Study on impacts of EU actions supporting the development of renewable energy technologies

Technology Sector Report

Solar thermal energy
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Study on impacts of EU actions supporting the development of renewable energy technologies

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1 Introduction

This report is the second technology sector report in the series of eight technology sector reports for the study *Impacts of EU actions supporting the development of renewable energy technologies*, prepared for the European Commission. The report has two objectives: describing how EU research and development (R&D) funding for the solar thermal technologies has impacted the solar thermal sector in the EU and describing more broadly the development of the solar thermal sector to which the EU R&D funding has contributed. It is based on a compilation of data from several databases, a questionnaire among coordinators of EU-funded R&D projects, case studies, interviews and literature research. The methodology applied for this study is documented in a separate deliverable.[1] Where relevant, limitations and assumptions are mentioned throughout this report.

Solar thermal energy refers to any technology that harnesses energy from the sun to generate thermal energy, which can be further converted into electricity or used directly as heat. In contrast to solar photovoltaic (PV), solar thermal technologies do not exhibit the PV effect. Solar thermal energy consists of two main technology categories: concentrated solar power (CSP), and solar heating and cooling technologies:

- CSP is a system that uses mirrors or lenses to concentrate a large area of sunlight into a smaller area to heat a medium (usually a liquid or gas) that is then used in a heat engine process (steam or gas turbine) to drive an electrical generator, thereby generating power;
- Solar heating is the collection of heat from the sun. The most common technologies for this process include evacuated tube collectors, glazed flat-plate collectors and unglazed water collectors. Solar cooling can be accomplished via desiccant or absorption chiller systems. In addition, PV-thermal hybrids (technology that converts solar radiation into thermal and electrical energy at the same time) are also classified under this category. This is because normally the aim of hybrid systems is to produce thermal energy first and then electricity.

1.1 Concentrated solar power

The first CSP plants were built more than 30 years ago (SEGS I-V in Dagget, California). These first plants were based on the Parabolic Trough design. In recent years, other concepts such as Linear Fresnel, Dish Stirling and Solar Tower have also been developed. Especially the tower systems are currently considered to be the natural evolution of the technology.

The central elements of a solar tower system include a receiver placed on top of a tower structure, a number of heliostats (mirrors) surrounding the receiver tracking and directing the sunlight to the receiver, a steam generation system, and a storage system. Typically, the system utilises molten salts as heat transfer medium to generate steam that drives the turbine for the generation of electricity and the molten salt system allows energy storage beyond the daylight hours.

Plant efficiencies in this solar tower configuration are considerably higher than parabolic trough plants. Due to the higher temperature being realised in the heat transfer fluid, higher temperature and pressure steam conditions are achieved and thus higher efficiencies are obtained in the turbine.

[1] Trinomics (2018) - Study on impacts of EU actions supporting the development of renewable energy technologies – Literature review and methodology (Deliverables D1.1 and D1.2)

Together with this, solar tower configuration still is considered to have an important learning curve ahead. In the past, almost all CSP plants were based on Parabolic Trough technology and important cost reductions have been achieved thanks to the knowledge gained from one plant to another. This is now happening in solar tower configuration and there is a strong consensus in the sector that tower technology will realise important cost reductions in the next years.

The future of CSP is linked to its thermal energy storage capability. Compared to other renewable energies, CSP is considered one of the few dispatchable renewable energy sources (RES) for large-scale electricity generation. This dispatchability is achieved due to the availability of low cost heat storage via molten salts. (Large-scale electrical storage via batteries is not yet robust enough or economically viable). So, CSP currently can produce electricity in a dispatchable way and thereby generate electricity in periods of the day where there is a shortage of generation capacity and when electricity prices are high. This is one of the main advantage of this technology compared to photovoltaics or wind energy.

For CSP, environmental requirements are likely to become more important, since CSP plants are expected to be located in regions outside Europe with more aggressive environmental conditions where water scarcity is a major issue, and this will have a significant impact on plant design and materials. Locations outside Europe will allow local industries to offer products/services for the sector and thus the European industry will face increased competition, particularly as many countries have adopted policies aimed at increasing the local content of CSP projects. For instance, South Africa defined a minimum local content requirement of 20 % in 2011 and has increased this to 45 % in 2015.

Within the EU, Concentrated Solar Power (CSP) is predominantly applied in Spain. In terms of deployment, the technology is still at an early stage compared with other renewables such as solar PV and wind.

1.2 Solar heating and cooling

The solar heating and cooling market consists of four types of applications:

a) solar water heating – a mature market facing increasing competition from PV systems and heat pumps;
b) solar-supported district heating and cooling (DH&C) systems;
c) solar heating and cooling applications in the commercial and industrial sector;
d) solar air-conditioning and cooling (by way of absorption and adsorption chillers).

Solar water heating is a mature market that is facing increasing competition from PV systems and heat pumps. District heating and cooling systems on the other hand have an increasing market uptake. By the end of 2016, 300 large-scale solar thermal systems more than 350 kWth (500 m^2) connected to heating networks and 18 systems connected to cooling networks were in operation. Denmark is the worldwide leader in solar DH&C. The use of solar heat for industrial processes (SHIP) is also growing, but mainly outside Europe. Different types of technologies coexist in this market, depending on the size of the installation and its operating temperature(s). Solar cooling is one of the most promising markets, thanks to the simultaneous occurrence of sunshine and demand for cooling. However, the market uptake is hindered by the high costs of the installations, which currently only offer a pay back in niche markets (hospitals and hotels, especially in island regions).

Although some of the solar thermal technologies are already mature and competitive, large research challenges remain to bring down costs and to advance towards the solar trigeneration concept (heating and cooling + electricity), which would allow solar energy to be the single source of energy, for example in zero-energy buildings, in areas of high solar irradiation.

2 Historical R&D funding

2.1 EU R&D funding

The EU has funded solar thermal technologies through its research and development programmes. Since FP5, the technologies have received EUR 400 million for 168 research projects, and another EUR 38 million for 16 projects on solar thermal in combination with other technologies (see Table 2.1).

Table 2.1 EU funding per framework programme (1998 to mid-March 2018, 2016 million euros[2])

	Solar thermal		Solar thermal and other RES	
Framework programme	EU funding	No. of projects	EU funding	No. of projects
FP5	56.48	47	1.91	4
FP6	21.92	22	7.75	2
FP7	207.95	53	22.77	9
Horizon 2020 (H2020) *(data available up to mid-March 2018)*	113.15	46	5.93	1
Total EU funding	**399.50**	**168**	**38.36**	**16**

Source: CORDIS (2018)
Note: Funding includes all funds made available through the Framework Programmes. It is not limited to the energy challenges but also includes funding through other programmes/instruments such as the SME instrument.
H2020 includes all projects awarded and registered in CORDIS up to mid-March 2018. As H2020 runs from 2014 to 2020, not all funding had been awarded at this point.

