Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy

FP7 Grant Agreement number:	**609837**
Start date of project:	**01/02/2014**
Duration of project:	**48 months**

Project Deliverable 5.3:

Report on mid-term and long-term industrial needs on STE components and system

WP5 – Task 5.3	**Deliverable** D5.3
Due date:	**01/2017**
Submitted	**02/2017**
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Document version:	**1**
Reviewed/supervised by:	**V. Vuillerme**
Dissemination Level	**PU**

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1. Introduction

This document is related to the activities done inside Task 5.3 of the STAGE-STE project. In the project, WP5 is devoted to “Relationship with Industry & Knowledge Transfer Activities”, activities lead by CEA. Within WP5 Task 5.3, lead by CNR, is focused on the “Joint framework for active collaboration with industry and dissemination activities”.

The main results of WP5 inside the STAGE-STE project should be:

- Evaluation of the expectations of the CSP market.
- Identification of the technological needs and future developments.

The STAGE-STE project includes the most important research centres, European and extra-European, working in the CSP (Concentrated Solar Power) field. The European centres are all members of the JP CSP of EERA. Some industrial companies are partners of STAGE-STE, including also the European Association of Industries (ESTELA).

2. Methodology

One of the most important actions of this task is to have an updated mapping of the Industrial Needs to improve and optimise the relationship with RTD organisations. To this aim, a dedicated survey has been developed, tested and distributed inside the partnership and outside.

The survey for industrial partners to evaluate the interaction between industries and research bodies was composed of the following 5 sections:

- *Section A: General data of the enterprise*
- *Section B: Organisation of production process and innovation*
- *Section C: Networks and relations*
- *Section D: Support from research centres*
- *Section E: Research Infrastructure topics*

Initially the survey was sent to the STAGE-STE industrial partners that helped to define the definitive version. Successively, in order to establish a connection with industrial associations of CSP companies round tables have been organised in Italy, Spain and Portugal. The survey was distributed in these round tables obtaining replies from the industrials working in the CSP field in Italy, Portugal and Spain. In other countries, it was not possible to organize round tables because there is not a significant industrial presence. Concerning the possibility to enlarge the database, the survey was shared with ESTELA, who participated to its development. Unfortunately, ESTELA realized a web version using only the first 4 sections (from A to D). Hence, it was not possible to merge the ESTELA data with the replies collected from the round tables.

The survey answers of the STAGE-STE partners have been considered as a separate group and have not been included in the respective national group. This choice is justified by the fact that they are a group homogeneous, as their replies show. However a comparison was made among the results of STAGE-STE partners, Italian, Portuguese and Spanish companies. All the total results are strongly affected by the Spanish group, because they are more than half in percentage (23 over 38). This represents the fact that the majority of the CSP firms in Europe is Spanish. It could be interesting to have also the results of other European countries, but the number of actors in this field is so limited that it is very difficult to have enough useful replies.

To complete the survey results, CEA has investigated the state of the art of patents in the CSP field. China dominates in the patent application for recent years (less than 4 years). USA and Europe possess the oldest patents confirming their earlier involvement in the CSP research.

Patent numbers per years always show a sharp peak around 2011-2012, immediately followed by a deep decrease up to now, as a reflection of the market trend.

The results of the survey for industrial partners were illustrated at the Solar Paces 2016 conference (Abu Dhabi - October 11-14 2016) in a workshop dedicated to WP5. The results of the survey and the data of the patents investigation were then synthetically presented at the EERA conference 2016 (Birmingham - November 24-25 2016) in the "Parallel Session on Standardisation/Coordination".

3. Results of the survey for industrial partners

The first step was the preparation of the survey questions concerning the relationship between research world and industries working in the CSP (Concentrating Solar Power) field. The final version of the survey for industrial partners was obtained with the suggestions of the STAGE-STE industrial partners, who have been the first to answer the survey questions.

The second step was the distribution of the survey to the industrials, which was done organising round tables in Italy, Portugal and Spain with the industrial associations of CSP companies. Since the subjects examined by the research were few, to obtain the maximum number of replies it was allowed to give incomplete answers to some questions, in case the internal policies do not allow to disclose these data.

The third step was to elaborate the answers (38 replies), in total but also geographically separating the replies. A comparison was made among the results of STAGE-STE partners, Italian, Portuguese and Spanish companies. These are the only countries having industrial CSP associations with which it was possible to organise round tables.

The survey results are illustrated in the next 4 sub-sections: 2.1 Section B - "Organisation of production process and innovation", 2.2 Section C – "Networks and relations", 2.3 Section D – "Support from research centres" and 2.4 Section E – "Research Infrastructure topics". Probably the most interesting results are those of Sections D and E.

3.1. Section B - "Organisation of production process and innovation"

Section B is intended to understand how the industries internally manage the innovation.

The principal results of the comparison are:

- The majority of firms working in CSP field does not have a R&D department (58%); but in the last 3 years the level of development and R&D is 3,82 over a rank from 1 to 5.

- To externalise the work, Portuguese and Italian prefer use national partners; while Spanish are more open to international collaborations.
- The main innovations introduced are “improvement of existing services” and “improvement of products”, and then “radically new products”.
- The companies mainly own national patents, but also some European patents, and they use few licensed patents.
- The major source of innovation is “cross functional teams”.
- The firms can use various public funding: European, local or national.

The results of Sect. B are presented in Figures 1-7 and Tables 1-6.

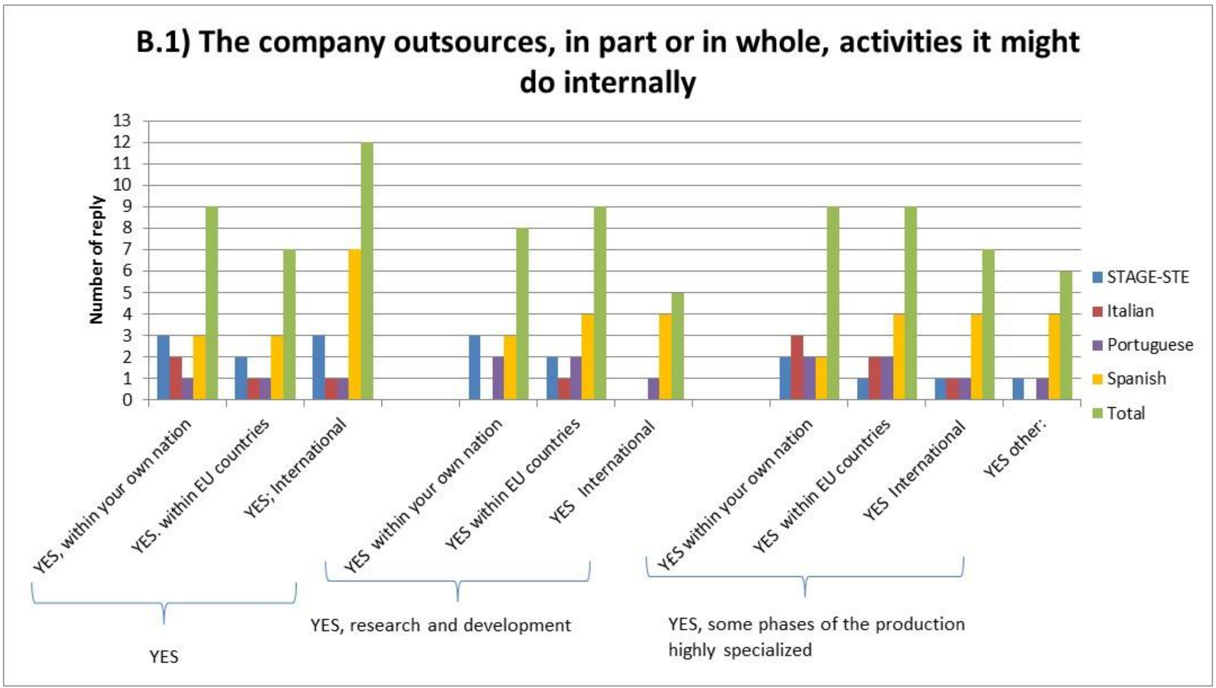

Figure 1. B.1 The company outsources activities it might do internally

Note: In this case multiple replies allowed.

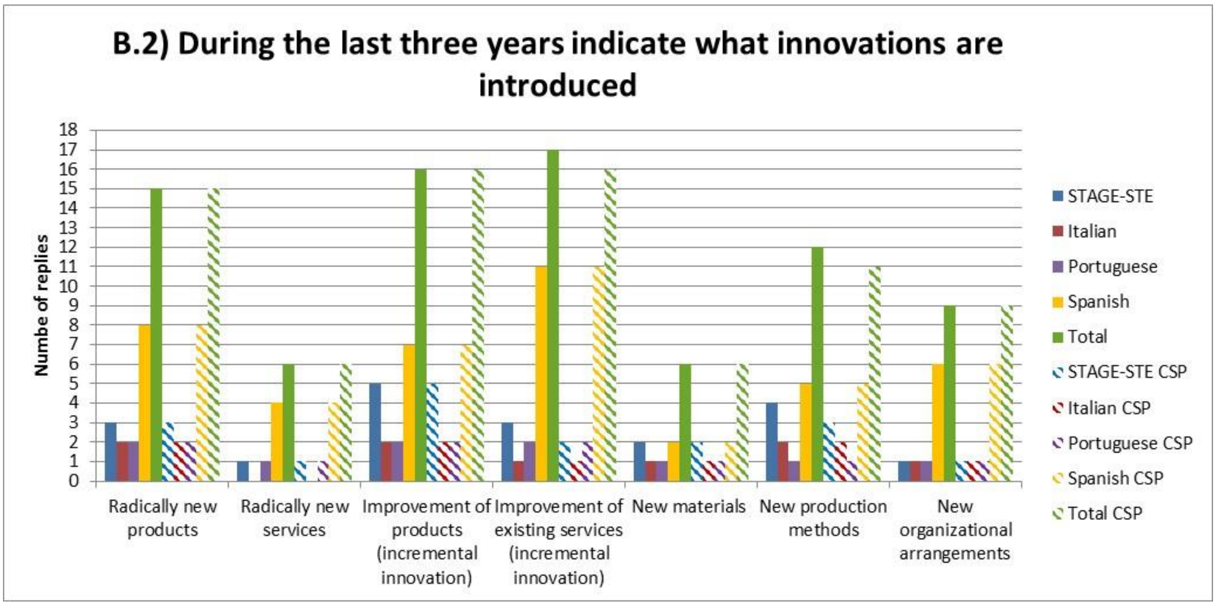

Figure 2. B.2 Innovations introduced during the last 3 years

Note: In this case multiple replies allowed.

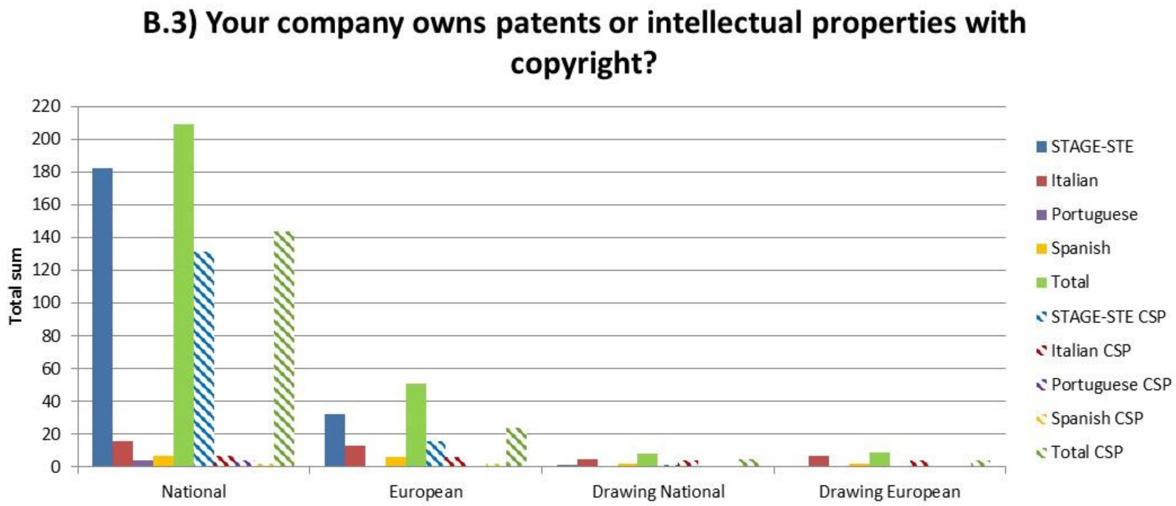

Figure 3. B.3 Patents or intellectual properties with copyright

Notes: In this case multiple replies allowed. Some replies do not indicate the numbers of patents but only the possession

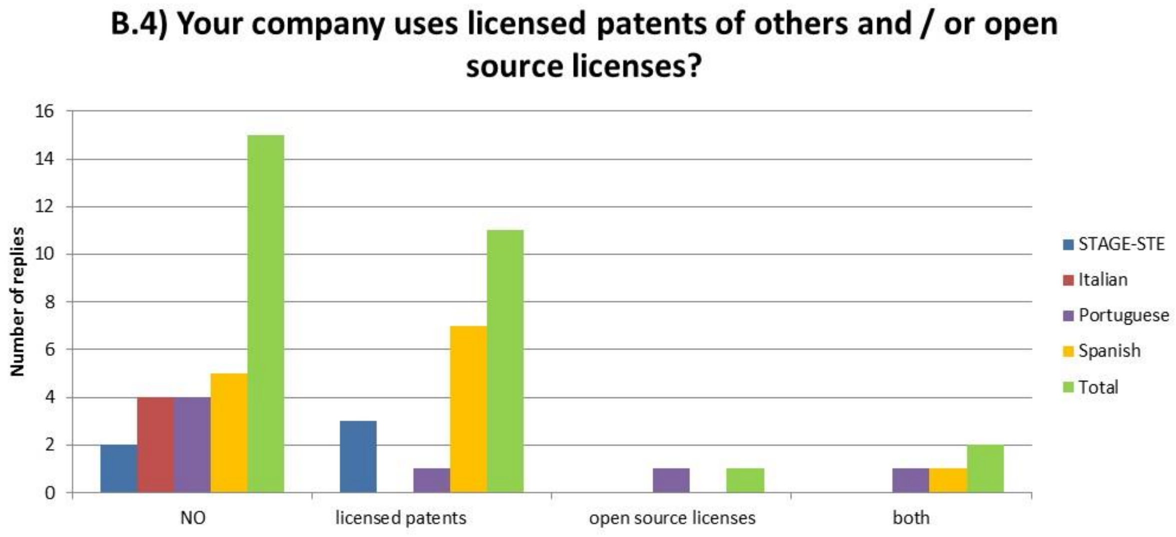

Figure 4. B.4 Use of licensed patents of others or open source licences

B.5) In your company is there a specific internal division dedicated to R & D activities related to CSP? Yes 16 (42%)

Table 1. B5 specific internal division dedicated to R & D activities related to CSP

	STAGE-STE	Italian	Portuguese	Spanish	Total
Yes	80%	40%	20%	29%	42%

Note: Each Percentage is calculated with respect to its group.

B.5.1) What percentage of the workforce is employed in this division? Mean 30% (max 70%, min 3%)

Table 2. B5.1 percentage of the workforce employed in this division

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	50%	17%	5%	27%	30%

B.5.2) On average, what percentage of turnover is allocated to R & D? Mean 21% (max 50%, min 4%)

Table 3. B5.2 percentage of turnover allocated to R & D

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	21%	4%	10%	26%	21%

B.5.3) With what degree in the last 3 years the function of development, R & D and technical design of your company has achieved its objectives? Mean 3,82 Max 5 Min 3.

Table 4. B5.3 degree achieved of R & D objectives in the last 3 years

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	4,50	4,50	3,50	3,57	3,82

Note: in this case the question allowed a reply in a Rank from 1 (Min) to 5 (Max). Each mean value is calculated with respect to its group.

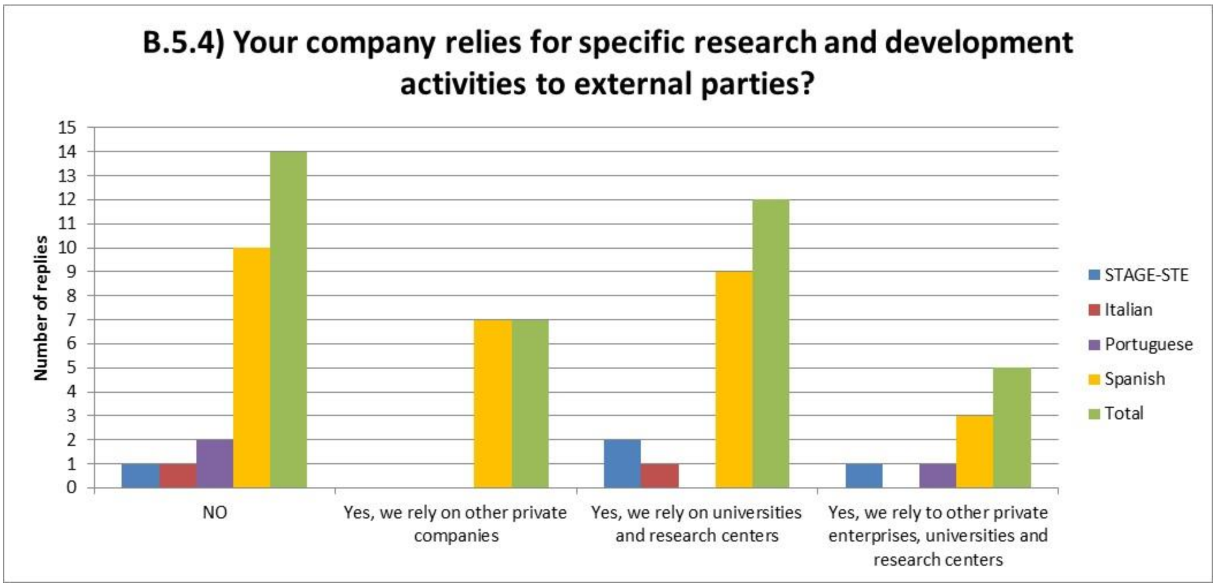

Figure 5. B5.4 if the company relies on specific R&D activities to external parties

B.6) In your company is there a dedicated R & D test infrastructure related to CSP? Yes total 17 (45% Existence of infrastructure)

Table 5. B6 dedicated R & D test infrastructure related to CSP

	STAGE-STE	Italian	Portuguese	Spanish	Total
Yes	80%	80%	20%	35%	45%

Note: each mean value is calculated with respect to its group.

