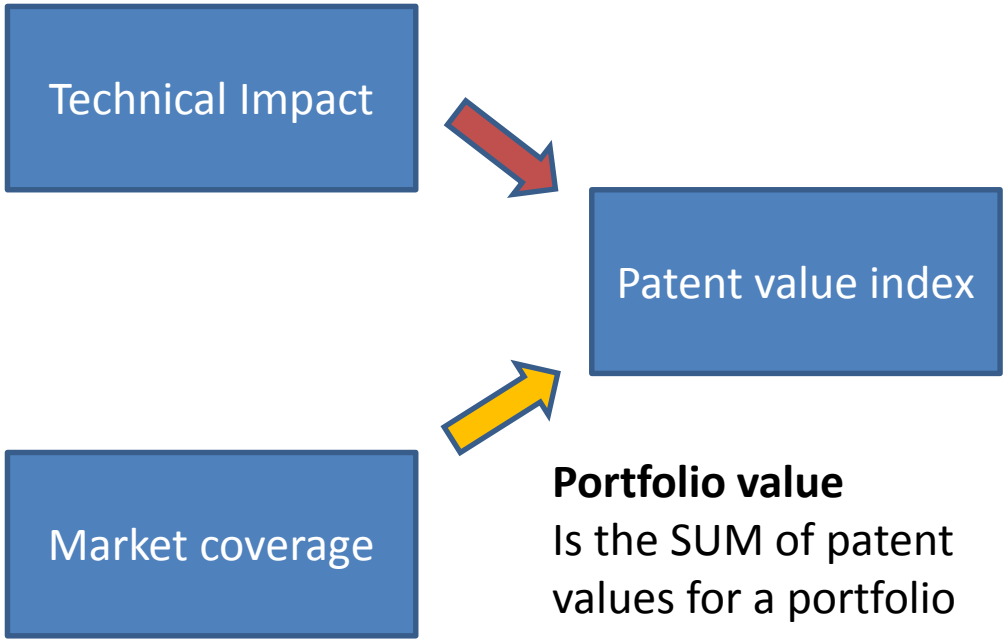
Annexes

Evaluation indicators

Patent value / portfolio value



Portfolio value
Is the SUM of patent values for a portfolio

Some interesting statistics to understand the results

500 global random families
Average patent value: 1.7

500 random families which have been litigated
Average patent value: 2.7

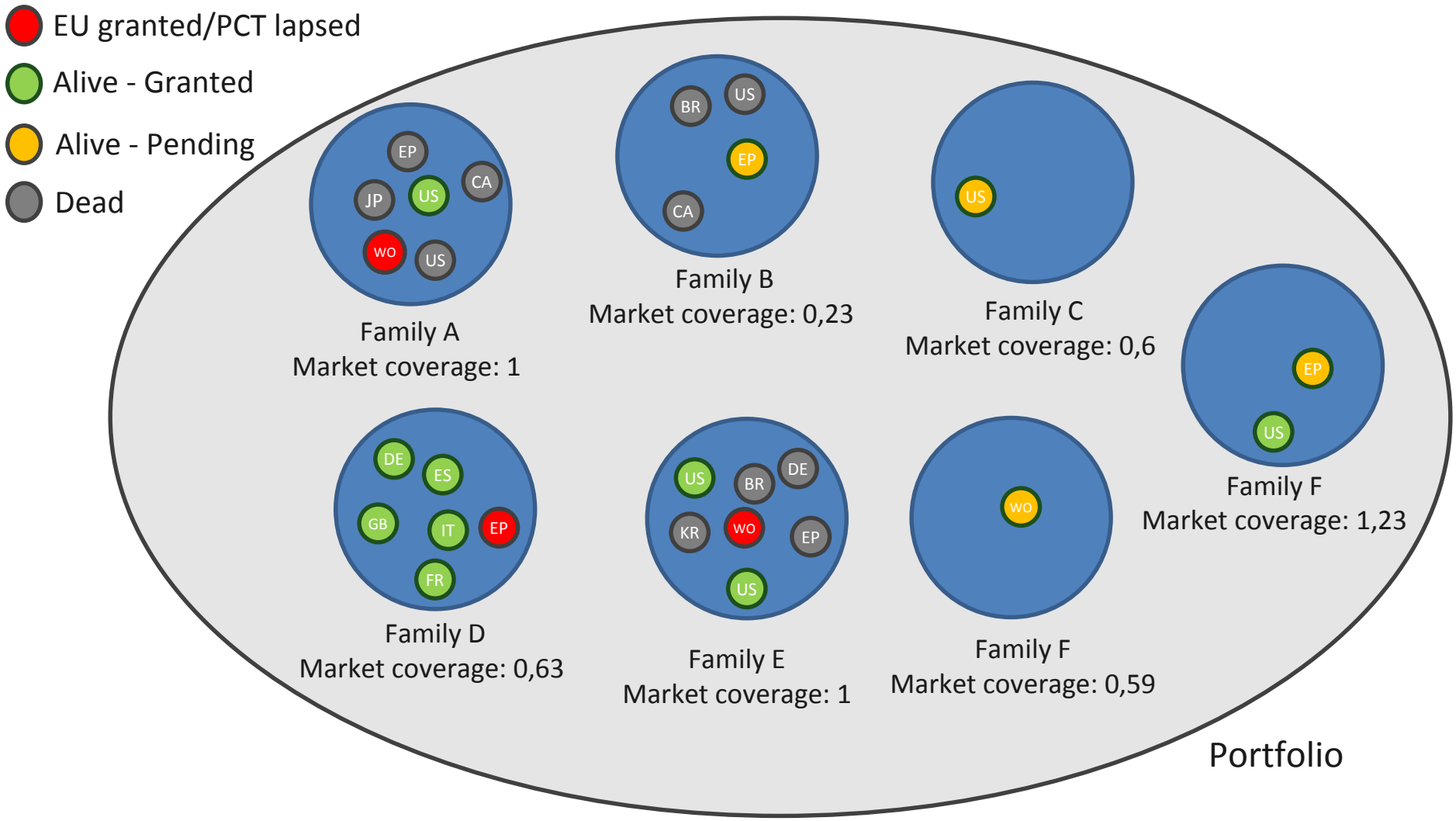
500 random families which have been opposed and remained alive
Average patent value: 2.8