There was a step change in EU R&D funding for solar thermal technologies between FP6 and FP7 when funding grew by a factor of 10. The total funding under Horizon 2020 (H2020) is not yet known as the programme has not finished, but the funding that has been allocated so far is already higher than the funding under FP5 and FP6, and is likely to reach a similar level to the funding available under FP7.

2.1.1 Evolution of research topics

EU funding was divided across several sub-technologies, as shown in Figure 2.1. Most of the funding was allocated to CSP, which received EUR 245 million in total, while most projects focused on solar heating and cooling (see Figure 2.2). Other sub-technologies that received funding focused on process heating and cooling, and PV-thermal hybrids.

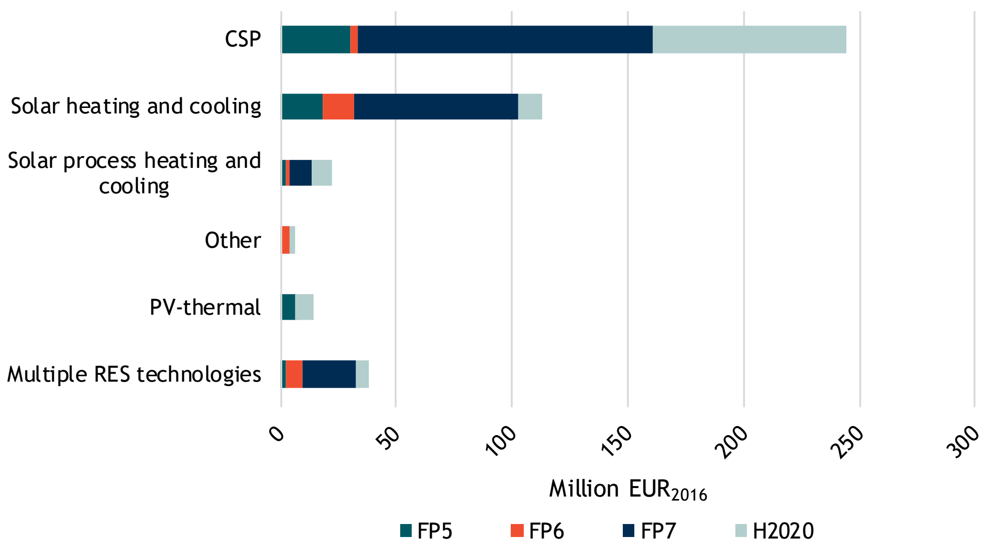
Analysing the technological fields funded in CSP projects, it clearly shows that CSP is still in its technological infancy, and many different technologies have been funded: Solar Tower concepts using innovative Heat Transfer Fluids (gases, particles, etc.), Dish Stirling systems, combined solar thermionic-thermoelectric systems, hybrid CSP plants, small/medium CSP plants based on Organic Rankine Cycle systems, etc. A number of projects have also focused on cross-cutting issues such as water use reduction, materials technologies, innovative thermal energy storage systems, and advanced systems for improved operations and maintenance (O&M). Several EU-funded projects linked to the evolution of the CSP sector in Europe in the last years such as SOLAR TRES by SENER INGENIERÍA Y SISTEMAS S.A. or the currently finished STAGE-STE (both projects are described in the detail in the case studies in Annex A).

In the case of the Solar Heating and Cooling projects, solar thermal energy has been proposed for many different purposes, such as: heating, cooling, desalination, cogeneration of heating and electricity, trigeneration of heating, cooling and electricity, and thermochemical processes. The application areas

[2] Historical values have been inflation adjusted to arrive at 2016 constant values. This has been done to show the values of budgets, prices and other monetary indicators without the impact of varying price levels over the years so that they can be compared over time more accurately.

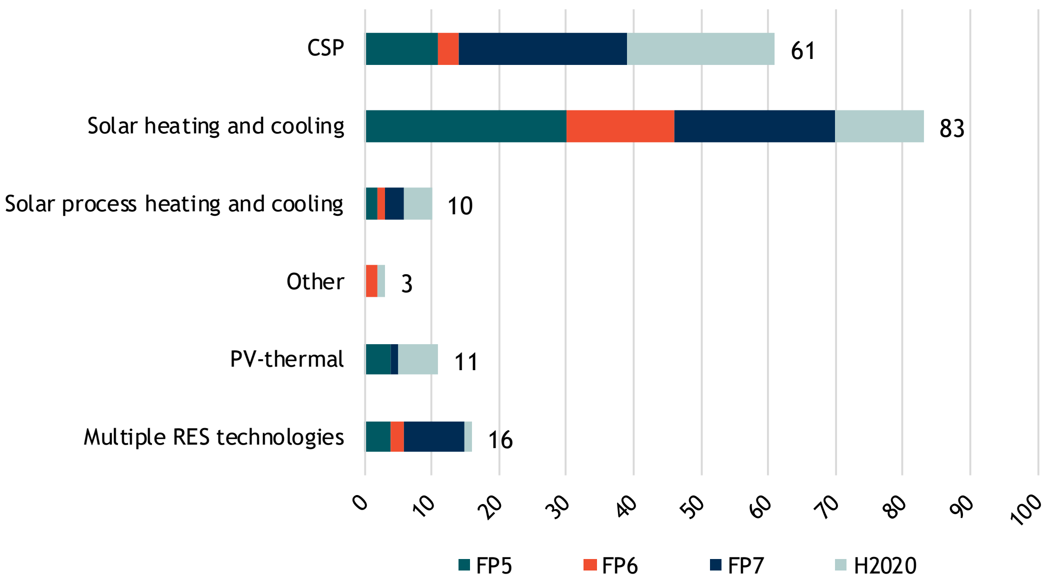
vary from individual residential and non-residential buildings to district heating and cooling systems and solar heating or cooling used in industrial processes. Research activities have addressed developments in the areas of improved components, and easier installation. Novel materials (e.g. polymers) for solar collectors also have been explored, and new concepts such as hybrid solar thermal/photovoltaic systems, and building integrated solar thermal collectors have been developed. Similar to CSP projects, several projects have also supported the development of novel thermal energy storage systems. Inside the solar thermal heating projects, importance is given to projects that link to large-scale heat generation for district heating and/or process heat.

Figure 2.1 EU funding per sub-technology/area (2016 million euros)



Source: CORDIS (2018)
The area 'multiple RES technologies' includes projects in which solar thermal is one of multiple RES technologies.

Figure 2.2 Number of projects per sub-technology/area



Source: CORDIS (2018)
The area 'multiple RES technologies' includes projects in which solar thermal is one of multiple RES technologies.