B.6.1) On average, what percentage of R & D tests are performed outside your own facilities? Mean Total 34% (max 80%, min 10%)

Table 6. B6.1 percentage of R & D tests performed outside your own facilities

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	33%	27%	15%	38%	34%

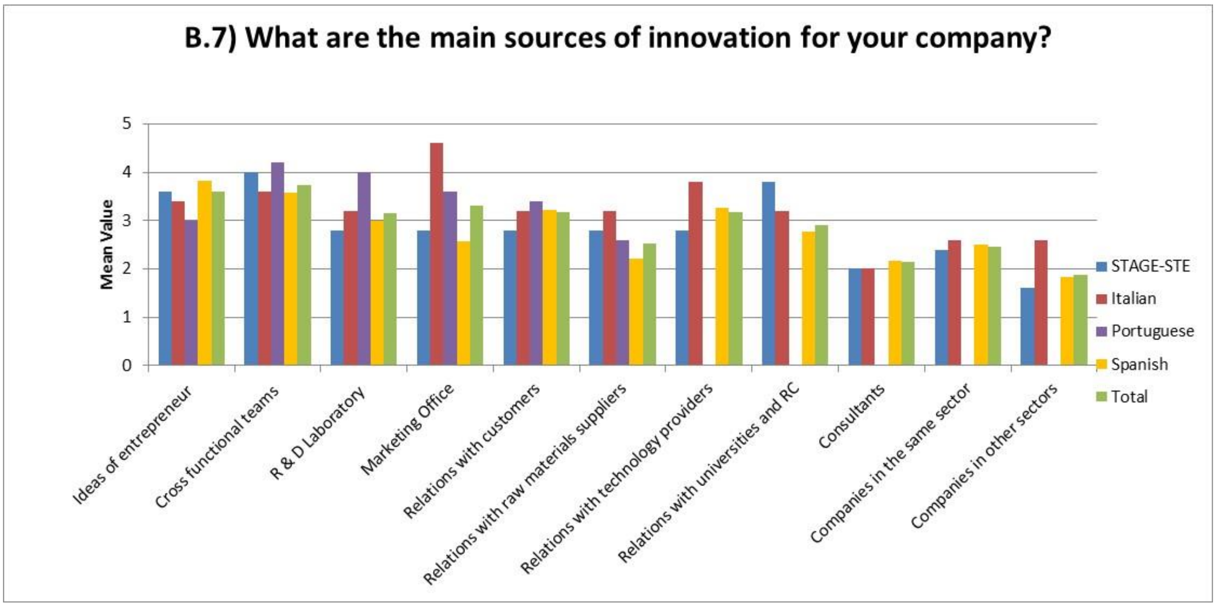

Figure 6. B7 the main sources of innovation in the company

Notes: The plot reports the mean values calculated on the possible replies. The question allowed a reply in a Rank from 1(Min) to 5(Max)

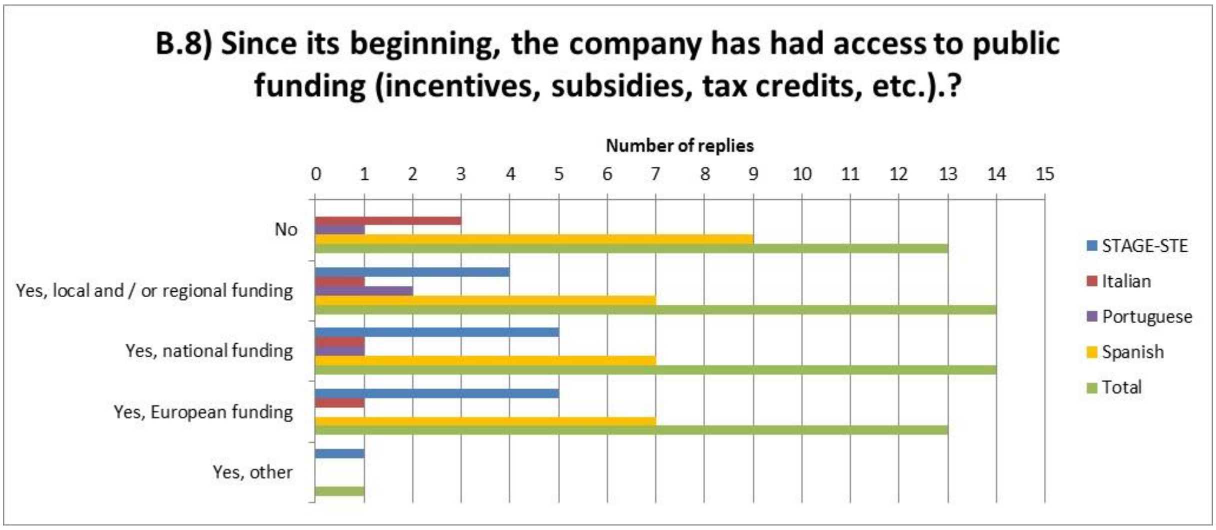

Figure 7. B8 access to public funding

Note: in this case multiple replies allowed.

3.2. Section C - "Networks and relations"

Section C investigates the current status of the relationship among industries, research and external subjects.

The evaluation about the quality of the relationship between research institutions and universities is not satisfactory (mean value 3,42 over a rank 1-5).

However the answers to the subsequent questions do not help in understanding the motivation of this dissatisfaction.

The principal way to transfer knowledge results physical meetings of the people actively participating in the work.

The results of Sect. C are presented in Figures 8-14 and Tables 7-9.

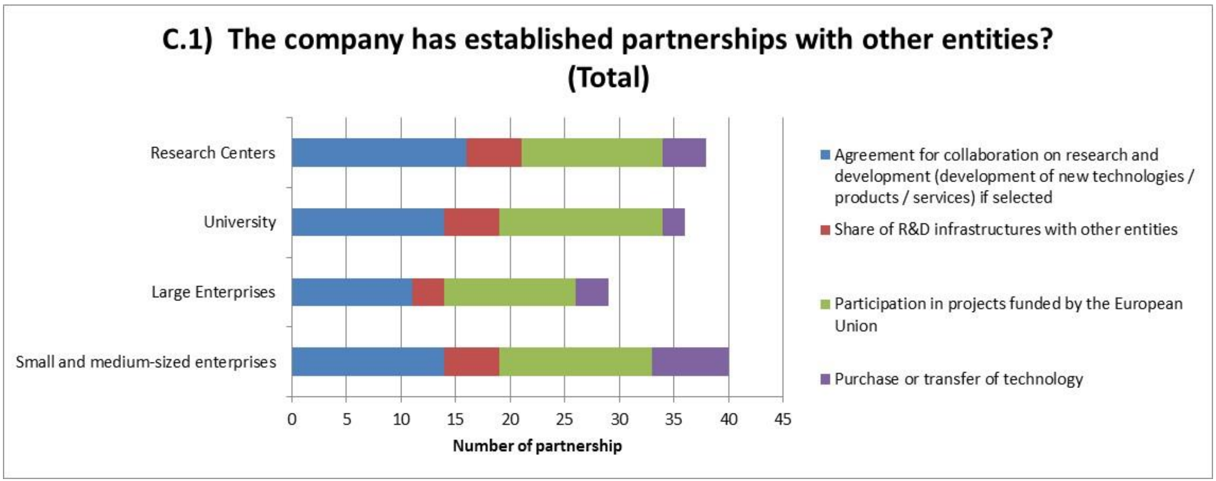

Figure 8. C1 established partnerships with other entities (total)

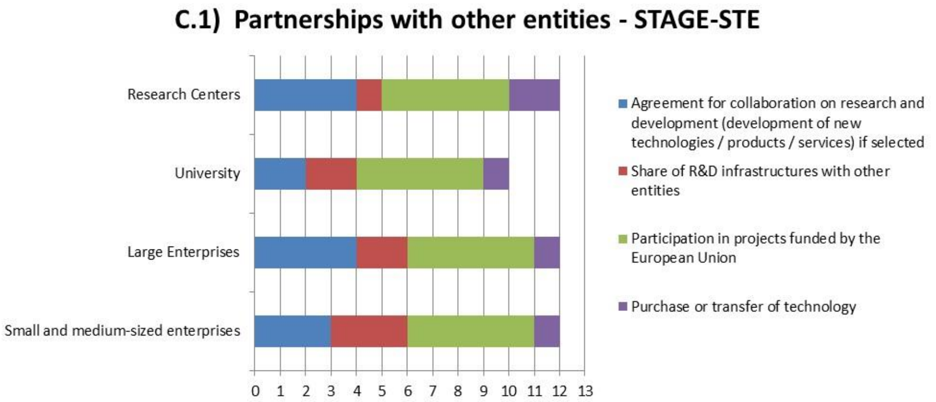

Figure 9. C1 established partnerships with other entities (STAGE-STE)

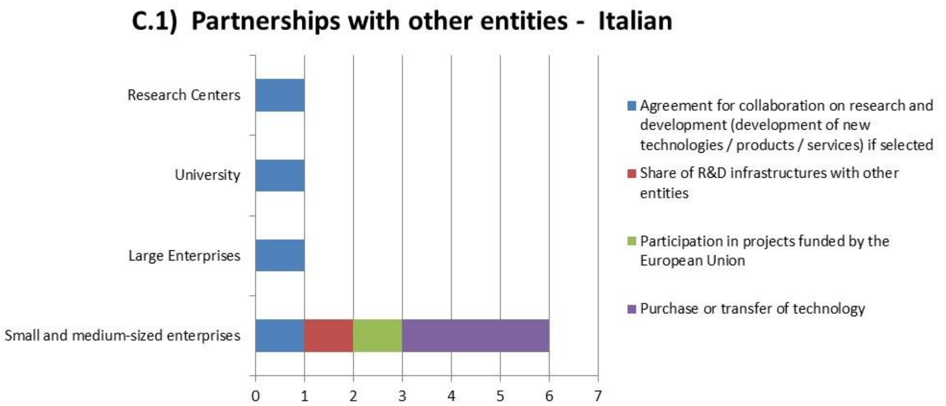

Figure 10. C1 established partnerships with other entities (Italian)

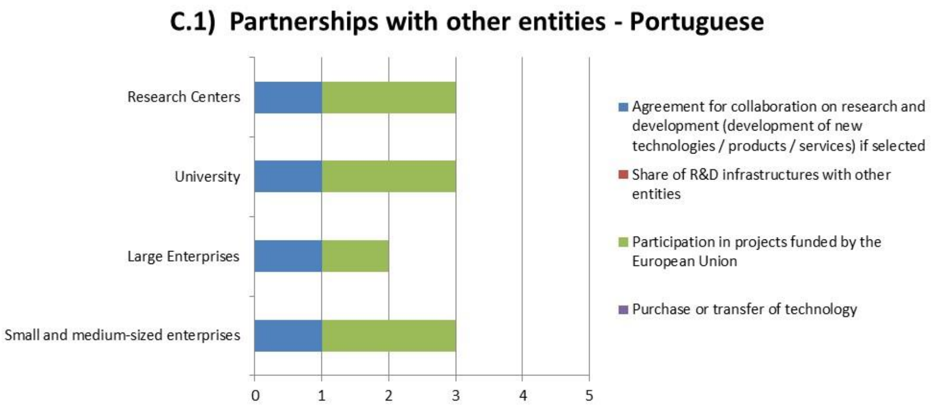

Figure 11. C1 established partnerships with other entities (Portuguese)

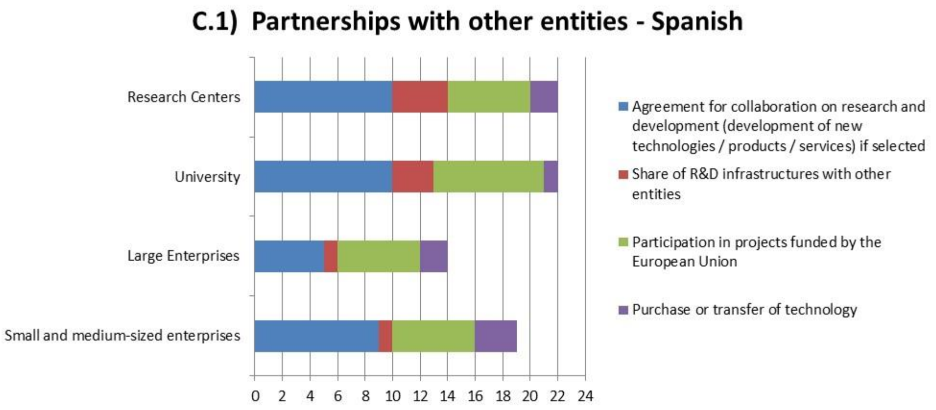

Figure 12. C1 established partnerships with other entities (Spanish)

C.1.1) With specific reference to possible collaborations with research centres, with which degree do you evaluate the results of the performed activity? Mean total 3,42 (max 4, min 2)

Table 7. C1.1 degree of satisfaction for the results of the collaborations with research centres

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	3,33	2,75	4,00	3,60	3,42

Note: in this case the question allowed a reply in a Rank from 1 (Min) to 5 (Max). Each mean value is calculated with respect to its group.

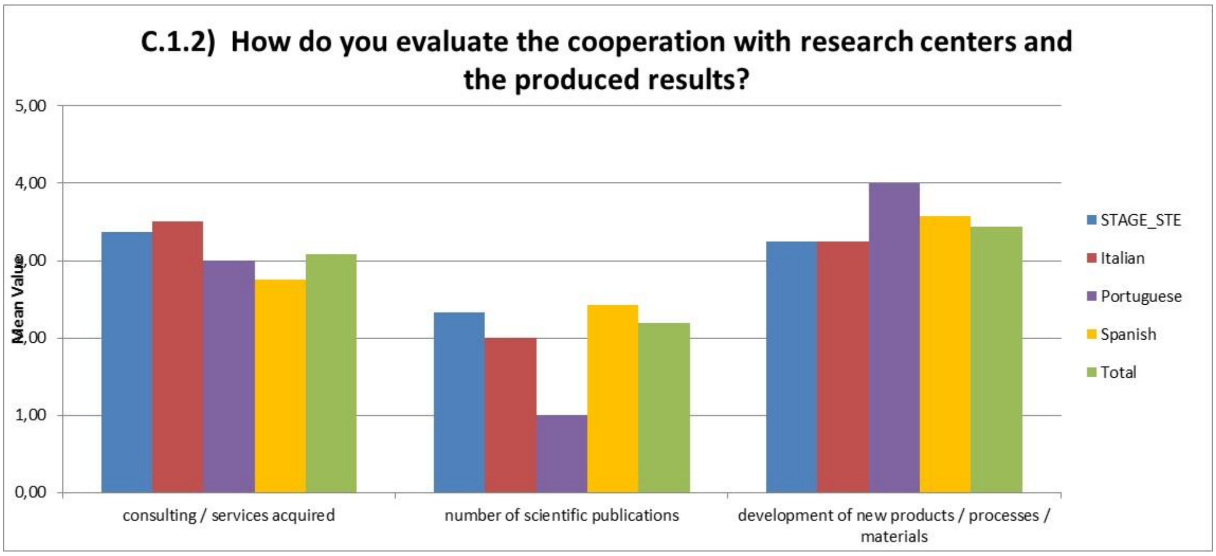

Figure 13. C1.2 evaluation of the collaborations with research centres

Note: in this case the question allowed a reply in a Rank from 1 (Min) to 5 (Max). The plot reports the mean values calculated on the possible replies.

C.1.3) How can the knowledge and information gained through collaboration with research centres were found to be crucial for your business? Mean 3,20 (max 5, min 2)

Table 8. C1.3 Importance for the business of the knowledge gained collaborating with research centres

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	3,75	3,00	3,00	3,13	3,21

Note: in this case the question allowed a reply in a Rank from 1 (Min) to 5 (Max). Each mean value is calculated with respect to its group.

C.1.4) In your experience, how do you evaluate the maintenance of the confidentiality in the R & D activities carried out with Research Centres? Mean 3,53 (max 5, min 3)

Table 9. C1.4 maintenance of the confidentiality in the R & D activities with Research Centres

	STAGE-STE	Italian	Portuguese	Spanish	Total
Mean	*	3,00	3,00	3,60	3,53

Note: in this case the question allowed a reply in a Rank from 1 (Min) to 5 (Max). Each mean value is calculated with respect to its group.

* This question was not present in the first version of the survey

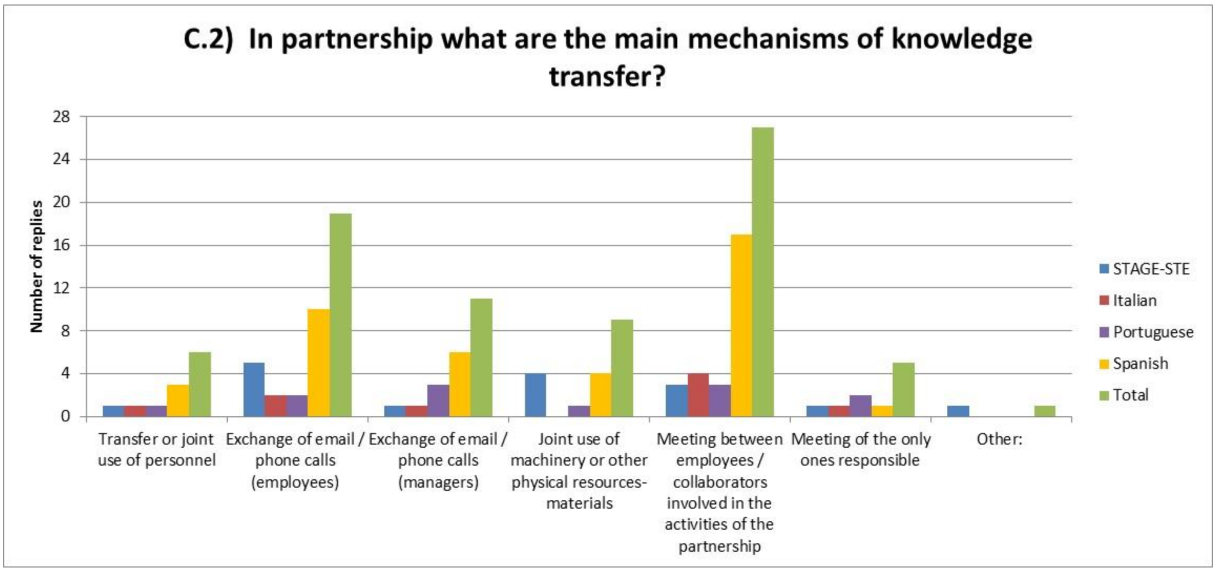

Figure 14. C2 main mechanism of knowledge transfer in partnership

Note: for this question multiple replies allowed.