500 random families which have been licensed
Average patent value: 3.3

500 random families covering SEP inventions
Average patent value: 3.8

The patent value is based on Technical impact and Geographic coverage. They are weighted and summed. The weight values have been calculated in order to give high scores to patents which have been litigated

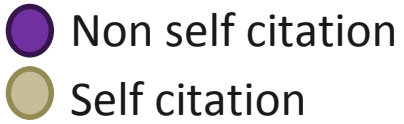
Market coverage



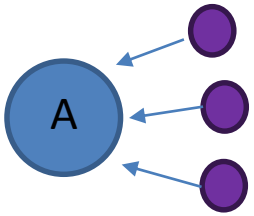
The market coverage is the percentage of the global market which is protected by the family (based on GDP).

- A reduction of 40% is given to pending countries.
- WO/EPs figures are calculated based on the countries where WO/EPs tend to be granted.

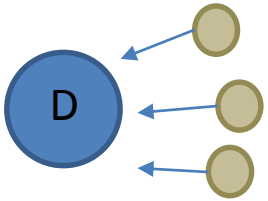
Technical impact



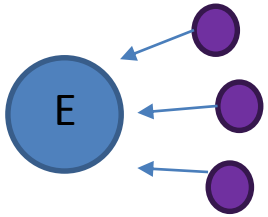
2000



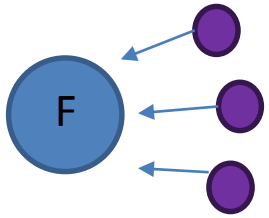
Technical Impact A: 0,64



Technical Impact D: 0,22

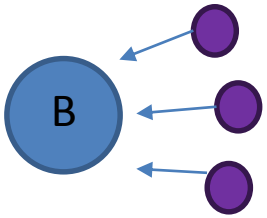


Technical Impact E: 0,8

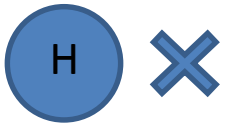


Technical Impact E: 0,45

2010

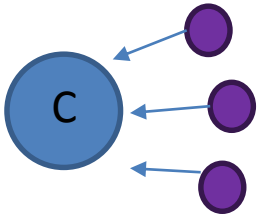


Technical Impact B: 0,85

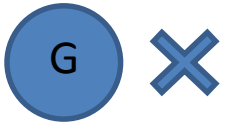


Technical Impact H: 0

2015



Technical Impact C: 1,31



Technical Impact G: 0

Chemical engineering | Civil engineering | Micros structure & nanotechnology

The technical impact is based on forward citations which are corrected depending on the nature of the citation (self/non self), the age and technical domain of the patent

LOG progression has also been used to model the increase of a patent's impact. In other words, the 1st citation increase more the impact than the 101st citation