2.1.2 Top recipients

The top 10 recipients of EU funding for solar thermal technologies include 8 research institutes, 1 manufacturer and 1 engineering, procurement and construction (EPC) company (see Table 2.2). These organisations have received 32 % of the EU funding over the most recent years (from 2008).3 The research institutes included in the top 10 are all active in CSP, some exclusively while others also have activities in solar heating and cooling. The manufacturer in the top 10, Laterizi Gambettola, is an Italian manufacturer of solar thermal collectors (solar heating). The EPC company, Cobra Instalaciones y Servicios, is a Spanish company that participated in the construction of many CSP plants. Further down the list, other industrial players such as Salvatore Trifone e Figli (#11), Acciona (#13) and Brightsource Industries (#16) can be found, showing that while the research institutes are the main recipients, there is also substantial industry involvement in the EU-funded solar thermal R&D projects.

Table 2.2 Top 10 recipients of EU funding by organisation (2008 - mid-March 2018, in 2016 euros)

Rank	Organisation	Type of organisation	Funding
1	Deutsches Zentrum Fuer Luft - Und Raumfahrt Ev (DLR)	Research institute	16 494 547
2	Centro De Investigaciones Energeticas, Medioambientales Y Tecnologicas-CIEMAT	Research institute	10 982 765
3	Centre National De La Recherche Scientifique	Research institute	8 271 057
4	Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V.	Research institute	7 492 800
5	Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile	Research institute	6 517 304
6	Laterizi Gambettola SRL	Manufacturer	5 204 009
7	Commissariat a L Energie Atomique et aux Energies Alternatives	Research institute	5 112 382
8	Fundacion Tekniker	Research institute	4 365 992
9	Cobra Instalaciones Y Servicios S.A	EPC company	4 220 716
10	The Cyprus Institute	Research institute	3 847 665

Source: CORDIS (2018)
The source data covered H2020 funding and FP7 funding from 2008, which includes 58 % of total funding for solar thermal identified in section 2.1. No data was available for recipients of FP5, FP6 and part of the FP7 funding. Projects under 'multiple RES technologies', as mentioned in the introduction of section 2.1, are not included in this Table.

The main recipients of EU funding in terms of countries are Spain, Germany and Italy (see Table 2.3). These countries received 56 % of the total EU funding available for solar thermal.

Table 2.3 Top 10 recipients of EU funding by country (2008 - mid-March 2018, in 2016 euros)

Rank	Country	Funding
1	Spain	56 594 944
2	Germany	38 801 344
3	Italy	32 227 030
4	France	24 786 685
5	United Kingdom	14 785 561
6	Switzerland	7 538 961
7	Austria	5 081 884
8	Cyprus	4 969 840
9	Israel	4 187 347
10	Greece	4 067 424

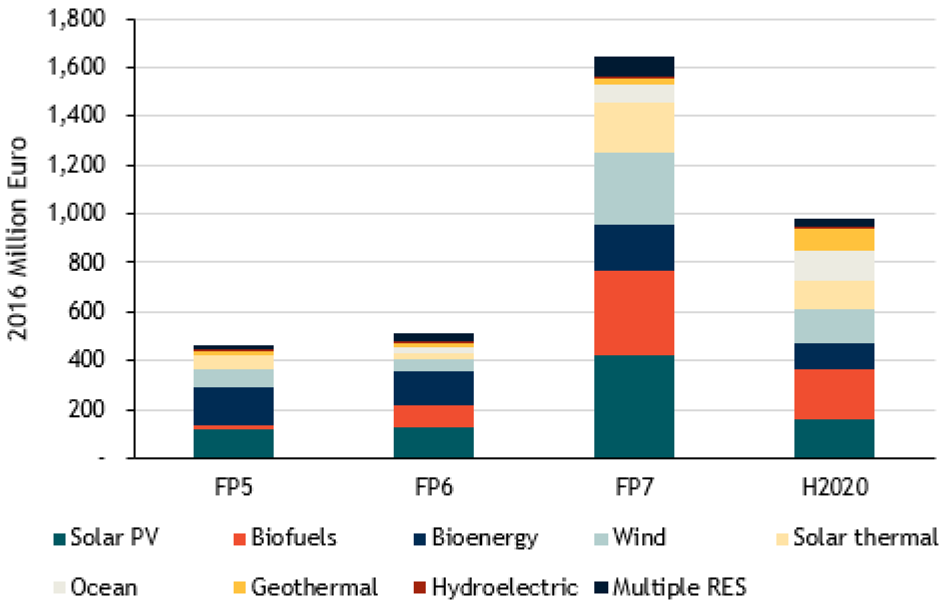
Source: CORDIS (2018)
The source data covered H2020 funding and FP7 funding from 2008, which includes 58 % of total funding for solar thermal identified in section 2.1. No data was available for recipients of FP5, FP6 and part of the FP7 funding. Projects under 'multiple RES technologies', as mentioned in the introduction of section 2.1, are not included in this Table.

[3] In RE sectors such as ocean (44 %), geothermal (53 %) and hydro (71 %), the top 10 organisations attract a relatively large share of the total funding. For bioenergy (15 %), solar PV (25 %), wind (26 %), biofuels (30 %) and solar thermal (32 %), the top 10 organisations attract much lower shares of the total funding available.

2.1.3 Share of total RE technology funding

Overall, solar thermal projects received 11 % of the EUR 3 603 million awarded to all RE technologies through the FP5, FP6, FP7 and H2020 programmes (so far). In FP5 it received 12.2 % of total funding, but in FP6 the share was reduced to 4.3 %. The highest share was in FP7, when it accounted for 12.6 % of the funding, while under H2020 it decreased to 11.6 %. Overall, this shows that solar thermal has received considerable support, but has not been one of the premier technologies that EU R&D focused on (see Figure 2.3).

Figure 2.3 Share of funding for each technology sector in proportion to overall funding (H2020 only up to mid-March 2018)



Source: CORDIS (2018)
The area 'multiple RES' includes projects of multiple RES technologies.