3.3. Section D - "Support from research centres"

Section D analyses the support that the industries obtain from the research entities, referring to the following 3 main arguments:

- *PRODUCT INNOVATION FOR CSP*
- *PROCESS INNOVATION FOR CSP*
- *INNOVATION IN THE ORGANISATION*

The most voted fields of interaction between industries and research centres are, respectively:

- *Experiment, test and certification (for PRODUCT)*
- *Support for the solution of possible environmental problems or safety issues (for PROCESS)*
- *Support for the presentation of projects for funding (for INNOVATION)*

The last result is in agreement with the answers of Sect. B.

The results of Sect. D are presented in Figures 15-17.

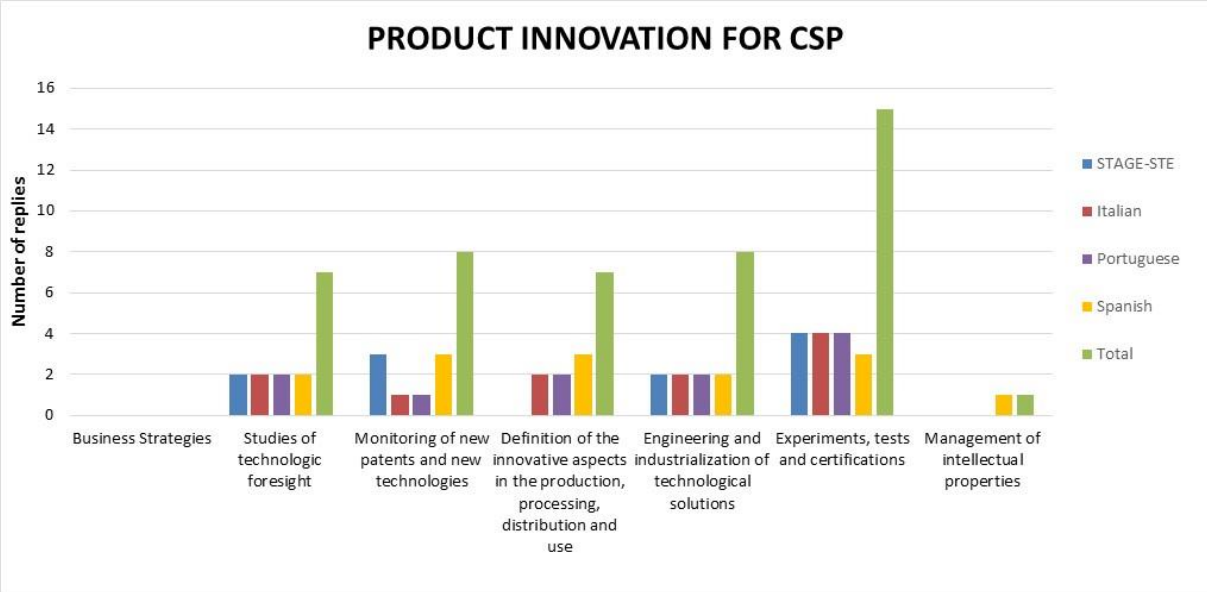

Figure 15. D1 Support from research centres in product innovation for CSP

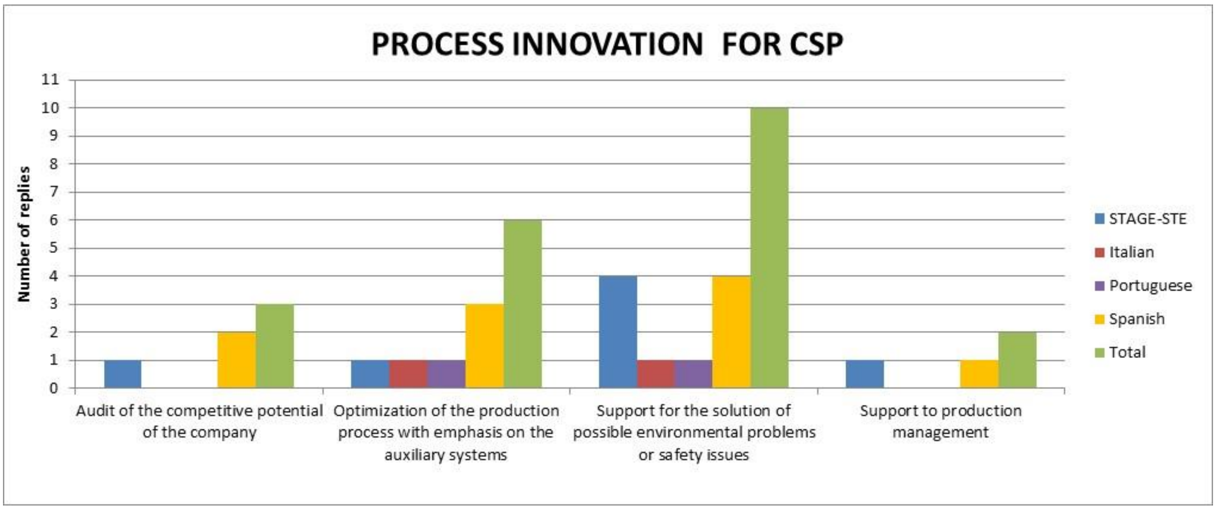

Figure 16. D2 Support from research centres in process innovation for CSP

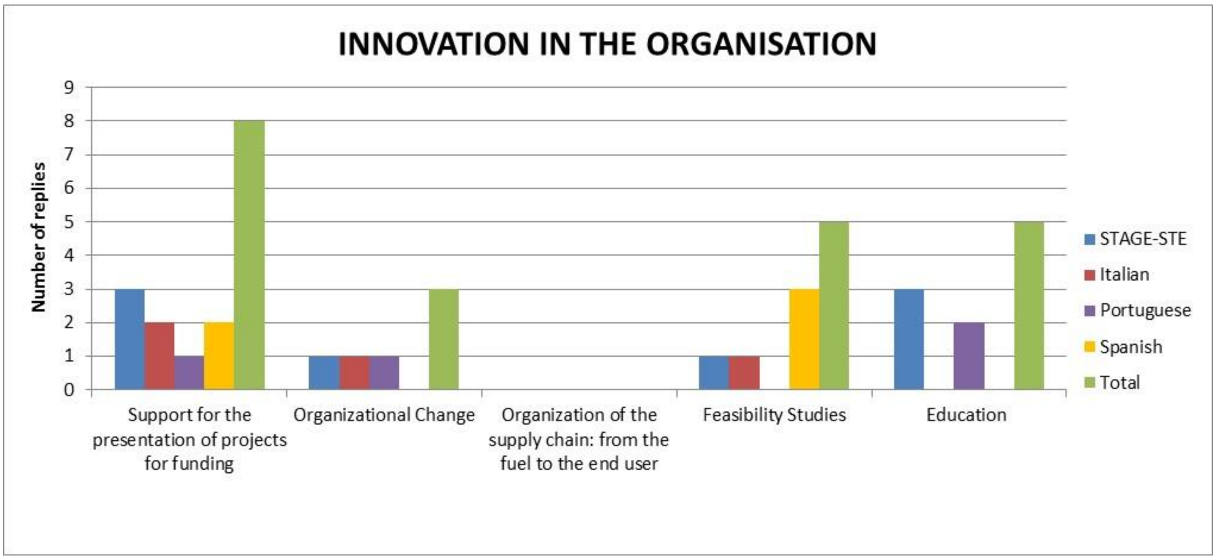

Figure 17. D3 Support from research centres in innovation of the organisation

3.4. Section E - "Research Infrastructure topics"

Section E proposes some research fields asking to specify the timing in which the problems should be resolved.

The main arguments are:

- *CROSS-CUTTING TOPICS*,
- *PARABOLIC TROUGHS*,
- *CENTRAL RECEIVER SYSTEMS*,
- *LINEAR FRESNEL CONCENTRATORS*,
- *PARABOLIC DISHES*.

The possible replies were Short Term (SH), Medium Term (MT) and Long Term (LT) allowing the multiple-choice option.

The most voted themes with their realisation timing for each field are:

- ST *(Working fluids analysis)* and MT *(Component durability under harsh environmental condition)* for *CROSS-CUTTING TOPICS*,
- ST *(Evaluation and characterisation of flexible connection)* but also MT *(Complete evaluation and characterisation of new collectors design) for PARABOLIC TROUGHS*,
- ST *(Evaluation and characterisation of receiver prototypes working with molten salts)* and MT *(Testing of new drive units for heliostats) for CENTRAL RECEIVER SYSTEMS,*
- MT *(Complete evaluation and characterisation of new LFC designs)* but also ST *(Evaluation and characterisation of new linear receivers for LFC) for LINEAR FRESNEL CONCENTRATORS*,
- MT and LT *(Evaluation and characterisation of new thermal engines) - (Evaluation and characterisation of new solar tracking systems) for PARABOLIC DISHES*.

The results of Sect. E are presented in Figures 18-22.

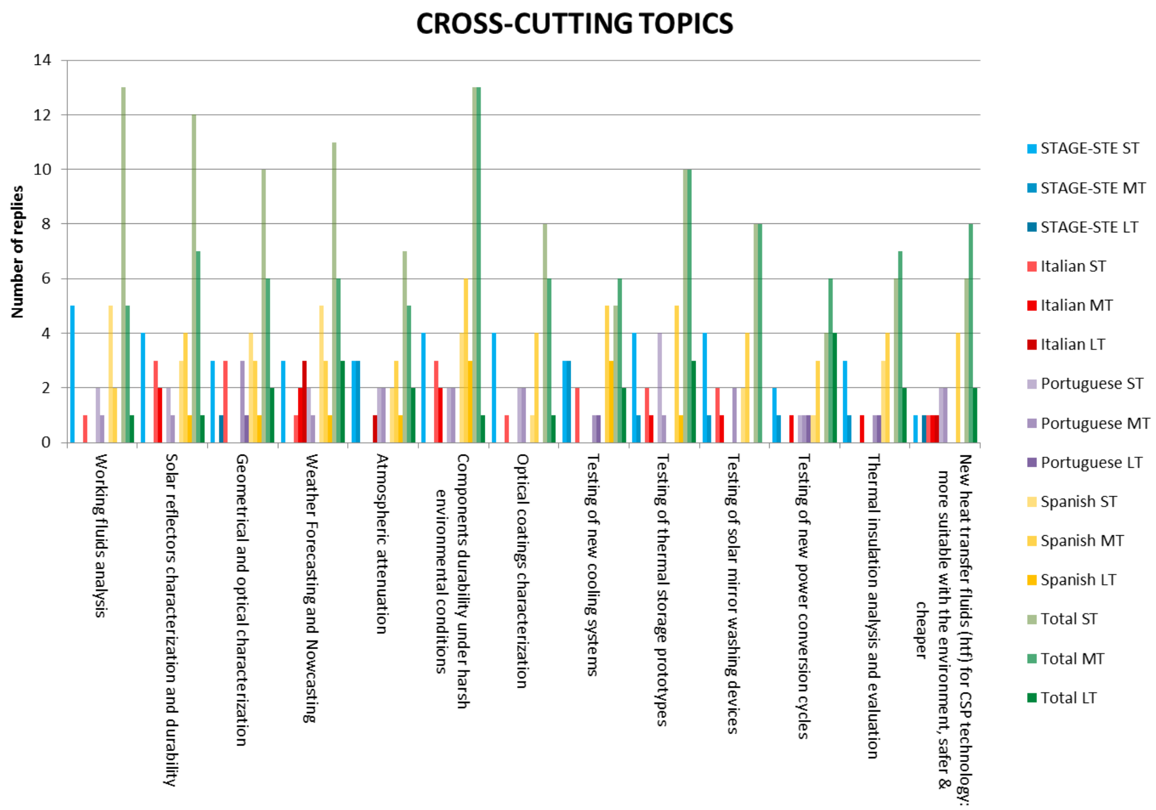

Figure 18. E1 realisation timing for cross-cutting topics

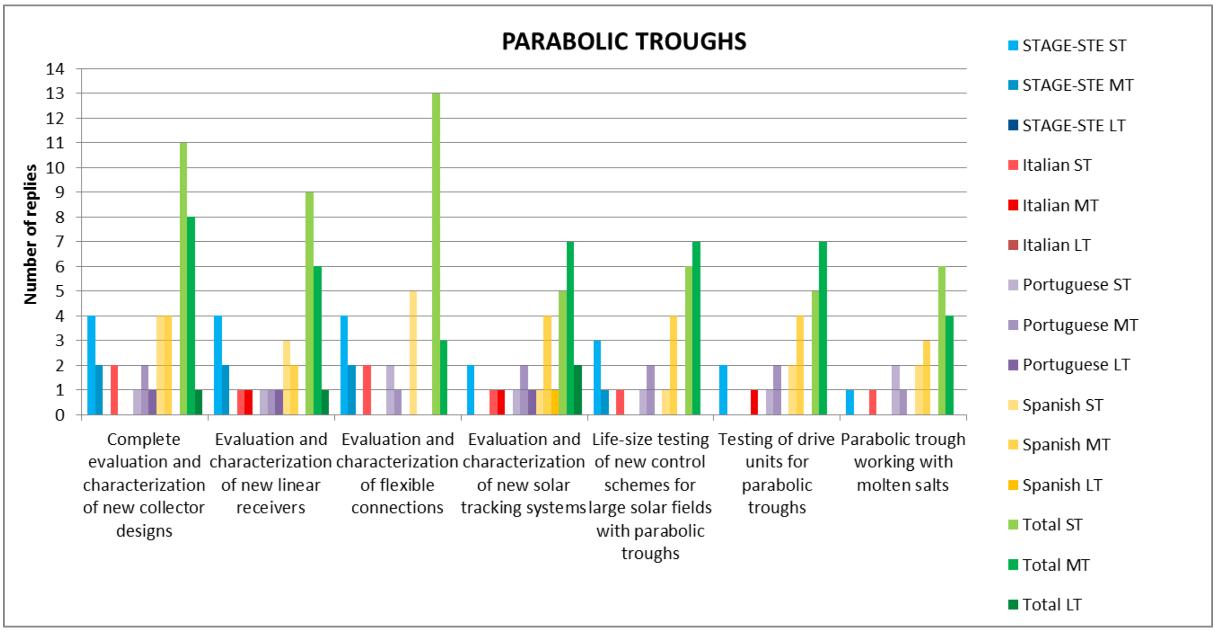

Figure 19. E2 realisation timing for parabolic troughs

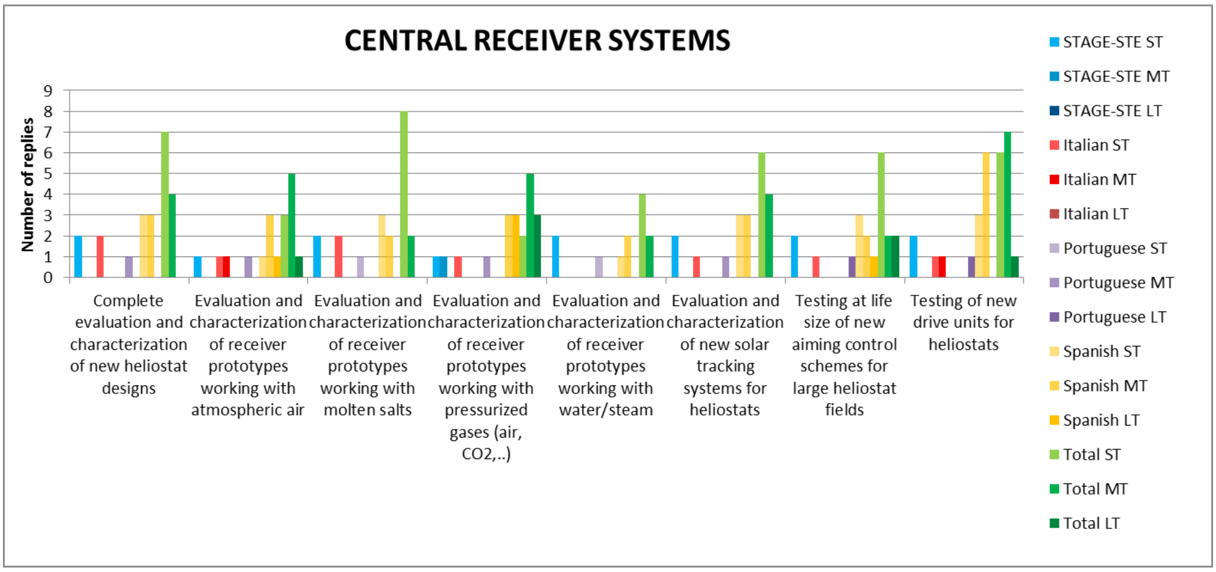

Figure 20. E3 realisation timing for central receiver systems

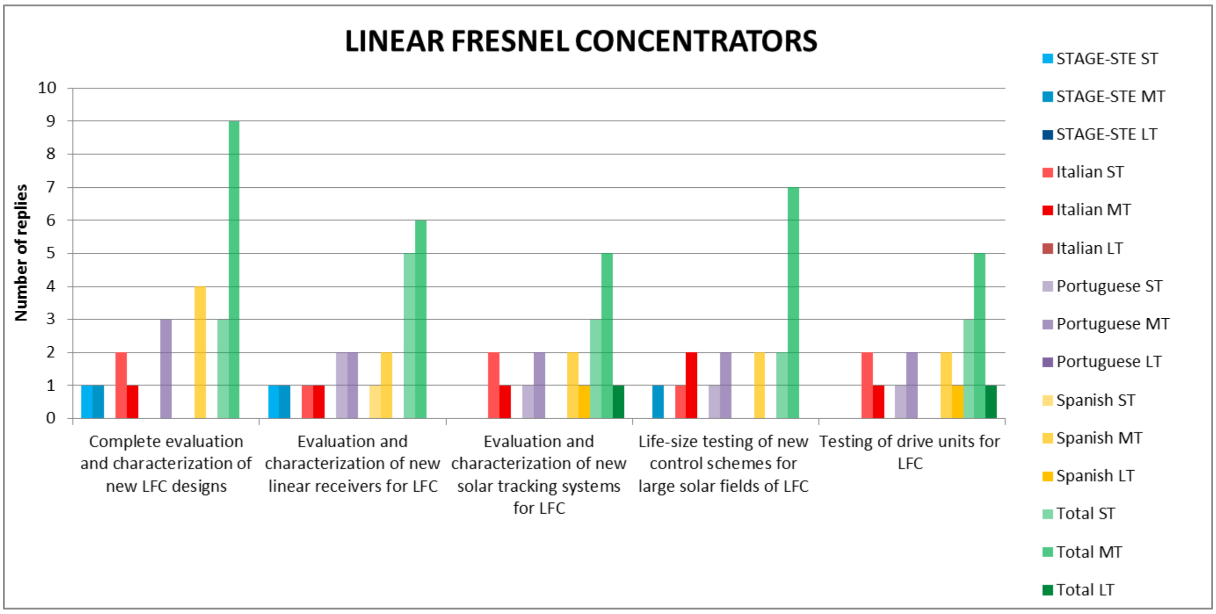

Figure 21. E4 realisation timing for linear Fresnel concentrators

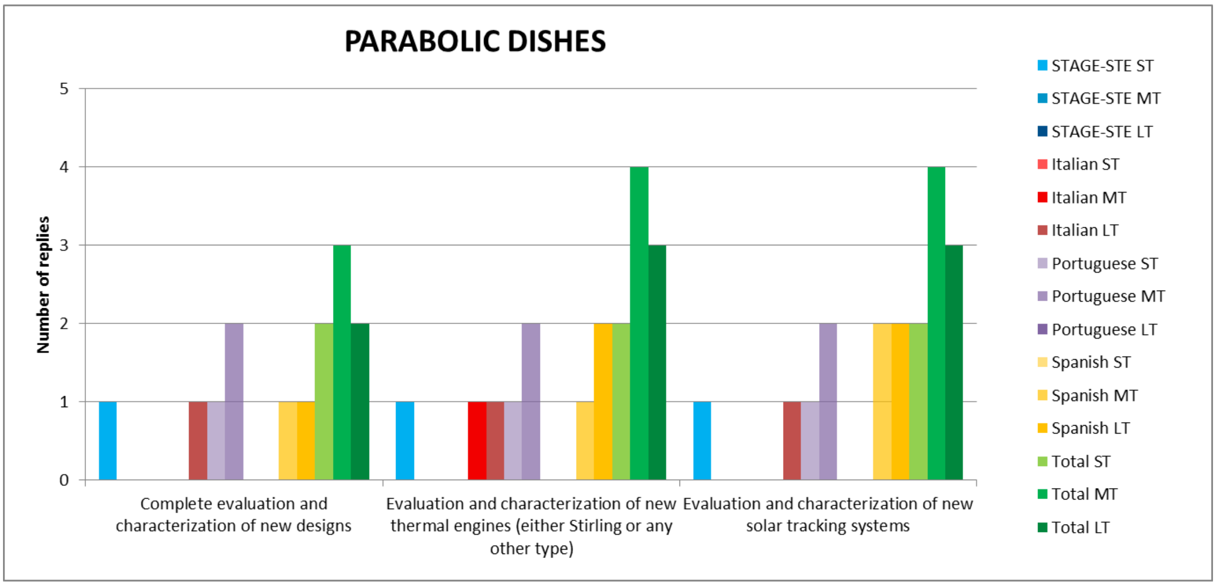

Figure 22. E5 realisation timing for parabolic dishes

4. Results of the CEA investigation of patents

To complete the survey results, CEA has investigated the state of the art of patents in the CSP field. The methodology for the constitution of the corpus document was done in 3 steps: search query, segmentation and analyses.

As the subject of query was very broad, there was a lot of noise, largely sorted by hand. And because the time gap between request and publication of a patent is long (~18 months), the study was limited to 2014-2015. Finally, an automatic data segmentation based on keywords found in the database was used, leading to a corpus of 3973 patents to be analysed. For all of these reasons, this is a non-exhaustive classification, possibility including noises and silences.

The main conclusions for the different types of analysis are:

Temporal analysis:

There are 2 different periods:

- **2006-2011**: very important increase of the patent number mainly due to China's high involvement,
- **2012-2014**: very important decrease of the patent number (including China but at a lower level).

Geographical analysis:

The main actors in patents is **China** (44%) but with few patent extension in foreign countries (about 3%, vs 60% & 43% for EU and NA); then come **North America** (25%), **Europe** (18%), **Asia** (excluding China) (9%) and **Russia** (2%).

Patent publication area is a good mirror of the marketplaces. The analysis shows the following raking: **USA** (14%), **China** (14%), **Australia** (10%) , **India** (9%), **Spain** (6%), **Israel** (5%), **Mexico** (4%), **Morocco** (4%), **South Africa** (1%), **Chile** (1%)

Legal status analysis:

66% of the analysed patents are in-force. Over the period 2006-2009, there are a few pending patents versus the number of lapsed or expired patents. On the contrary, over the period 2010-2014, there is an important growth of pending patents versus lapsed or expired patents. This means that the CSP Market is getting more competitive during the second period. Another information is that there are more lapsed patents in Europe than in US and China. This is clearly pointed out the decreasing interest of EU for CSP technologies.

Technological components analysis:

The **Solar Field** is the first technical component of interest, with 82% of the analysed patents, Then comes the **Power block** and the **Storage** (respectively with 31% and 13% of the analysed patents).

Interest for **Solar Field** and **Power Block** varied in time, with a peak in 2011. On the contrary, interest for **Thermal Storage** is constant since 2011, which certainly expresses the importance that represents this component for CSP and STE.

It is surprising to note the very low number of patents concerning the **Operation** of CSP plants, while this problematic remains a major challenge.

Solar field technology analysis:

Power Tower technology is concerned with 40% of the corpus, followed by **Parabolic Through** and **Linear Fresnel** with 30% each. Interest for **Power Tower** over these two other technologies begins in 2011, and reach a pick in 2012.

Dish technology suffer a lack of interest with only 7 % of the analysed patents.

Applications Analysis:

67% of the analysed patents deals with **High Temperature** applications, and related to the following topics:

Electrical production (70% of **High Temperature** patents),

Desalination (12 % of **High Temperature** patents),

Industrial process heating (10% of **High Temperature** patents).

21% of the analysed patents deals with **Low Temperature** applications, and 26% of these patents are related to **Heating/Cooling**.

Finally, 12% of the analysed patents deals with **Mid Temperature** applications, and 15% of these patents are related to **Cooking/Drying**.

Depositor Analysis:

The 5 main depositors are the following: **Abengoa** (E), **Siemens** (D), **Supcon** (RPC), **Academy of Chineses Sciences** (RPC) and **University of Zhejiang** (RPC).

China is an emerging actor: its patents are newer (<5 years) and most of its depositors are academics, a sign of a lower industrial maturity.

EU and **US** are historical actors and they are the owner of the oldest patents (>10 years). But this analysis shows a decrease of activity of the main companies (**Abengoa**, **Areva**, **Siemens**).

There is very few collaboration between industrial and academics (most of collaboration in patents are among academics). The reason can be a poor technology transfer for these patents, but perhaps also the low relevance of these patents.

The complete results of this investigation can be found in ANNEXE I. A short version of this document was presented at the EERA conference 2016 (Birmingham - November 24-25 2016) in the "Parallel Session on Standardisation/Coordination".

5. Principal events

The main events organised to accomplish the task are listed below, grouped for typology and chronologically ordered.

Meetings

- Meeting with Industrial Partners WP5 / task 5.3 Coordination Meeting, 4/11/2014, Brussel.
- Meeting with Industrial Partners WP5 / task 5.3 2nd Coordination Meeting, 27/10/2015, Firenze.
- Technical Meeting WP5 / task 5.3, 19/01/2016, Freiburg.

Round tables

- Italian round table in Milan on 9th April 2015 on the subject "RESEARCH-INDUSTRY INTERACTION IN THE SECTOR OF CONCENTRATING SOLAR POWER (CSP)".
- Roundtable organised in Portugal within the 3rd Symposium on Solar Energy (Evora, 1st - 2nd of February 2016): "Solar Concentration and the Future".
- Roundtable organised in Spain within the General Assembly PROTERMOSOLAR, Madrid, 27th June 2016.

Workshop and Conference

- Workshop on best practices to promote IP transfer to the industry, titled “IP Transfer and Relationship between Industry and Research in STE Field”, held on 13/10/2016 at Abu Dhabi as a side event connected to the Solar Paces 2016 Conference.
- Participation titled “Investigating the industrial needs in the CSP research” to the EERA Conference 2016, held in Birmingham 24/11/2016.

6. ANNEX I:

State of the art of IP in the CSP.pdf

DE LA RECHERCHE À L'INDUSTRIE

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CONCENTRATING SOLAR POWER

September 2016

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SOMMAIRE

Context

STAGE STE is a European project aimed at ensuring the excellence of Europe in Concentrating Solar Thermal Energy. The project started in February 2014 and participants are 41: 23 European research centers, 9 big companies in the sector, 9 non EU reference organisations

Among the main objectives:

- ✓ Transforming the consortium in the reference structure for the CSP
- ✓ Boosting cooperation between European research institutions
- ✓ Accelerate technology transfer to industry

The **work- package 5** is coordinated by CEA. This work-package aims to promote relations and technology transfer between research institutes and industry in order to relaunch CSP in industry and better exploit research results

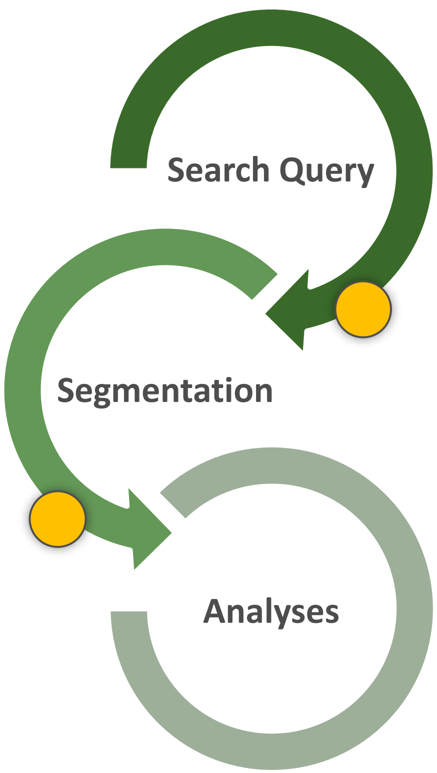
Objectives

The **objective** of the study realised by the SBEM (CEA marketing and bibliometrics department) is to know the evolution of IP in the field of solar thermal

This study is part of the needs of the work- package 5 and can help the alliance to better connect with industry in order to build targeted proposals

METHODOLOGY

➢ **The methodology is iterative , includes 3 main stages and allows interaction with the experts**



Definition of key words from the input data and discussions with experts
Construction of the search query (combination of different keywords)
Querying of the scientific database ORBIT and constitution of the corpus of documents

The data from the research equation are then confronted with the documents published by the key players in the field
Depending on the volume of data, a focus can be done

Integration of documents in the statistical analysis tool IP - METRIX
Segmentation of the database made according to the needs expressed by the client
Validation via secure access to experts at the base (IP -Metrix interface)

Organisation and standardisation of the database and organisations.
Analysis of documents via the tool IP - METRIX then information addition by web searches on actors , technologies , news

Expert validation required

*Silence = unrecovered relevant data
**Noise = irrelevant data recovered

***This study has some limits*:**

✓<u>very broad subject</u> : complicated process, establishment of a large body of documents and a lot of noise (largely sorted by hand)

✓<u>Scope</u>: we limited our searches by keyword

✓<u>Patents</u>:

This analysis covers both patent applications and granted patents. That is to say, all documents collected does not necessarily result in granting of patents (either rejection by the office, or abandonment of the applicant).

18 months elapse between the filing and the publication of the patent application (publicly accessible) : years 2014 and 2015 are not covered completely by the search

✓<u>Automatic Data Segmentation</u>: The classification of patents and publications was conducted mainly by "automatic" ranking that is to say by keywords found in the database

➔ ***non-exhaustive classification and possibilities of noise* or silence*****

<u>NB: This study which had to be initially an update of a previous study with regard to last 3 years can be considered pretty near a full study : the search queries and the keywords were revised and updated, segmentation has been reviewed and adapted to customer needs, data were analysed with the help of new statistical tool IP -Metrix</u>

3 document collection strategies:
1 general strategy, 1 strategy by technology and 1 strategy by actors

Constitution of database
Database ORBIT

Corpus of **4827 patents**

Suppression of off-topics
Statistical Tool IP-METRIX

Corpus of **3973 patents**

Sorting by Applications, Technologies, Elements and General
Statistical tool IP-METRIX

Corpus of **3973 sorted patents**

CSP general

Solar Thermal Electricity
Concentrated solar power
Concentrated solar thermal
Concentrated solar collector
Concentrated solar reflector
Concentrated solar system
Concentrated solar Tower
Thermodynamic solar

Etc.

By technology

Parabolic Trough
Parabolic Trough
Cylindric Trough
Etc.

Linear Fresnel
Fresnel (sauf Lens)

DISH STIRLING
Dish Stirling
Dish collector
Etc.
(sauf antenne)

Central receiver
Solar Tower
Power Tower
Etc.

By Actor

Notable actors in the field

except PHOTOVOLTAIC*

Queries made by using Boolean operators (AND , OR, NOT) and proximity operators (distance between two words)

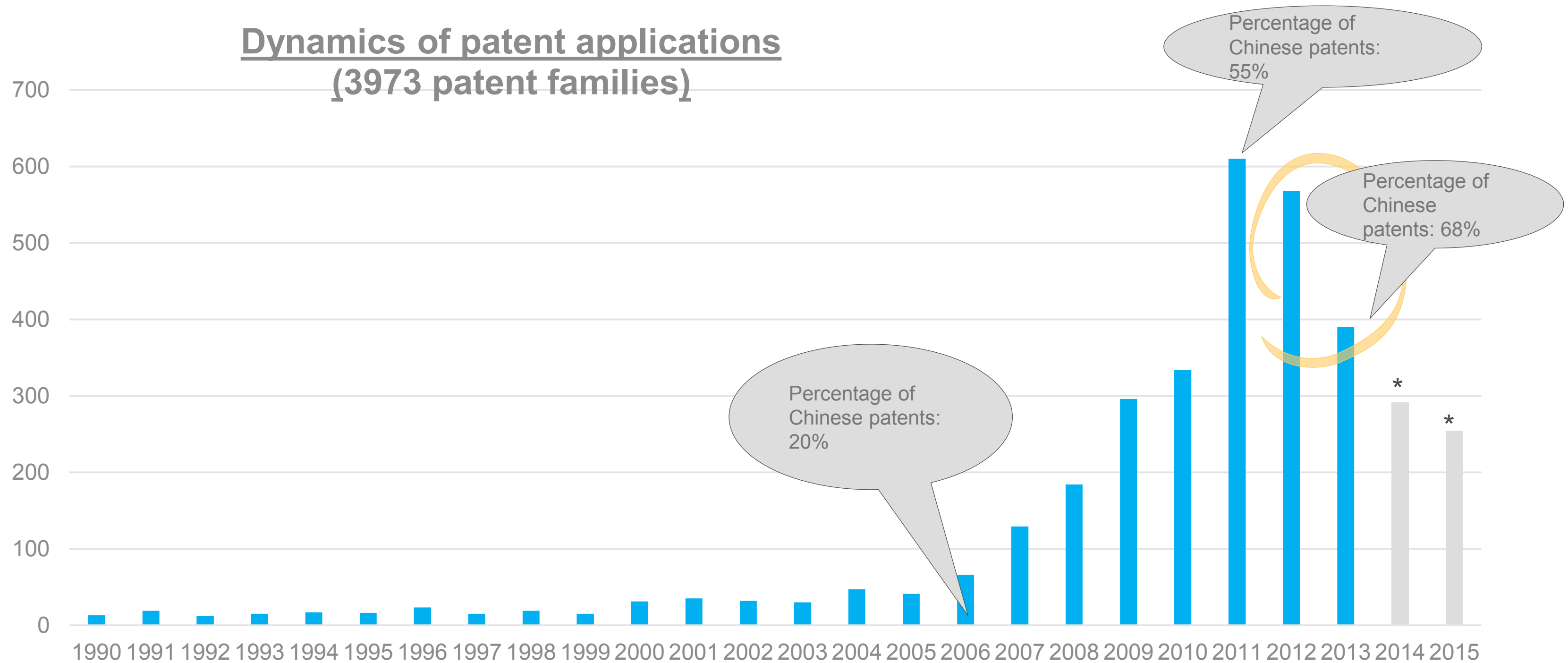
Search for keywords in the fields: Title , abstract, object of the invention, independent claims, advantages of the invention over the prior art

* we do not take into account CSP-PV hybrid applications

SOMMAIRE

DYNAMICS OF PATENT APPLICATIONS

- **There has been a sharp increase in patents from 2006, mainly due to the high productivity of Chinese actors on the subject**
- **From 2012 the interest in these technologies seems to decrease . This phenomenon is less pronounced for China**



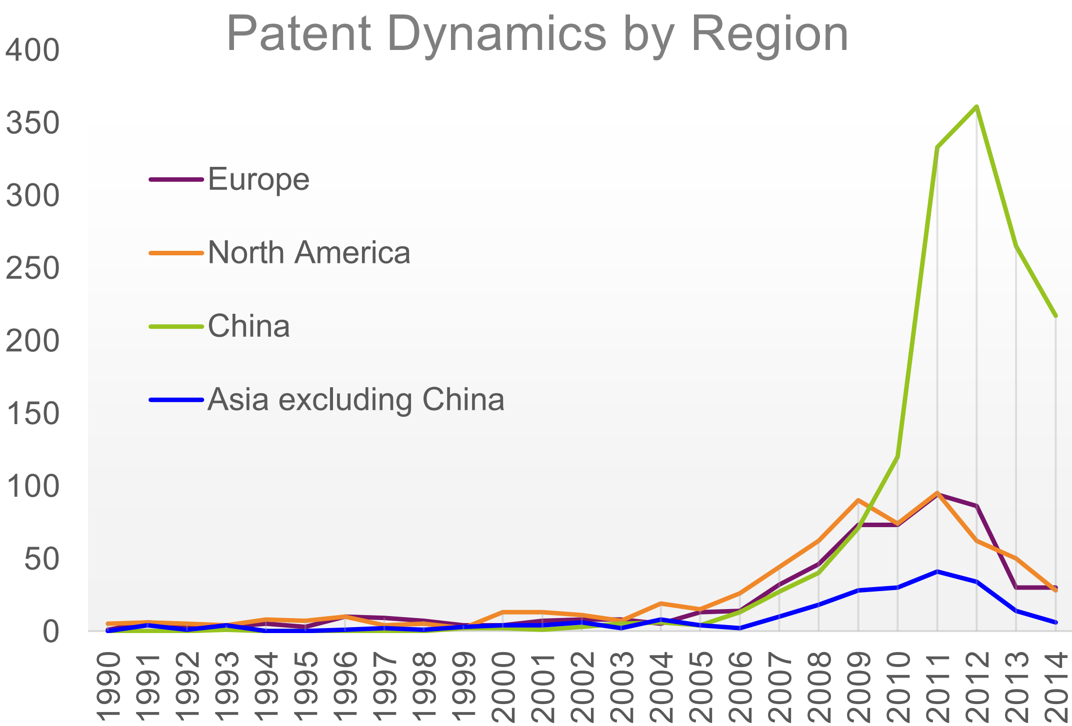
CAGR Chinese patents 2006-2011 = 91%
CAGR patents 2006-2011 = 56%

NB : Analyses based on priority patent applications

The compound annual growth rate (CAGR) is the mean annual growth rate of investment over a specified period of time longer than one year.