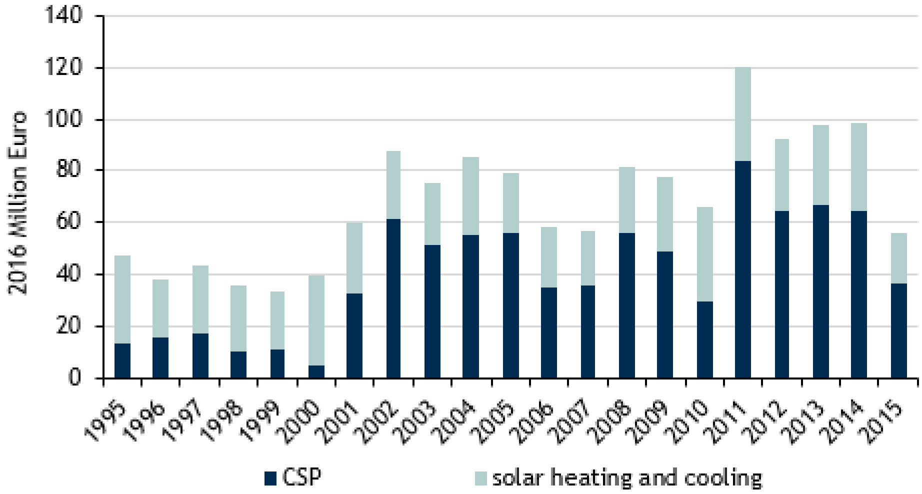
2.2 Member State R&D funding

2.2.1 Evolution over time

Annual R&D funding by Member States (MS) increased after 2000, from EUR 40 million on average between 1995-2000, to EUR 73 million on average between 2001 and 2010 (see Figure 2.4). This is about 5.5 times as high as the average annual EU funding from the FPs between 2001-2010 (EUR 13.4 million). MS funding increased further between 2011 and 2015 to an average of EUR 93 million a year, which was about twice as large as EU funding in the same period, which also increased substantially. Funding in 2010 and 2015 is lower because data was not available for Italy, which is one of the largest funders of solar thermal technologies.

MS R&D funding for solar heating and cooling has been stable during the last 20 years, which between 1995 and 2000 was the largest recipient of R&D funding for solar thermal technologies. In CSP, clear variations are visible. Starting in 2001, MS R&D funding for CSP increased quickly. Even though no new installed capacity has been added since 2013, R&D budgets have not decreased. R&D funding for CSP continues to play a big role in the overall funding for solar thermal technologies, taking up two-thirds of the total funding. The experience gained during previous installations have permitted EU industry to be active in almost all the CSP projects around the world.

Figure 2.4 Annual MS R&D funding in the EU for solar thermal



Source: Based on data from OECD/IEA (2018).
Note: Data for 20 EU countries was available in this source: The EU15 plus Czech Republic, Estonia, Hungary, Poland, Slovakia from the New Member States (NMS-13). Data for Italy was not available for 2010 and 2015, and data for the UK was not available for 2008.

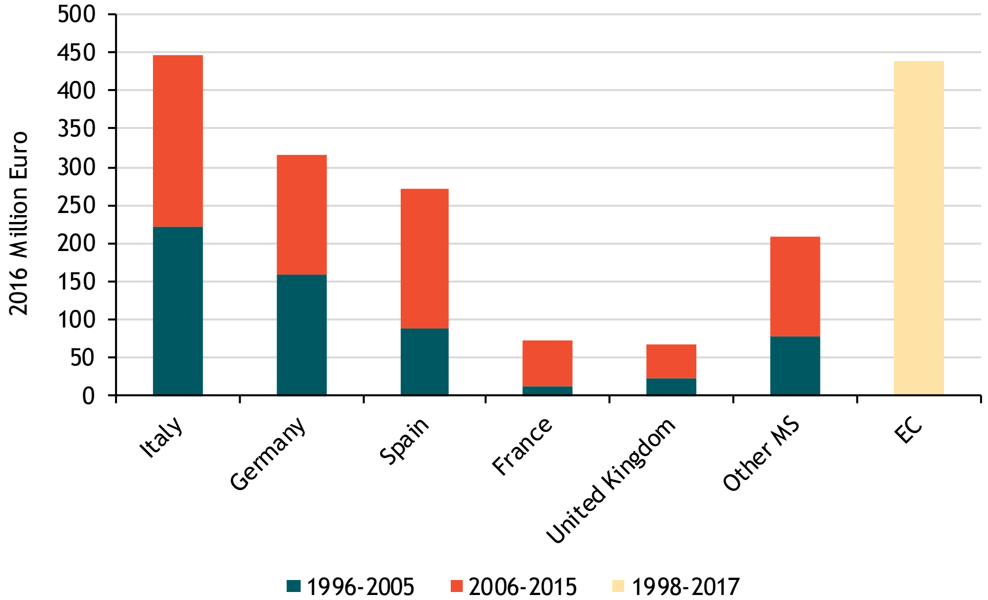
2.2.2 Largest MS funders

Figure 2.5 shows the EU funding compared to the largest five MS funders, which were Italy, Germany, Spain, France and the United Kingdom. Together, they accounted for 90 % of all MS R&D funding. The largest two funders of CSP are Spain and Italy, which are countries with a lot of solar resources. They respectively spent 93 % and 82 % of their solar thermal R&D budgets on CSP. Germany has been very active in CSP as well. For instance, the German Aerospace Center (DLR) has been part of the Plataforma Solar de Almería since 1987, one of the major infrastructures on CSP in the world. Other important players in CSP include the German research institute Fraunhofer ISE.

Large funders for solar heating and cooling include several countries with less solar irradiation, such as the United Kingdom, Germany and Austria. The United Kingdom and Austria spent nearly all of their solar thermal R&D budgets on heating and cooling (H&C), whereas Germany and France show a more equal allocation between the two technologies. Austria has several important research institutes, universities and an active industry in solar H&C. It also has a large installed capacity of solar thermal collectors (see section 5.1).

Italy provided more funding to R&D on CSP technologies than Spain, but did not install any CSP plants (see section 5.1). This illustrates that MS-funded R&D in solar thermal technologies is not the only driver for sector development. The main drivers for CSP installations in Spain were national policies and feed-in tariffs, which aided the development of the industry (see also section 5.1). In Italy there are no important industrial players, but it has research institutions and universities that publish a significant amount of research papers on CSP (see section 3.2).

Figure 2.5 Solar thermal R&D budgets of the Member States with the largest R&D budgets for solar thermal (1996-2015) and the EC (1998-2017)

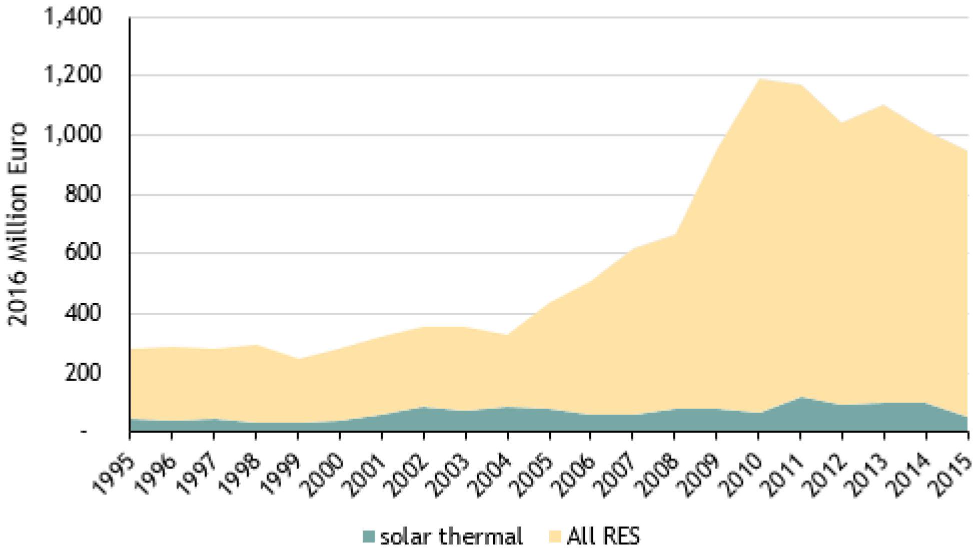


Source: Own elaboration based on data from OECD iLibrary and CORDIS (2018). Data for Italy was not available for 2010 and 2015, and data for the UK was not available for 2008.
Note: Time window of comparison between MS and EC funding is shifted 2 years due to data availability of MS budgets for the scope of analysis (FP5-H2020).