* Years 2014 and 2015 are incomplete because of the period of 18 months (at least) between the submission and the publication of a patent.
Representation of one family member : 1 patent = 1 patent invention

PATENT DYNAMICS BY MAIN GEOGRAPHICAL REGION



Portion of international application by geographical region

Europe: 60 %

North America: 43 %

China: 3%

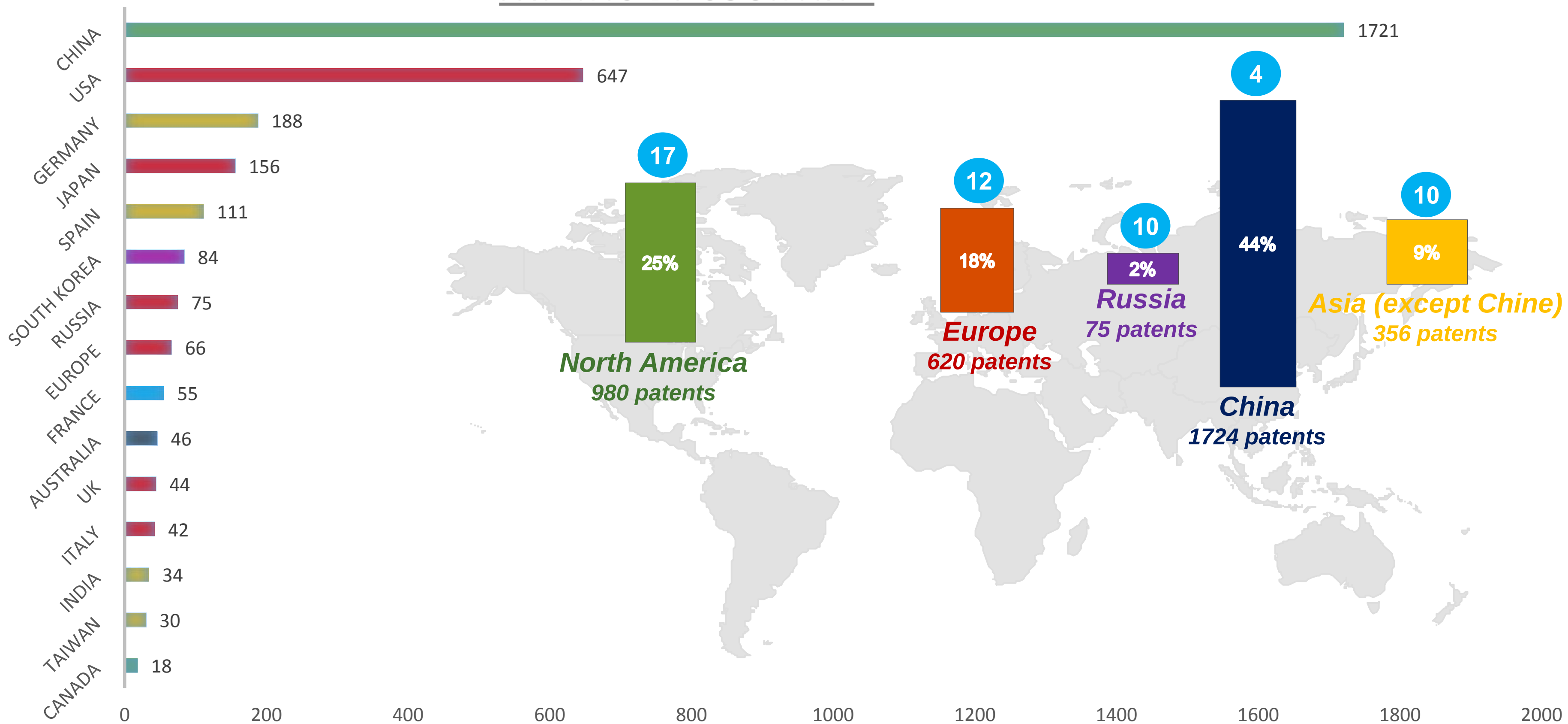
Asia excluding China: 39 %

- **We notice a sharp increase in patent filings from 2006. This increase affects all geographical areas but is particularly evident in China**
- **For North America , Asia and Europe the interest in this area appears to decrease from 2011 (from 2012 for China)**
- **Concerning the portion of international applications by countries: the 3 % of Chinese applications are international (55 patents) while the 60% of European patents are international**

MAIN GEOGRAPHICAL AREAS OF INVENTION AND R & D

- We observe the dominance of China in patent applications (1721 patents, 44% of total number of patents)
- Chinese patents are also the most recent (average age = 4 years).
- North America patents are the oldest (average age = 17 years)

PATENTS BY COUNTRY*



x Average age of documents

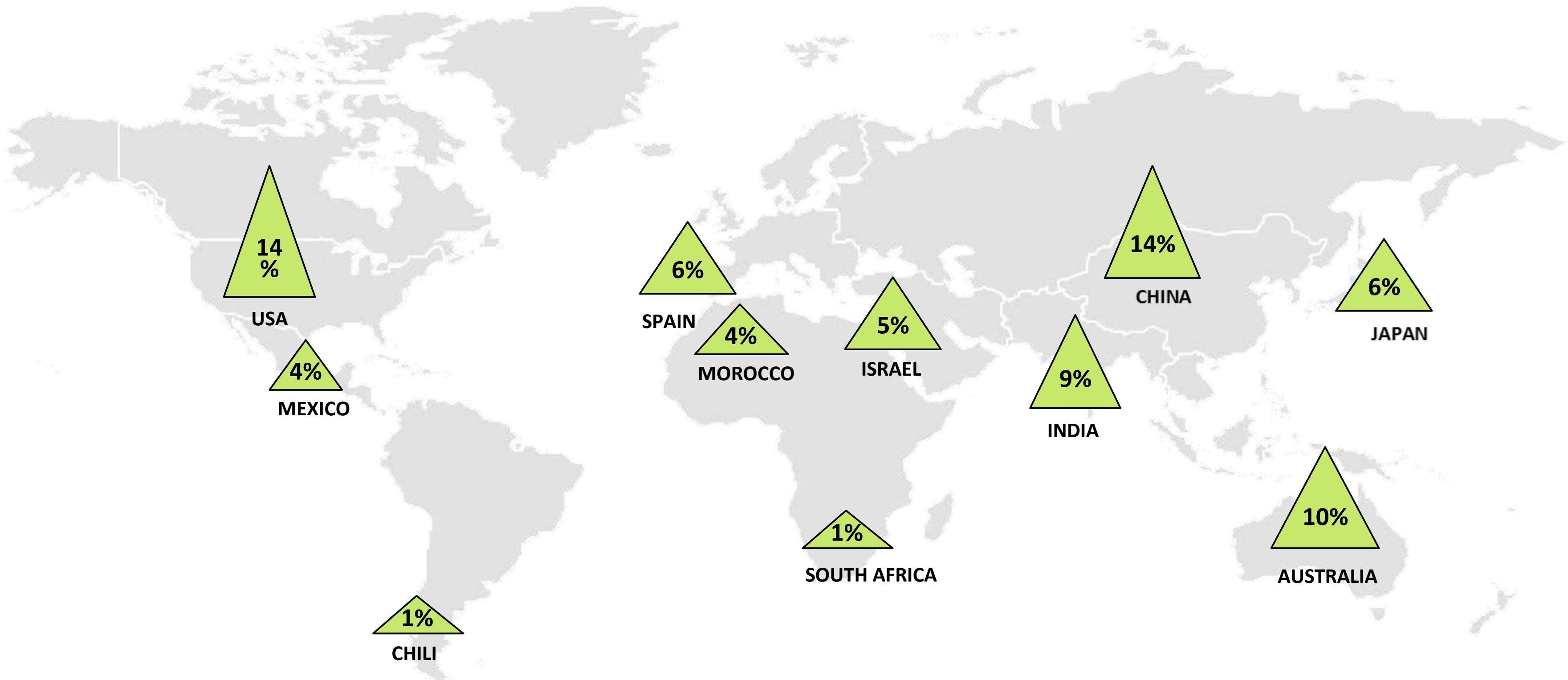
NB Analyses based on priority applications patents

* If represents at least 2%

POWERFUL GEOGRAPHIC AREAS IN TERMS OF MARKET

- The 30 % of the patent applications of the base (1189 to 3973 in total) are international and the mains designated countries are China and United States
- Australia and India are not very active in terms of research but present a market potential (9% and 10% of the total number of international patents)
- Israel , Morocco , Spain, Mexico have a potential market probably also related to the climatic conditions

PUBLICATION COUNTRIES*



International patent application:
informs about the value of an area from a market point of view

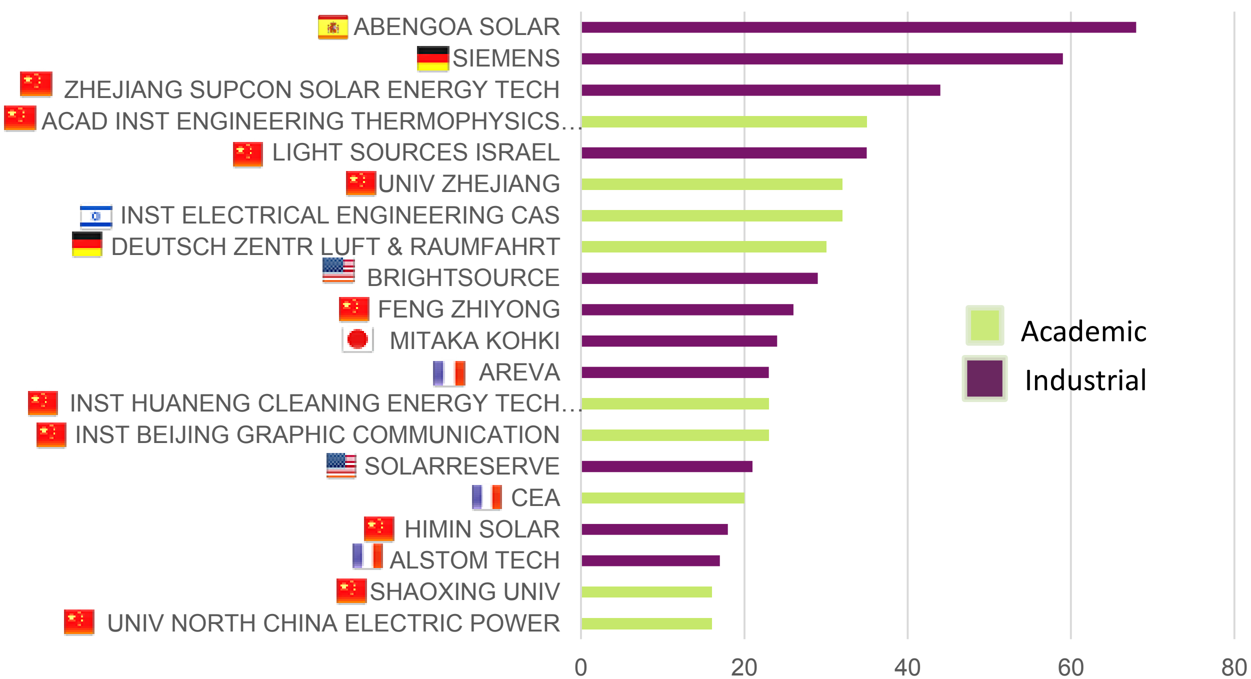
*if at least the 5% of the total of international patents

ACTORS

KEY DEPOSITORS

- Several known actors in Europe, China and the US
- Several Chinese academic actors : lower maturity of China on the subject?

Key depositors (> 16 families)



Average patent age

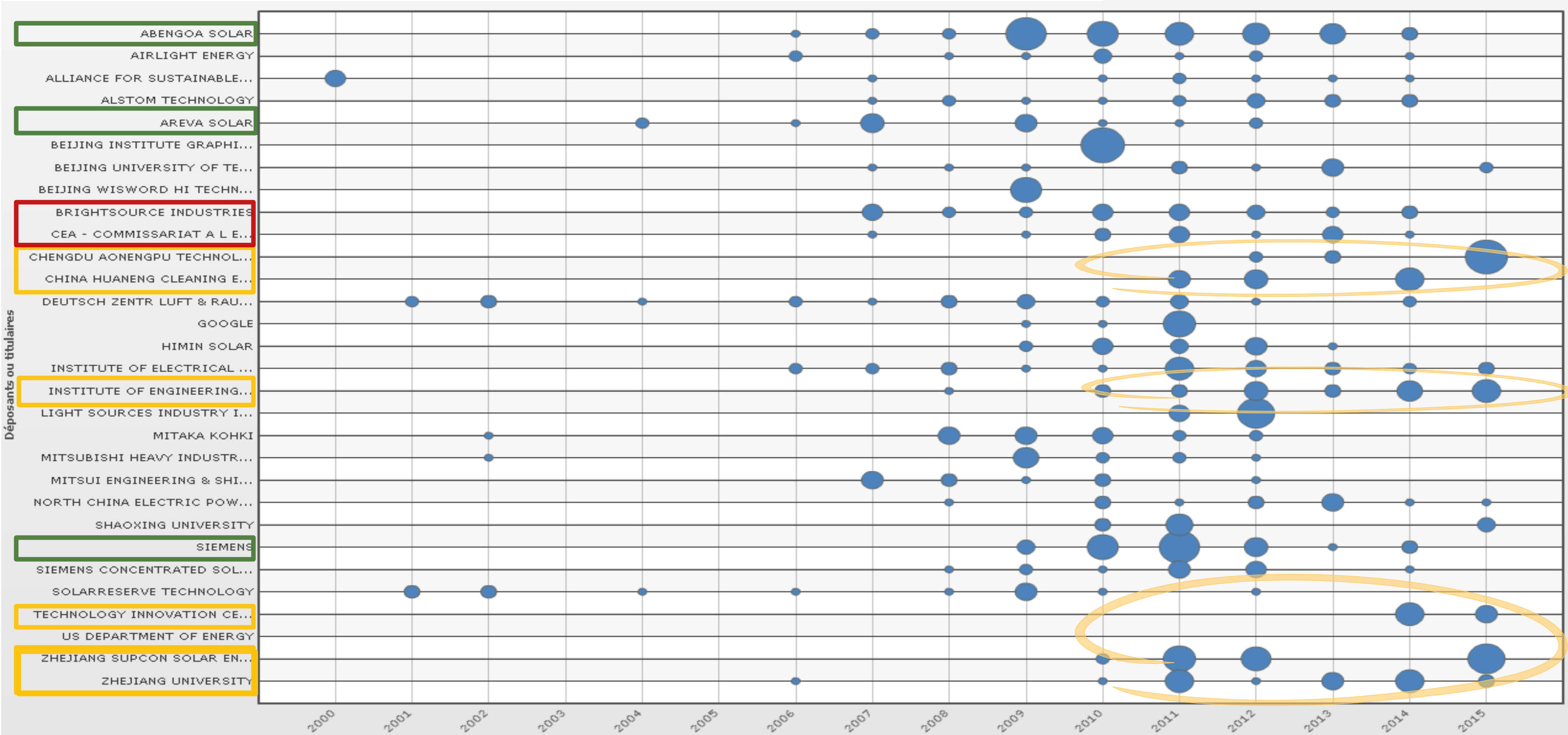
ORGANISATION	Average age (years)
ABENGOA SOLAR	5,57
SIEMENS	7,32
ZHEJIANG SUPCON SOLAR ENERGY TECH	3,25
LIGHT SOURCES ISRAEL	4,26
ACAD INST ENGINEERING THERMOPHYSICS CHINESE SCIENCES	2,97
INST ELECTRICAL ENGINEERING CAS	5,03
UNIV ZHEJIANG	3,47
DEUTSCH ZENTR LUFT & RAUMFAHRT	9,77
BRIGHTSOURCE	5,79
FENG ZHIYONG	1,46
MITAKA KOHKI	7,88
INST BEIJING GRAPHIC COMMUNICATION	6,00
INST HUANENG CLEANING ENERGY TECH RESEARCH CHINA	3,39
AREVA	8,17
SOLARRESERVE	10,38
CEA	9,85
HIMIN SOLAR	5,06
ALSTOM TECH	4,65
UNIV NORTH CHINA ELECTRIC POWER	4,00

- Actors with a high patent average age (> 8 years) are all European
- By contrast, among the major depositors, Chinese players have the most recent patents (< 4 years)

ACTORS

INVESTMENT TRENDS OF MAIN DEPOSITORS

Main depositors: investment trends



Several historic actors like ABENGOA, AREVA and SIEMENS lower their investment in the sector

CEA and BRIGHTSOURCE maintain constant interest in the field

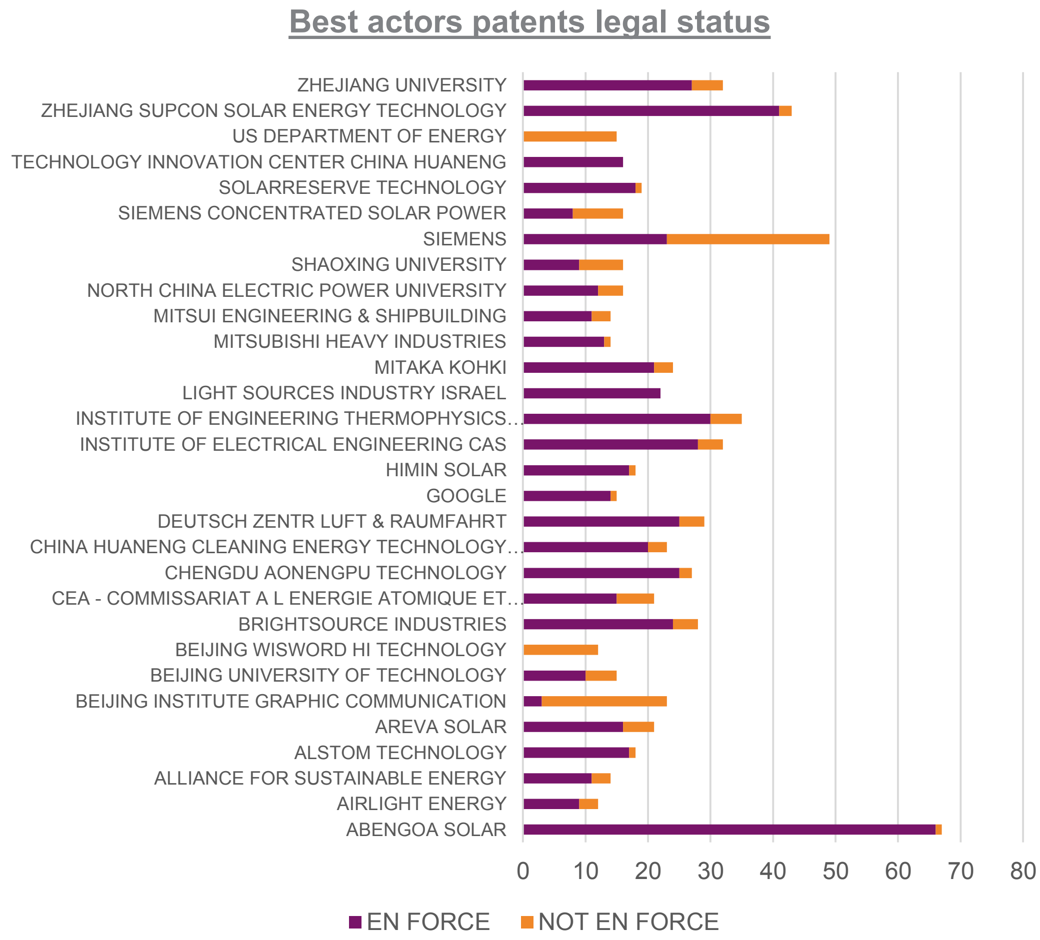
Emerging Actors => many Chinese actors

CHENGDU AONENGPU TECHNOLOGY, CHINA HUANENG CLEANING ENERGY TECHNOLOGY RESEARCH INSTITUTE, INSTITUTE OF ENGINEERING THERMOPHYSICS CHINESE ACADEMY OF SCIENCES, ZHEJIANG SUPCON SOLAR ENERGY TECHNOLOGY et ZHEJIANG UNIVERSITY et TECHNOLOGY INNOVATION CENTER CHINA HUANENG

BEST ACTORS PATENT LEGAL STATUS

- ABENGOA, SUPCON SOLAR, INSTITUTE OF ENGINEERING THERMOPHYSICS CHINESE ACADEMY OF SCIENCES and almost all the Chinese actors: large percentage of patents is in force

- SIEMENS, US DEPARTEMENT OF ENERGY, BEIJING INSTITUTE GRAPHIC COMMUNICATION, BEIJING WISWORD HI TECHNOLOGY: patents not in force are more than patents in force



NEWS 2016 FROM SOME RELEVANT DEPOSITORS

- **Abengoa (Espagne)**

Troubled Spanish engineering and renewables group Abengoa announced August 2016 it has reached a debt restructuring and recapitalisation agreement with a group of investors and creditors.

The company, since November 2015 has been trying to avoid Spain's largest bankruptcy: The restructuring deal will provide the company with much-needed cash, after its finances were so stretched over recent months that it has failed to pay some wages on time.

- **Siemens (Germany)**

The German group closed its solar division in 2013. They wanted to become the world leader in solar thermal, but this division has not been up to expectations mainly due to fierce competition and price reductions. Components for the CSP as the turbines are nevertheless still part of the Siemens product offer

Zhejiang SUPCON Solar Technology (China)

China wants to have 3GW of solar thermal energy for 2020. New CSP plant construction projects have been launched in this regard. The first CSP plant marketed in China is the Delingha plant (capacity of 50 mWatt). This plant is operated by SUPCON Group.

- **Brightsources (US)**

BrightSource Energy is currently deploying advanced solar field technologies at the 121 megawatts (MW) Ashalim Solar Thermal Power Station located in Israel's Negev Desert. The fourth generation of BrightSource's solar field technologies are designed to further optimise power production, reduce construction time and lower project costs

- **ACS Cobra (Spain)**

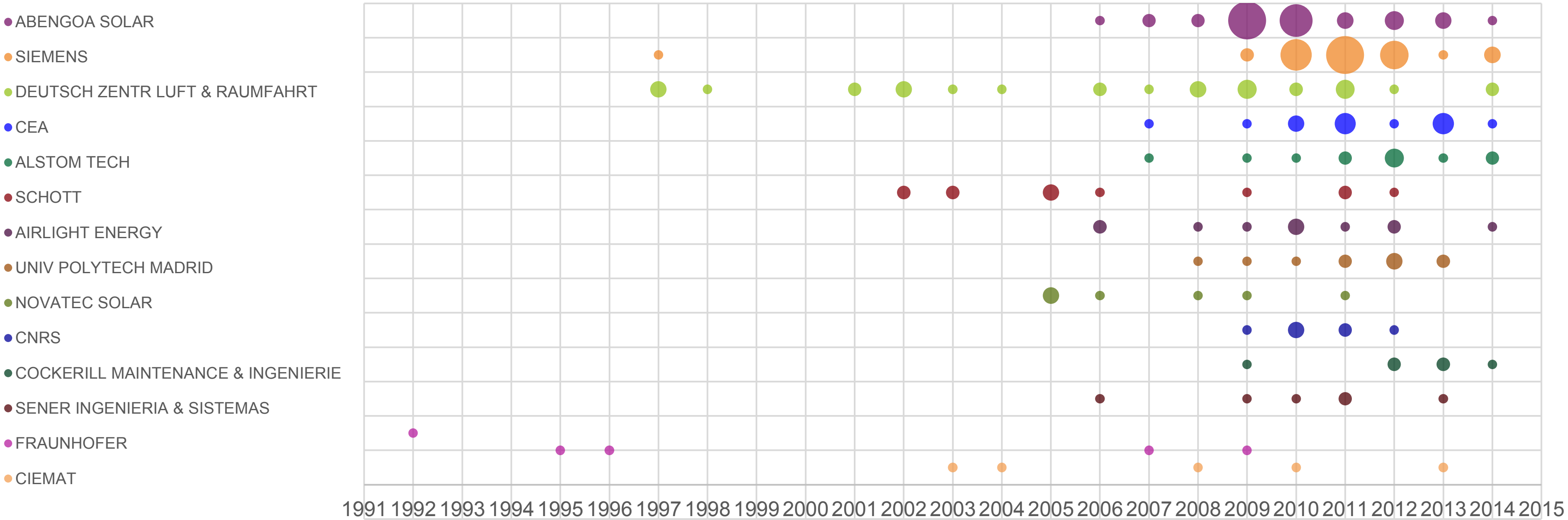
ACS, through its subsidiary Cobra, has been selected by the consortium Ilangalethu for construction, operation and maintenance of a Concentrating Solar Power (CSP) plant in South Africa that will be executed under a turnkey contract worth approximately 550 million euros. It has good results in 2015

- **SENER and ACCIONA (Spain)**

Spanish companies Sener Group and Acciona have recently started construction of the 100-MW Kathu concentrating solar power (CSP) plant in Northern Cape, South Africa. The power plant will be equipped with a molten salt storage system allowing for 4.5 hours of thermal energy storage. Commercial operation is set to begin in 2018

FOCUS ON THE MAIN EUROPEAN DEPOSITORS

TOP EUROPEAN ACTORS (> 4 *families*)



In the top European depositors we find some known Spanish, German and French organisms:

ABENGOA Spain), CSP sector leader, after a big activity in 2009 and 2010 seems to have lost interest in the domain starting from 2011

Almost the same for SIEMENS (Germany), which entered late the domain (2009) and went out in 2013: his activity is down after expansion years 2010-2011-2012

CEA (France) have upward and downward trend activity but do not seem to have the reduction of interest during the last years

ALSTOM (France) seems to have quite good activity in 2014 but its CSP division has been bought by GE (US) at the end of 2015

SCHOTT SOLAR (Germany) recently sold its business of the solar receivers to RIOGLASS SOLAR (Spain) and has no activity patents since 2013

NOM	Nombre documents	PAY
ABENGOA SOLAR	44	Spain
SIEMENS	43	Germany
DEUTSCH ZENTR LUFT & RAUMFAHRT	30	Germany
CEA	20	France
ALSTOM TECH	12	France
SCHOTT	12	Germany
AIRLIGHT ENERGY	11	Swiss
UNIV POLYTECH MADRID	10	Spain
CNRS	7	France
SENER INGENIERIA & SISTEMAS	7	Spain
NOVATEC SOLAR	7	Germany
COCKERILL MAINTENANCE & INGENIERIE	6	Belgium
FLAGSOL	5	Germany
FRAUNHOFER	5	Germany
CIEMAT	5	Spain

ACTORS

MAIN COLLABORATIONS

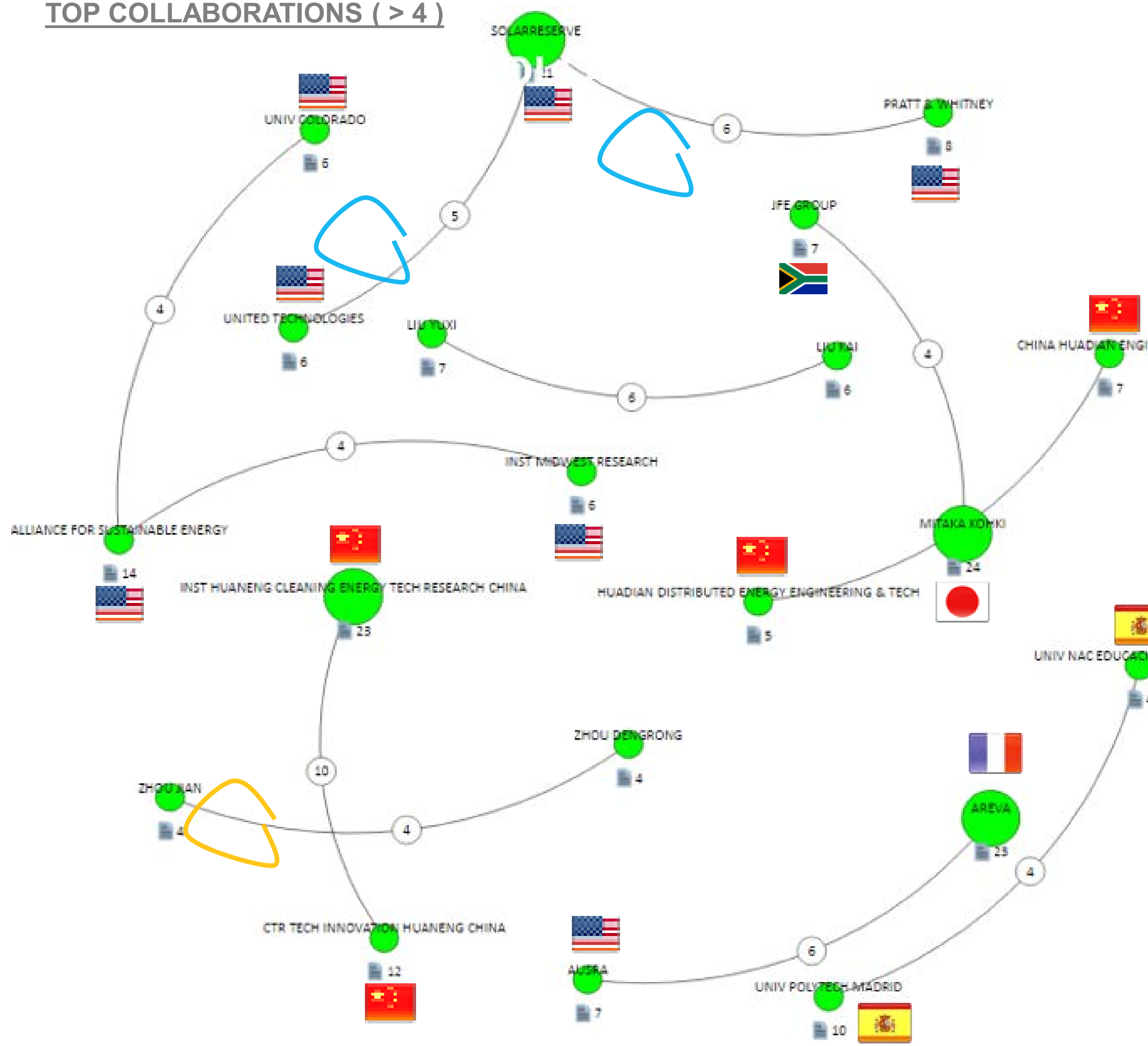
Many collaborations (10) between INST HUANENG CLEANING ENERGY TECH RESEARCH CHINA and CTR TECH INNOVATION HUANENG CHINA (academic)

Many collaborations for SOLAR RESERVE (5 documents with United Technologies and 6 with Pratt & Withney) and MITAKA KOHKI (7 documents with CHINA HUADIAN ENGINEERING, 7 with JFE GROUPE and 5 with HUADIAN DISTRIBUTED ENERGY ENGINEERING & TECH)

Very few collaborations between industrial and academic players.

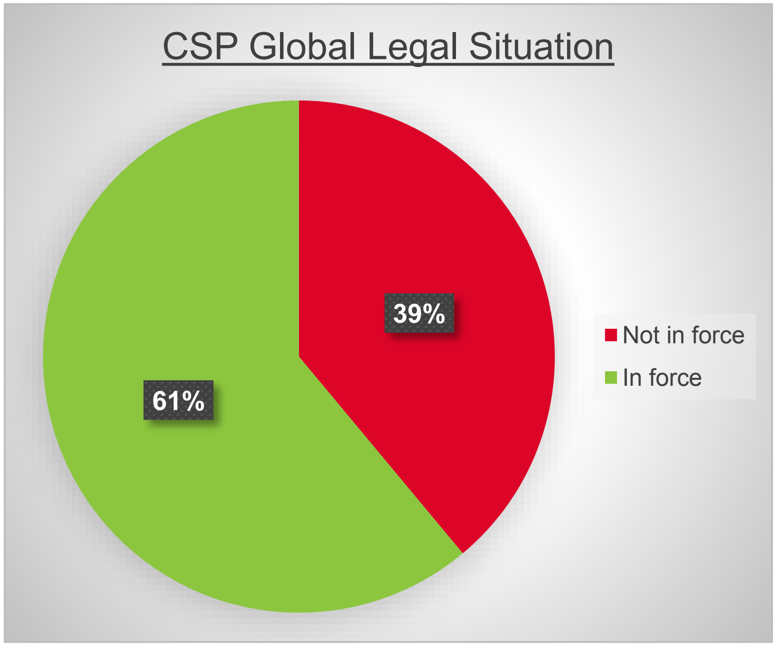
Among these collaborations, 3 documents shared between CEA and SALZGITTER MANNESMANN PRECISION ETIRAGE (not in the picture)

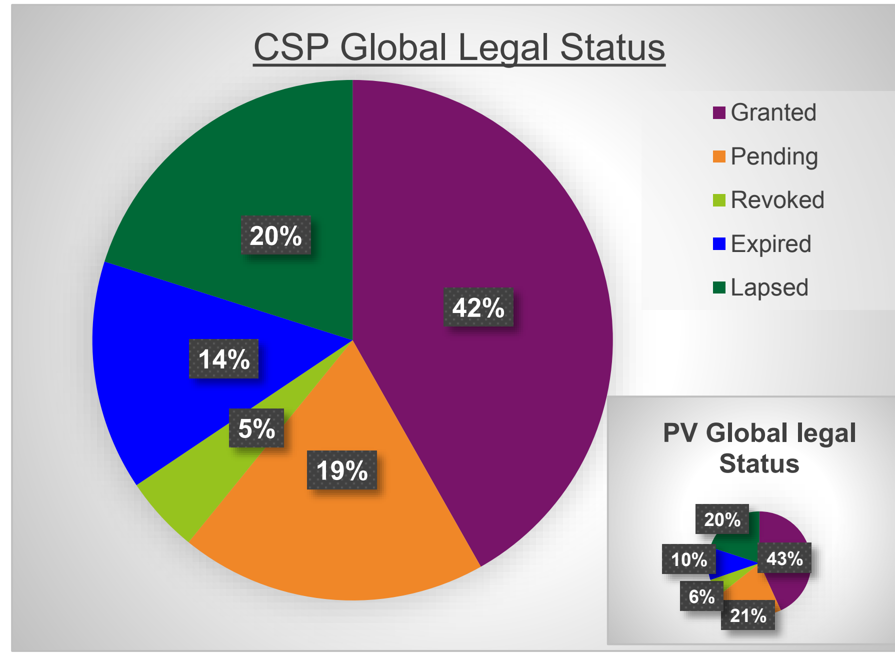
TOP COLLABORATIONS (> 4)