2.2.3 *Share of total RE technology funding*

In the period 1995 to 2015, MS allocated 12.7 % of their national research, development and demonstration (RD&D) funding for renewable energy (RE) technologies to solar thermal. In 1995, the share of solar thermal funding was 20.6 %. This share oscillated over the following years until it reached its peak from 2002 until 2004, with a share of approximately 30 %. From 2005 to 2010, the total funding for RE technologies increased, while for solar thermal the opposite happened; leading to a much lower share of all national R&D funding available for RE (+/- 10 %). After 2010, total funding for RE technologies started a decreasing trend. During this period solar thermal's share of funding remained relatively stable, oscillating around 10 %. Overall, it can be observed that solar thermal has become a lower priority for MS compared to other RE technologies, but that the technology still receives a significant share of the total MS R&D budgets.

Figure 2.6 Share of national R&D funding for solar thermal in proportion to the overall funding for all RE technologies



Source: Based on data from OECD/IEA (2018).
Note: Data for 20 EU countries was available in this source: The EU15 plus Czech Republic, Estonia, Hungary, Poland, Slovakia from the New Member States (NMS-13). Data for Italy was not available for 2010 and 2015, and data for the UK was not available for 2008.

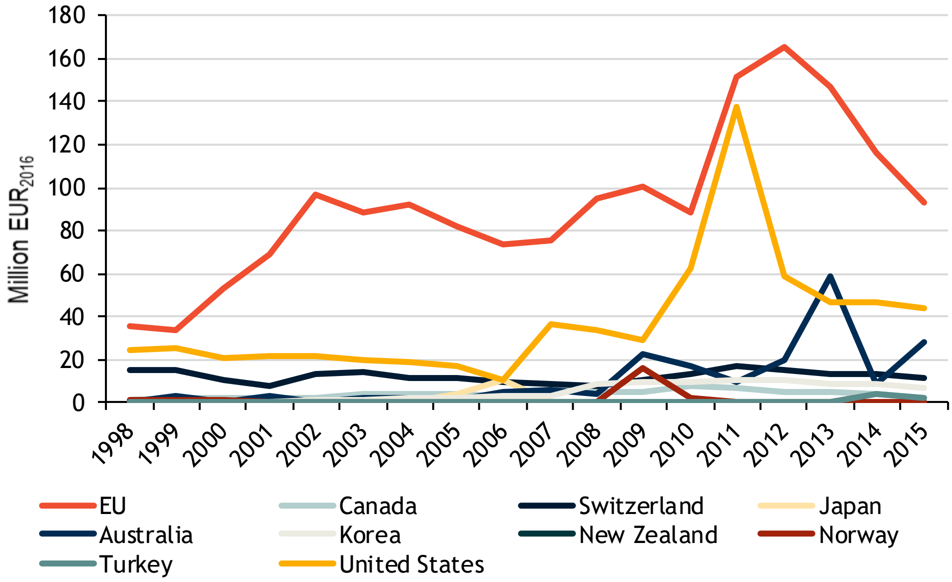
2.3 Private and international R&D funding

2.3.1 International public R&D funding

R&D funding for solar thermal technologies from the EU and MS combined is larger than in other countries, spending on average EUR 92 million per year between 1998 and 2015 (see Figure 2.7). The United States of America (USA) provided EUR 37 million per year on average between 1995 and 2015, of which nearly all went to CSP technologies. Its SUNSHOT programme had clearly defined objectives for the technologies to be developed, as well as cost reduction objectives. Together with Spain, it is the global leader in CSP installations and has been driving technology development in the sector over the last decade.

Switzerland is the next largest funder with EUR 13 million per year on solar thermal R&D funding on average, with an equal allocation between CSP and H&C. Australia also had significant budgets for both technologies, with average spending of EUR 9 million a year. Other countries with significant R&D budgets for solar thermal are Korea and Canada.

Figure 2.7 Comparison of international R&D funding for solar thermal



Source: OECD/IEA (2018).
Note: EU: European Commission and Member State budgets combined.
National budgets for 2016 were excluded from the analysis because they are early estimates and lack reliability/coverage. Data covers 20 EU countries: the EU15 and Czech Republic, Estonia, Hungary, Poland, Slovakia and the European funding programmes FP5, FP6, FP7 and H2020 (starting in 1998). For countries outside the EU, national budgets were available for Australia, Canada, Japan, Korea, New Zealand, Norway, Switzerland, Turkey and the USA. Data for Italy was not available for 2010 and 2015, and data for the UK was not available for 2008.

2.3.2 Private R&D funding

There is no data available on private R&D funding for solar thermal. The only data source that includes solar thermal in its statistics provides an aggregate number for solar PV and solar thermal together. As solar thermal private R&D is estimated to be a small share of the total solar R&D budgets, no reliable estimate on the magnitude of private R&D funding could be provided.

Conclusions

EU funding for solar thermal research was modest in the earlier years (FP5 and FP6) but has increased to considerable research budgets in FP7 and H2020. Compared to other RE technologies, solar thermal receives moderate support with a share of about 11 %. In terms of technologies, CSP received most of the funding, about twice as much as solar heating and cooling. The projects cover a wide range of technologies and applications, including the integration of energy storage technology.

The main recipients of EU funding include the leading research institutions on the topic as well as several industrial players. In terms of countries, Spain, Germany and Italy have received most EU funding, which coincides with the leading national research budgets that these countries have for solar thermal technologies. The MS research budgets increased significantly in the early 2000s, preceding the increase of EU solar thermal funding from 2007 onwards. Since then, MS research budgets have remained relatively stable in absolute terms. Their share of the overall MS RE technology research budgets has decreased considerably however, showing that the technology has been less popular in recent years. Still, the combined EU and MS R&D budgets for solar thermal are leading internationally.

3 Research effectiveness

R&D projects can lead to patents, publications, spin-offs and several other, less concrete but potentially important direct outputs such as standardisation and knowledge exchange. Such impacts are the most direct impacts of R&D funding and therefore provide the cleanest view on the effectiveness of research budgets spent. In this section we discuss patents, publications, spin-offs and other direct research outputs, and their relation to R&D funding for the solar thermal sector.