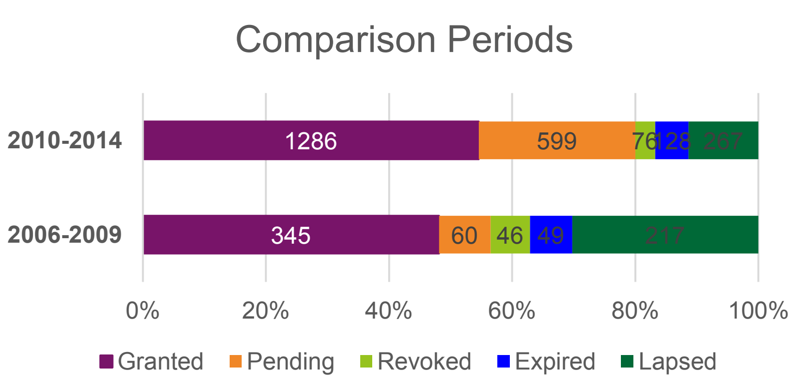


THE OVERALL LEGAL STATUS

- 39% of total patents applications concerning CSP are not in force and 61% are in force
- In detail: 19% of CSP applications are pending, 42% are granted, 20% are lapsed and 14% are expired (note that only 10% of PV applications are expired)







Patents in force:

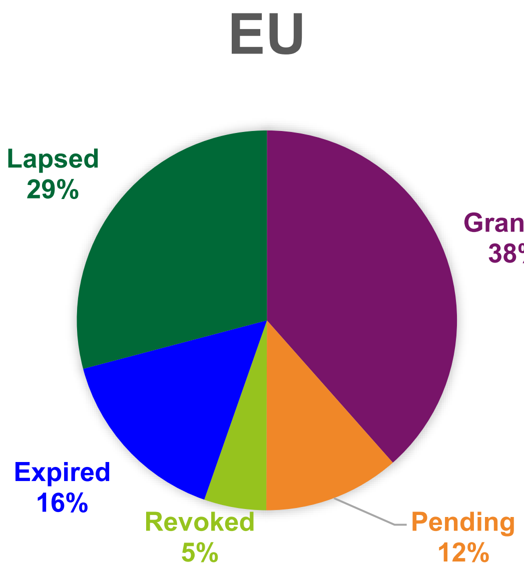
Granted : Delivered – Current Protection
Pending: Examination in progress

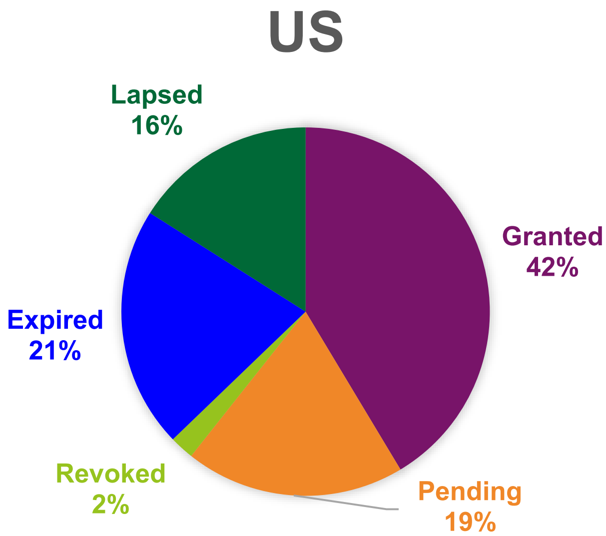
Patents not in force:

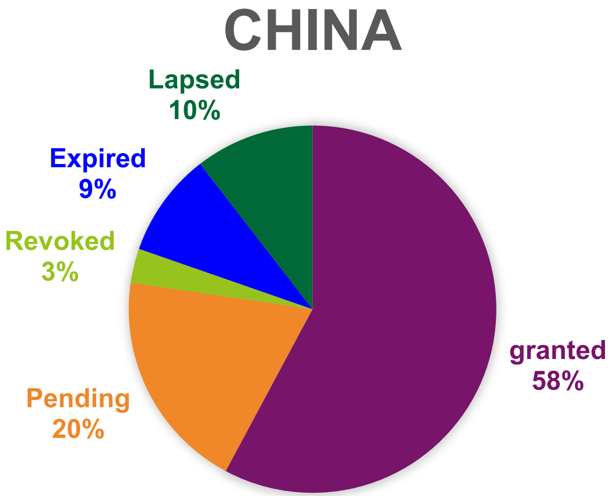
Lapsed : Did not arrive at the term of the duration of protection
Expired : Arrived at the term of the duration of protection
Revoked : Revoked during the procedure of examination

LEGAL STATUS BY GEOGRAPHIC AREAS

- The percentage of lapsed EU patents (29%) is higher than that of China (10%) and US (16%) indicating declining interest of European organisation for the sector.
- Similarly, the percentage of European pending applications (12%) is lower than other countries







SOMMAIRE

SEGMENTATION OF THE BASE

CONCENTRATED SOLAR POWER

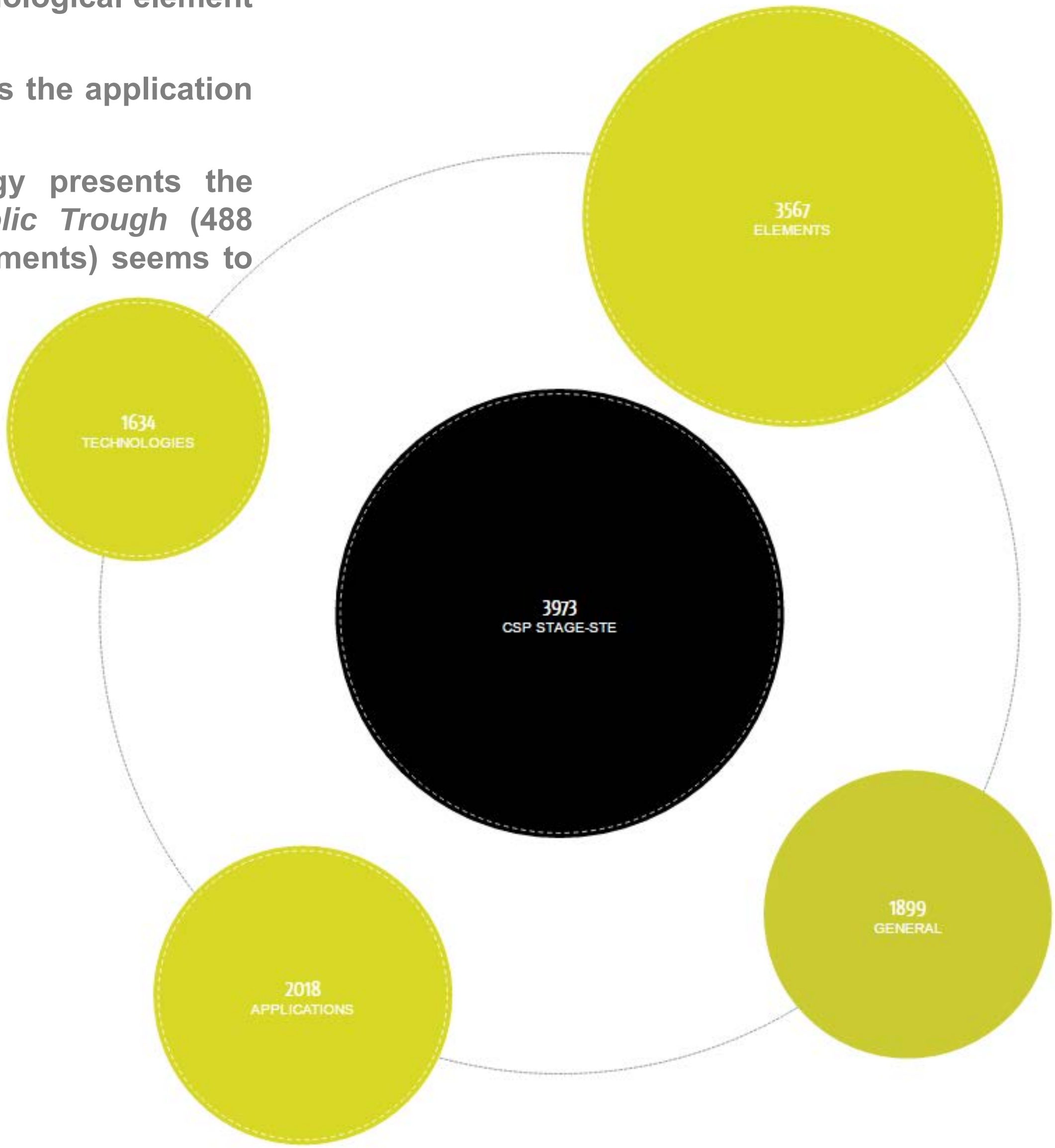
- **Applications**
  - **High Temp Collectors**
    - Desalinisation / Distillation
    - Electricity Generation
    - Enhanced oil Recovery
    - Gasification
    - Hybrid
    - Industrial Process Heating
    - Solar Fuel / H2 production
  - **Medium Temp Collectors**
    - Cooking
    - Drying
  - **Low Temp Collectors**
    - Cooling
    - Heating
    - Ventilation
- **Elements** (Technological Components)
  - **Operation**
  - **Power Block**
  - **Solar Field**
  - **Thermal Storage**
- **Technologies**
  - Dish Stirling
  - Fresnel Reflectors
  - Parabolic Trough
  - Power Tower
- **General**

Corpus of patents were classified according to these criteria automatically (by keywords)

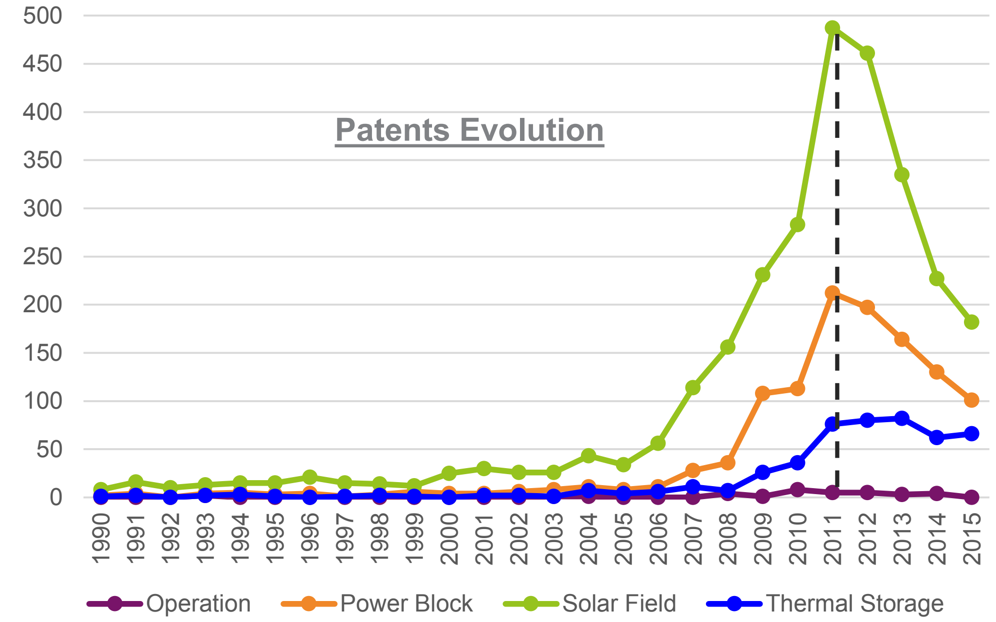
DISTRIBUTION OF DOCUMENTS

- **ELEMENTS:** ***Solar Field*** **is the most cited technological element (3269 patents)**
- **APPLICATIONS:** ***High Temperature collectors*** **is the application collecting more success (1697 documents)**
- **TECHNOLOGIES :** ***Power Tower*** **technology presents the largest number of documents (667).** ***Parabolic Trough*** **(488 documents) and** ***Fresnel Reflectors*** **(475 documents) seems to be quite cited too**

	Nb of documents
ELEMENTS	**3567**
Solar Field	3269
Power Block	1254
Thermal Storage	508
Operation	38
APPLICATIONS	**2018**
High Temperature Collectors	1697
Low Temperature Collectors	521
Medium temperature Collectors	311
TECHNOLOGIES	**1634**
Power Tower	667
Parabolic Trough	488
Fresnel Reflectors	475
Dish Stirling	122



TECHNOLOGICAL BRICKS: TEMPORAL DYNAMICS



- <u>We notice 2 different periods of activity</u>:
  - ***<u>From 2006 to 2011</u>***

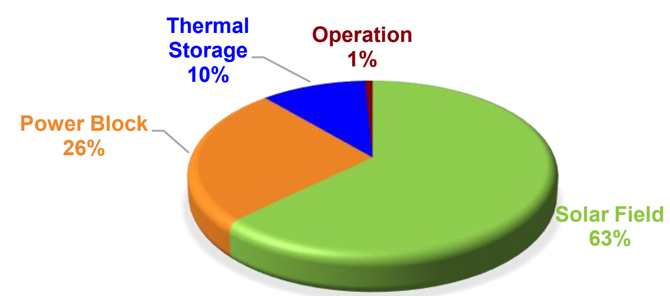
    Raising interest for all the technological bricks (the interest for the brick *Operation* remains marginal over all the period)
  - ***<u>After 2011</u>***

    ***Power Block* and *Solar Field* technological bricks seem to arouse less interest. They remain in any case the most quoted in patents.**

    The interest for bricks *Thermal Storage* and *Operation* remains constant over the period

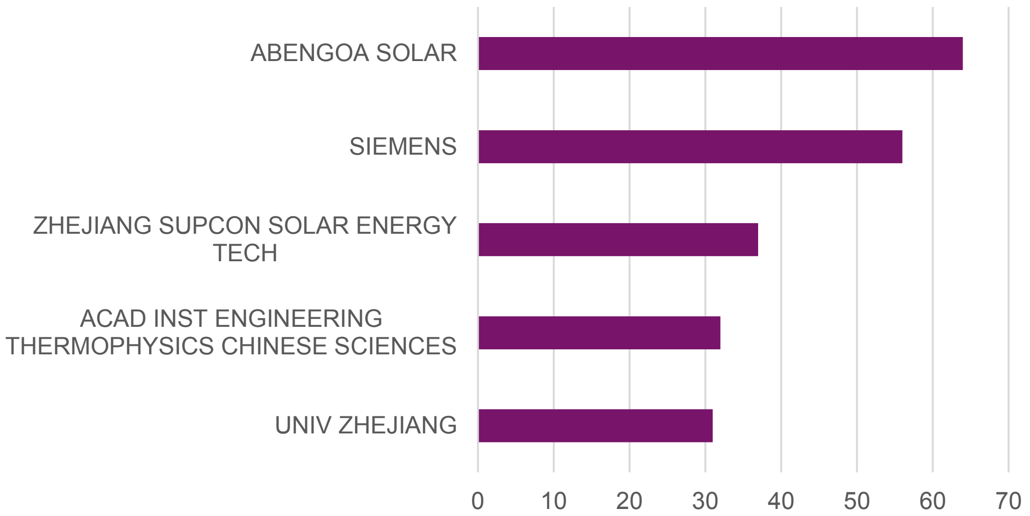
- **The brick *Solar Field* is by far he most important by the number of patents**

<u>Patents Distribution</u>



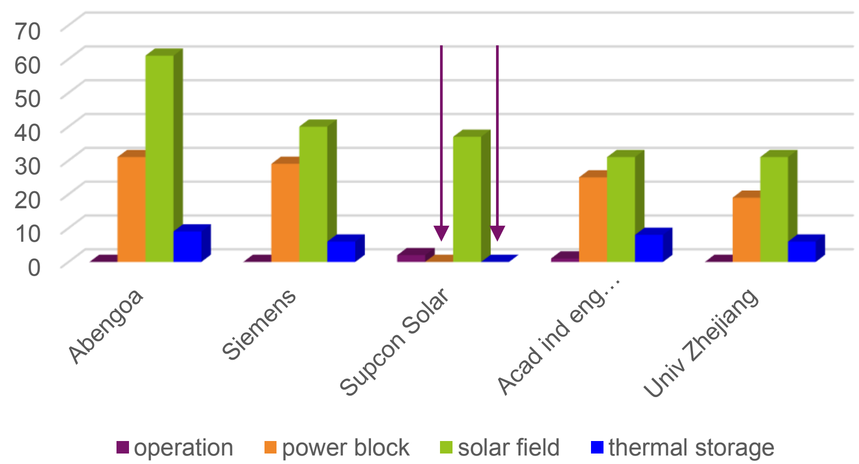
TECHNOLOGICAL BRICKS: ACTORS

Top 5 actors



- **We find the main actors of the domain**

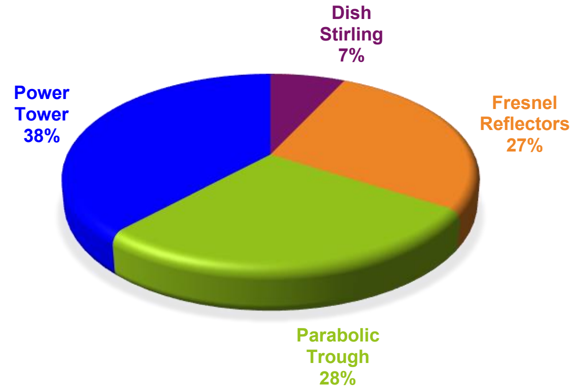
Patent Distribution by actor



- **For all the 5 top actors the largest number of patents relates to *Solar Field* technological brick**
- **For 4 of the 5 top actors *Power Block* technological brick is in second position. In contrast, SUPCON SOLAR has very few documents concerning this brick as well as for the *Thermal Storage* brick**
- ***Operation* brick seem arouses less interest in top 5 actors**

TECHNOLOGIES: TEMPORAL DYNAMIC

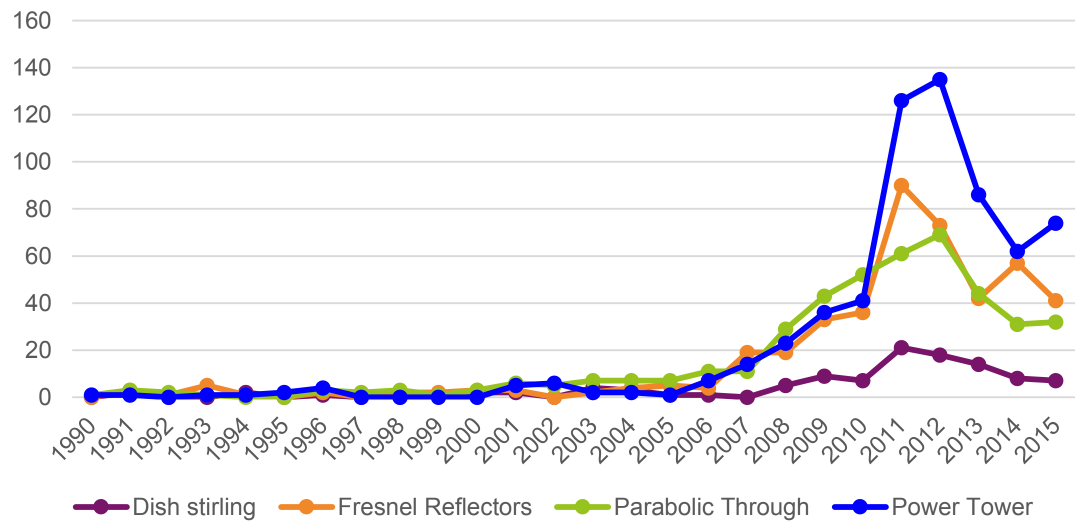
Patents Distribution



- The technology which arouses the biggest interest is the *Power Tower*
- *Dish Stirling* seems to be the less interesting technology

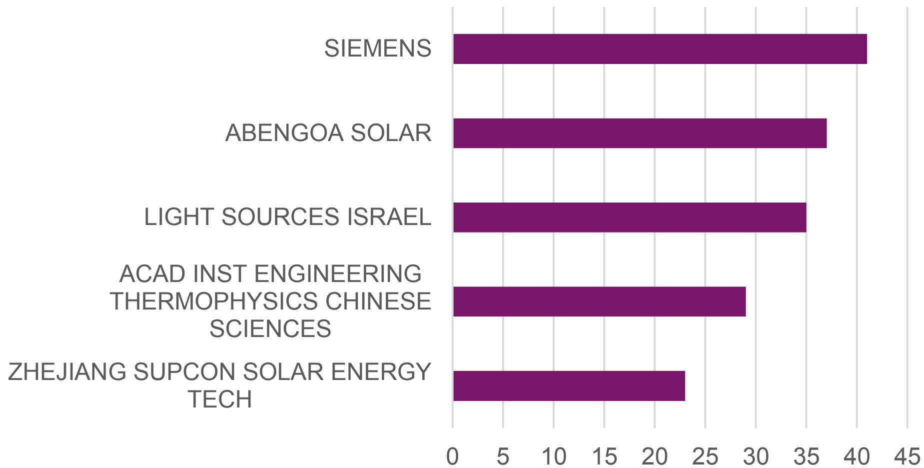
- Different periods of activity:
  - 2006-2010: increasing interest for all technologies. Exponential Evolution for *Power Tower*
  - 2011: Patent applications for *Power Tower* are twice patent applications for *Parabolic Trough*. *Dish Stirling* has the lowest number of patent applications
  - 2011-2013: drop in patent applications
  - After 2013: the number of patent applications for every technology seems to stabilise (In spite of the fact that we have no complete visibility over the years 2014 and 2015)

Patent Evolution



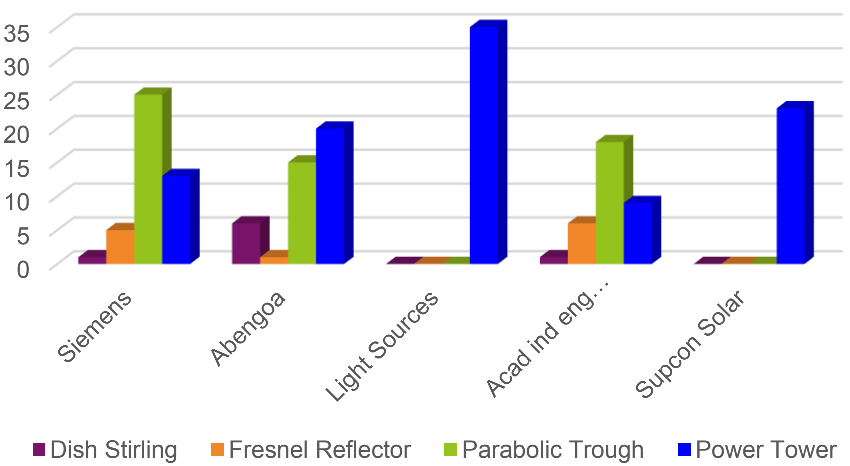
TECHNOLOGIES: ACTORS

Top 5 players



- We find the main actors of the domain

Patents Distribution by actors



Different specialisations for different actors:

- **LIGHT SOURCE and SUPCON SOLAR seems to be specialised in *Power Tower***
- **ACAD ING ENG THERMOPHYSICS SCIENCE focalises mainly on *Parabolic Through* technology**
- **ABENGOA is interested in *Power Tower* as well in *Parabolic Trough***

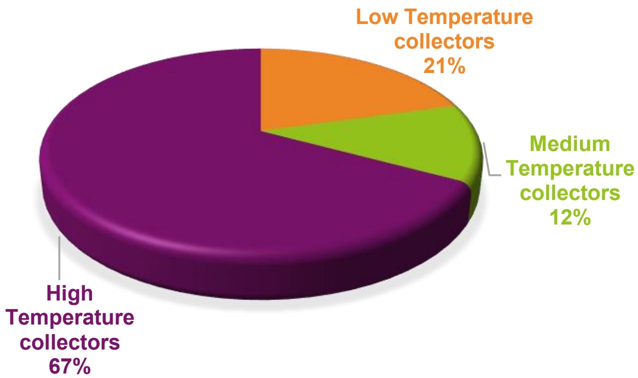
APPLICATIONS: TEMPORAL DYNAMICS

High Temperature Collectors is the application which awakes the biggest interest (1697 documents, 67% of *Applications* folder corpus)

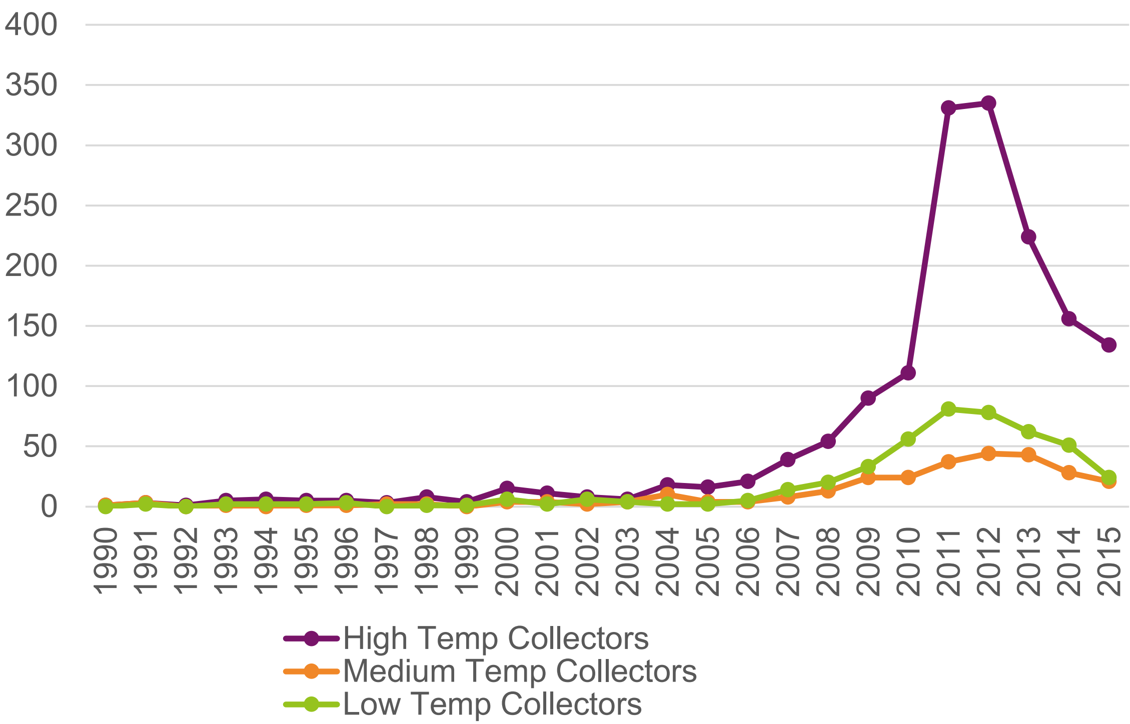
Among 1697 documents concerning *High temperature collectors* :

- ✓ 1396 mentions *Electricity Generation* applications,
- ✓ 249 mentions *Desalinisation* applications
- ✓ 197 mentions *Industrial process heating* application

Patents Distribution



Patents Evolution

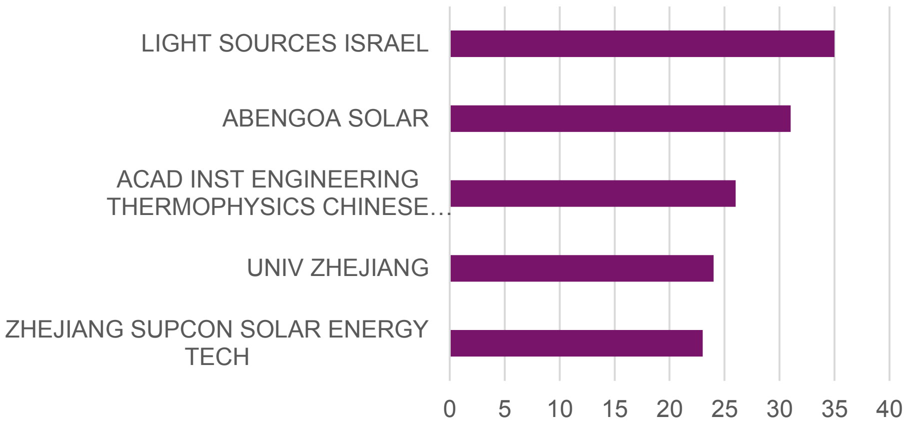


- Different periods of activity:
  - 2006-2011: increasing interest for all Applications. Sharp rise for *High Temperature Collectors*
  - 2012: Patent applications for *High Temperature Collectors* are 4 time patent applications for *Low temperature collectors.*
  - After 2012: drop in patent applications (sharp drop for *High temperature Collectors*)

SEGMENTATION ANALYSIS

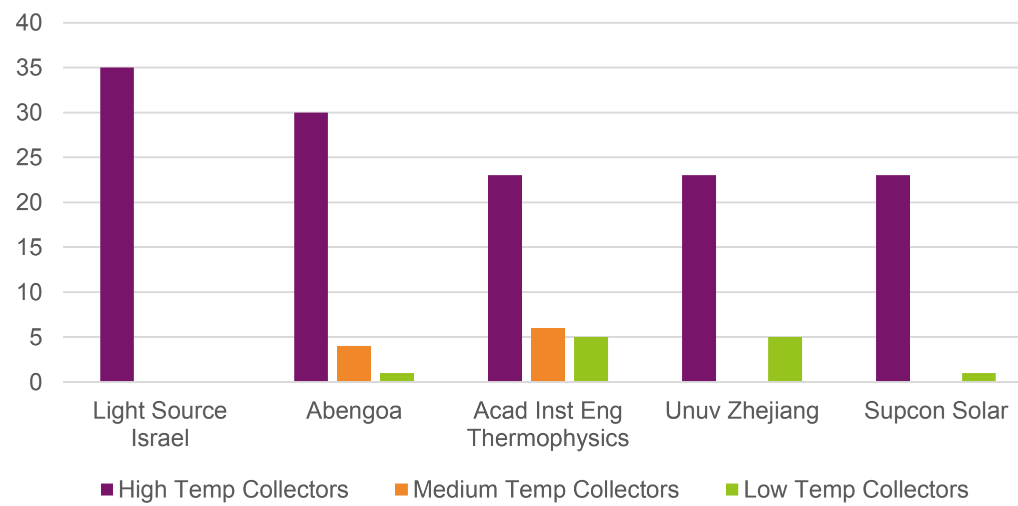
APPLICATIONS: ACTORS

Top 5 Actors



- We always find the principal actors of the domain

Patent Distribution by actors



Specializations:

- **LIGHT SOURCE and SUPCON SOLAR seems to be specialised in *High Temperature Collectors***
- **ACAD IND ENG THERMOPHYSICS CHINESE SCIENCE and ABENGOA activity is mainly on *High temperature collectors* but also on *Medium and Low temperature collectors***

SEGMENTATION ANALYSIS

CROSSOVER MATRIX

No documents — All documents

Crossover Matrix Applications vs Technologies

	Dish Stirling	Fresnel Reflectors	Parabolic Trough	Power Tower
High Temp Collectors	60	217	153	404
Low Temp Collectors	8	71	49	40
Medium Temp Collectors	12	48	28	37

Crossover Matrix High Temperature Applications vs Technologies

	Dish Stirling	Fresnel Reflectors	Parabolic Trough	Power Tower
Desalinization/Disti...	4	41	24	54
Electricity Generation	48	173	118	358
Enhanced oil recovery	0	1	0	2
Gasification	2	6	10	22
Hybrid	7	20	18	45
Industrial process heating	5	25	35	23
Solar Fuel / H2 production	8	16	8	40

- *High Temperature Collectors* is the field which collects the main number of patent applications, mainly concerning *Power Tower* and *Fresnel Reflector* Technologies
- *Electricity generation* is by far the principal high Temperature application. The desalinisation is quite interesting too

Crossover Matrix Elements vs Technologies

	Dish Stirling	Fresnel Reflectors	Parabolic Trough	Power Tower
Operation	0	4	2	6
Power Block	84	182	142	291
Solar Field	97	415	425	547
Thermal Storage	13	50	69	130

- *Solar Field* is the most cited technological component for all 4 Technologies. It is followed by *Power Block* element

1. INTRODUCTION

- Context and Objectives
- Methodology
- Limits
- Constitution of the database
- Search queries

2. GLOBAL OVERVIEW

- Temporal Evolution
- Geographic origin
- Actors
- Legal Status

3. SEGMENTATION ANALYSIS

- Documentary database
- Temporal Dynamics by segment
- Top Actors by segment
- Crossover Matrix

4. CONCLUSIONS

CONCLUSIONS

Corpus of 3973 sorted patents (excluding PV)

- Temporal Analysis
  - 2 different periods :
    - 2006-2011 : very important increase of the patent number mainly due to China's high involvement
    - **2012-2014 : very important decrease of the patent number** (including China but at a lower level)
- Geographical analysis
  - **The main actors in patents are Chinese (44%)** but with few patent extension in foreign countries (about 3%, vs 60% & 43% for EU and NA); then come North America (25%) Europe (18%), Asia (excluding China) (9%) and Russia (2%)
  - **Patent publication area is a good mirror of the market areas** : USA (14%), China (14%), Australia (10%) , India (9%), Spain(6%), Israël (5%), Mexico (4%), Morroco (4%), South Africa (1%), Chile (1%)
- Legal status analysis :
  - around 2/3 of the 4000 patents are in force
  - 2006-2009 : few pending patents versus the number of patents lapsed or expired
  - 2010-2014 : important growth of the pending patent number versus patent lapsed or expired

    → **CSP Market is getting more competitive**
  - In Europe more lapsed patent than in US and China

    → **decreasing interest of EU for CSP technologies**

- **Depositor Analysis**

  - 5 main depositors : Abengoa (E), Siemens (D), Supcon (RPC), Academy of Chineses Sciences (RPC), University of Zhejiang (RPC)
  - **China = emerging actor**
    - most of depositors are academics → lower maturity ?
    - Patents are newer (< 5 years)
  - EU & US = historical actors
    - Owning the older patents (>10 years)
    - **Decrease of activity from the historical industrial actors** (Abengoa, Areva, Siemens)
  - Most of collaboration in patents are among academics : **Very few collaboration between industrial and academics !**
    - **→ low relevance of patents ?**
    - **→ low transfer capacity for patents ?**

- <u>Technological block analysis</u>

  - **Solar field = first technical block of interest** (in 82% patents)
  - Power block (31%), and Storage (13%),
  - **Operation of CSP plants = lack of interest (1%)**
  - Interest for SF and PB varied in time, Interest in ST storage constant in time (because of other applications ?)

- <u>Solar field technology analysis</u>

  - **Tower (40%)** (large peak then very very important decrease)
  - **PT & LFR (30% each)** (peak then decrease)
  - Dish (7 %) → lack of interest

CONCLUSIONS

- Applications Analysis

  - **High Temperature** :
    - ✓ Electrical production (in 70% of related patents)
    - ✓ **Desalination (in 12 %** of related patents)
    - ✓ **Industrial process heating (in 10%** of related patents)

  - **Mid Temperature :**
    - ✓ **Cooking/Drying (in 15%** of related patents)

  - **Low Temperature :**
    - **Heating/Cooling (in 26%** of related patents)

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