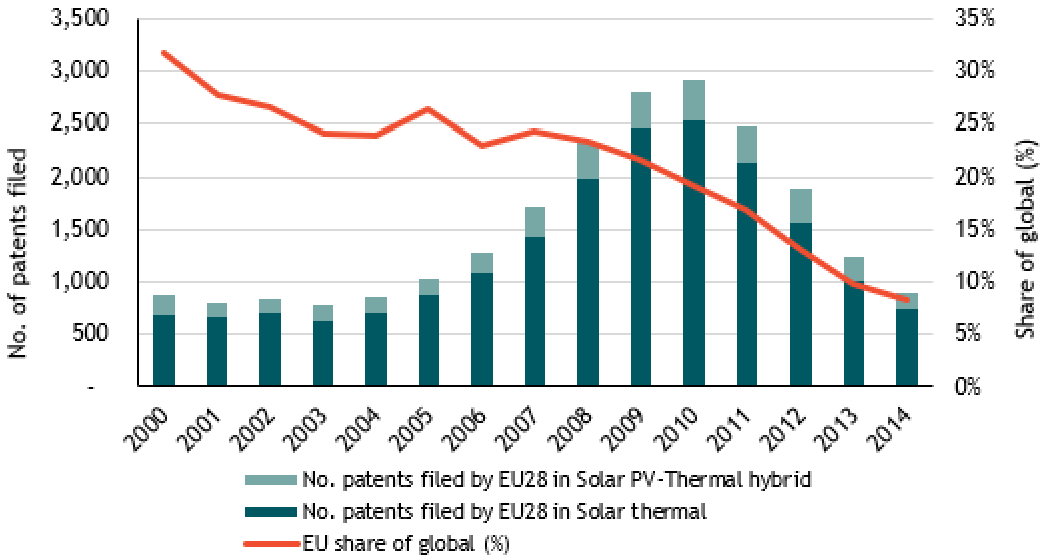
3.1 Patents

Patents are a useful indicator to measure the output of R&D funding as they provide a direct measurement of the impact in terms of novel knowledge generated. Furthermore, patent data are readily available, in a standardised form. However, some limitations have to be taken into account, such as the fact that filing a patent is not an objective of all research projects and that the economic value of patents varies significantly.

3.1.1 Evolution over time

Figure 3.1 shows the pattern of patents filed for solar thermal technologies in the EU. The number of EU patents filed increased up to 2010, after which it decreased again to pre-2005 levels.

Figure 3.1 Evolution of solar thermal patents filed by EU countries



Source: IRENA INSPIRE (2017)

There is a downward trend in EU's share of global patents filed for solar thermal technologies, decreasing from nearly half of all global patents in 2000 to only 10 % in 2014. The share dropped even in years that the absolute number of EU patents increased. This is largely caused by a sharp increase in patents filed by China, growing from 500 patents/year in the early 2000s to more than 5000 patents/year from 2012 onwards. At the same time, EU companies have started to question the benefits of patenting and are increasingly choosing to move fast to reap the benefits of their inventions, rather than patenting.

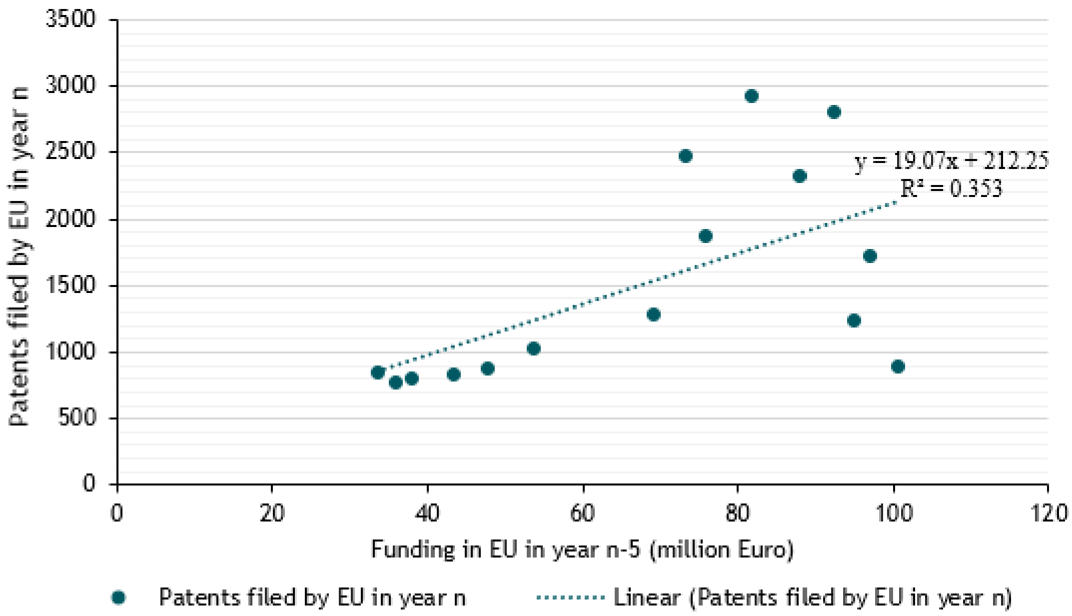
From 2002 to 2014, more than 8 000 patents were filed in Germany, which made it the MS where most EU patents were filed (42 % of the total number), followed by Spain (14 %), France (11 %), United Kingdom (5 %), Austria (5 %) and Italy (5 %). These are the same MS that provided the largest funding, although Italy provided the most funding but is surpassed by five other MS in terms of patents.

3.1.2 Effectiveness of R&D funding in producing new patents

In theory, higher R&D budgets in a region are expected to lead to an increase in the number of patents filed from that region. The extent to which this relation exists in the sector provides insight into the objectives of the research (is it targeted at technology development, so more likely to result to a patent application?) and the effectiveness of the research (was it successful in developing the technology so resulting in a patent application?).

Figure 3.2 compares the total amount of patents filed to the amount of EU R&D funding (MS + EU combined), accounting for a time lag between the moment of funding and the patent application. The highest correlation is visible with a time lag of 5 years. Even then, there is no clear correlation between the number of patents and the amount of EU funding; the funding levels do not explain the number of patents filed. This is in line with the findings for other RE sectors and underlines that patent applications are generally not a primary objective of a research project.

Figure 3.2 Patent effectiveness



Notes: We tested a delay of 0, 1, 2, 3, 4 and 5 years for the patents filed from year 2000-2014. 2015 data of patents was excluded because the source (IRENA) mentioned it is common to have delays of 3 years from a patent application and the year is reflected in the database. The correlation went up when 2015 data was excluded. A delay of 5 years between funding year and patents filed showed the highest correlation (R^2 = 0.353).

3.1.3 Contribution of EU funding

To help capture more directly the impact of EU-funding through the Framework Programmes (FP5 to H2020) a questionnaire was sent out to all project coordinators involved in research to develop the solar thermal energy technology sector. 168 Framework Programme projects in solar thermal energy were identified for this study. Out of these, it was not possible to contact all project coordinators (due to missing contact links on CORDIS). 124 project coordinators were contacted with a request to participate in the questionnaire. The overall response rate was 27 % (33 out of 124 projects). Project coordinators of FP7 and H2020 programmes constituted the large majority of responses.

Even though patent applications are often not a primary objective of research projects, several EU-funded projects have led to a patent application. Out of the 33 questionnaires that have been completed by solar thermal projects, 4 reported a patent application as one of their outputs.

3.2 Publications

Like patents, publications of research papers are a useful indicator to measure the output of R&D funding, as there is enough data available to make a comparison between the EU's performance and the rest of the world. Moreover, publications have a close relation with public R&D funding, allowing us to differentiate the effect of public R&D funding from private R&D funding. Publications are categorised by country on the basis of the address of the author. If it has authors from different regions, the publication is counted for both regions.

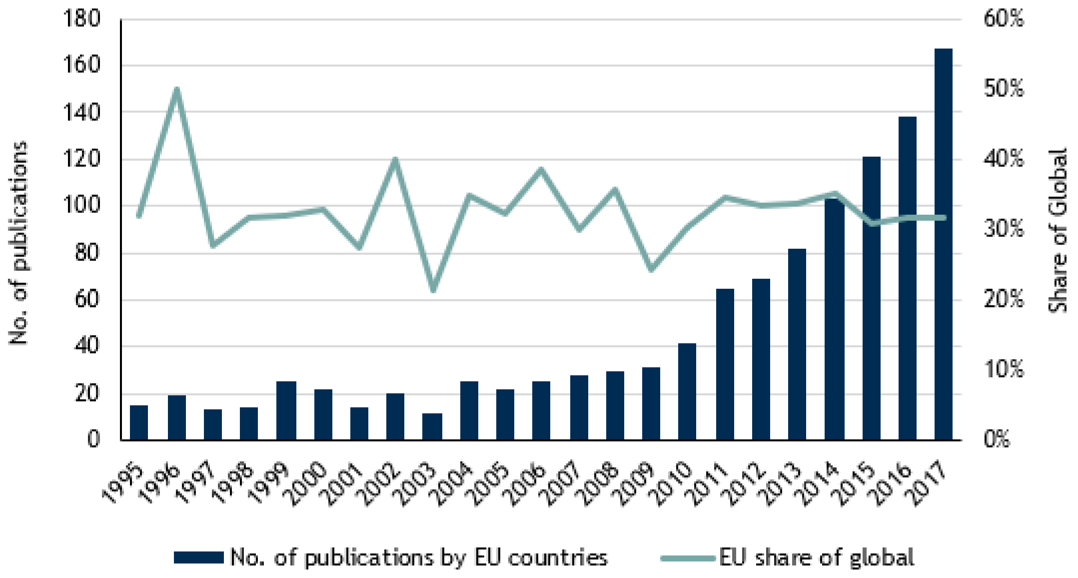
3.2.1 Evolution over time

Figure 3.3 shows the pattern of solar thermal publications by EU-based authors over the years. The number of publications on solar thermal energy increased over the years.

EU-based authors were involved in a third of the global publications between 1995-2017, making it the global leader. Outside of the EU, the largest number of publications had authors from China, the USA, and Canada. Combined, these authors were also involved in a third of the global publications between 1995-2017. Particularly in recent years, China has authored a large number of publications (20 % to 25 %), but this is still less than publications by EU authors.

Within the EU, Germany has authored the most publications (202), followed by Spain (200), France (157), UK (153), and Italy (139). These five MS are also the five largest R&D funders, which seems to indicate a correlation between R&D funding and publications.

Figure 3.3 Evolution of solar thermal publications by EU countries



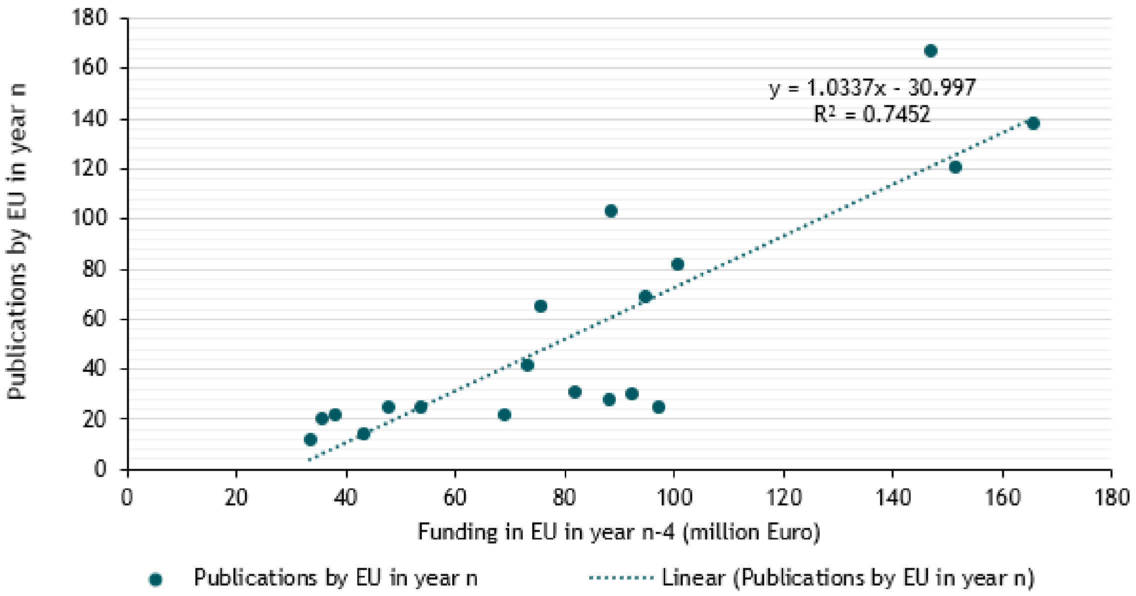
Source: Web of Science (2018)
Notes: keywords used are: 'solar heating' or 'concentrating solar' in the title, topics and abstract of articles between 1995-2017. The share of global refers only to those publications with an address listed. 1 % of the global publications had no address listed in that period of time. One article can have multiple authors (therefore, also multiple countries). The count is the number of articles in which at least one author listed a EU MS as their address.

3.2.2 R&D funding effectiveness in producing publications

In theory, higher R&D budgets in a region are expected to lead to an increase in the number of publications from that region. The extent to which this relation exists in the solar thermal energy sector provides insight into the objectives of the research (does it aim for a publication?) and the effectiveness of the research (is it successful in realising a publication?).

Figure 3.4 compares the total amount of EU publications to the amount of EU R&D funding (MS + EU combined), accounting for a time lag between the moment of funding and the publication. The number of publications correlates more closely to R&D funding than the number of patents does, indicating that publicly funded R&D projects in the solar thermal energy sector have a higher focus on publishing and/or are more effective at publishing. This is in line with the findings for other RE sectors and underlines that publishing is often one of the primary objectives of a research project.

Figure 3.4 Publication effectiveness



Notes:We tested the publication effectiveness of R&D funding for the period 1995-2017. Funding in EU includes EU funding and MS funding. We tested different delays (0, 1, 2, 3, 4 and 5 years) to evaluate which one had the highest correlation. After two years of delay, for each year of delay, the sample size was reduced by one number (e.g. with 0, 1 and 2 years of delay the sample size was 21 years, with 3 delay the sample size was 20 years, etc.)
With no delays (n-0), the R^2 is the lowest of all the ones tested (0.4046). The highest R^2 was found using 4 years of delay (0.7452).

3.2.3 Contribution of EU funding

The correlation between R&D funding in the EU and publications by EU authors shows that there is a clear relation between the amount of funding and the number of publications. To what extent the funding through the European Commission contributed to these publications is the topic of this section.

Between 2008-2017, 153 publications explicitly reported benefitting from EU funding sources[4], which equates to 18 % of the total number of EU publications in those years. Not all publications report all sources of funding that they benefitted from, therefore it is likely that the real figure is higher.

[4] The EU funding sources are not always specified and may therefore include funding from other instruments than the Framework Programmes, such as funding from the EIB. The majority (82 %) did specify an FP explicitly however, so the inaccuracy resulting from a potential inclusion of publications that benefitted from other EU funding programmes is limited.

The high number of European publications that benefitted from EU funding is further confirmed by the questionnaire responses. More than 35 % of the respondents reported one or more publications as one of the outputs of the project. The Framework Programmes clearly play an important role in maintaining the EU's leading academic position in solar thermal.

The top EU organisations in terms of publications are listed in Table 3.1. It shows that the top 3 organisations in terms of EU funding are also among the top publishing organisations in the EU, confirming that the EU framework programmes support the academic leadership of the EU.

Table 3.1 Top organisations in the EU contributing to solar thermal publications (1995-2017)

Rank	Institutions	Country	No. Publications	EU funding rank
1	Centre National de la Recherche Scientifique CNRS	France	101	3
2	Helmholtz Association	Germany	75	30+
3	German Aerospace Centre DLR	Germany	65	1
4	University of Nottingham	UK	35	30+
5	Ulster University	UK	34	30+
6	Consejo Superior de Investigaciones Cientificas CSIC	Spain	24	30+
7	Polytechnic University of Madrid	Spain	22	30+
8	Universidade de Lisboa	Portugal	22	30+
9	CIEMAT	Spain	21	2
10	Technical University of Denmark	Denmark	21	30+

Source: Web of Science (2018)
Note: The count is the number of articles in which at least one author listed the European organisation as their address.

3.3 Start-ups and spin-offs

The creation of start-ups and spin-offs is another potential impact of research projects, which can function as an important link between research and the development of a European industry. Start-ups and spin-offs are not reported consistently, however. Therefore, questionnaire results are used to provide insight into these impacts.

While only 1 of the 33 projects that completed the questionnaire for this study reported a spin-off or start-up as one of the outputs of their project, EU funding has been clearly supportive for the EU solar thermal start-up community. 21 SMEs received funding through the SME instrument which aims to support ground-breaking innovative ideas developed by small and medium-sized companies and is part of the Framework Programmes. This way, the start-ups that emerge across the EU are supported in the development of their technology. Examples include:

1. SUN GEN: an Italian SME that has developed innovative optics to concentrate sunlight which is supported through the Focalstream project;
2. SunOyster System: A German SME, founded in 2011, that is developing and commercialising a highly efficient solar collector and is supported through the SOcool project (see project spotlight box below and case study in Annex A);
3. Fresnex: a German SME, founded in 2012, that has introduced a solar steam generation system for industrial applications to the market and is supported through the helioSTEAM project.

Project spotlight: Novel heating and cooling system - SOcool

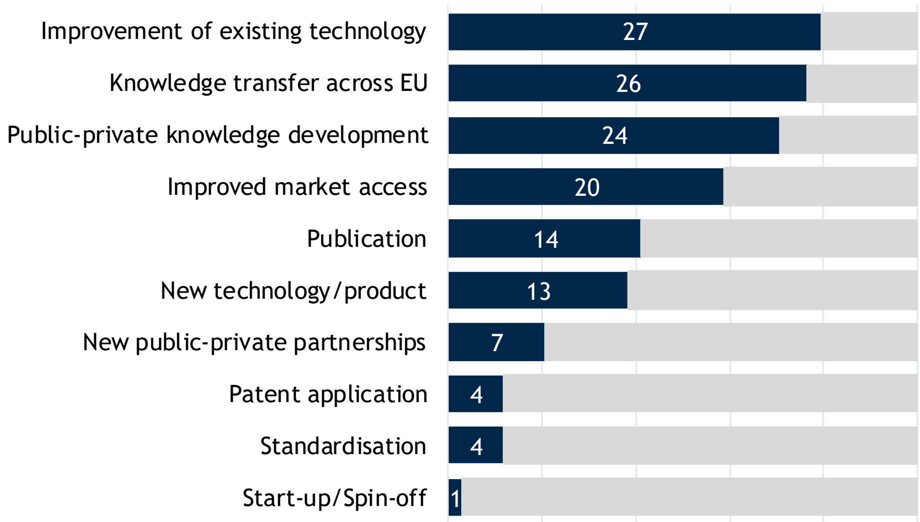
The SOcool project (SunOyster Cooling; H2020-SMEINST-2-2016-2017; September 2017 to August 2018; EU funding: EUR 1.4 million; Coordinator: SunOyster) is based on a patented innovation of concentrating photovoltaic/thermal (CPVT) system combined with chillers to provide cost-efficient solar energy in forms of electricity, heat and cold. SunOyster is building-up a production pilot line, testing and certifying three product packages, carrying-out a demonstration project, and launching large-scale commercialisation with the help of an SME-Instrument grant.

See annex A for a detailed case study on the SOcool project.

3.4 Other research outputs

While patents, publications and start-ups/spin-offs are often the most tangible and easily quantifiable outputs of EU-funded research of RE technologies, there are many other outputs that contribute to the development of a leading sector. To get a better understanding of these other impacts, a questionnaire was sent out to project coordinators of EU-funded R&D projects. The results of the questionnaire are presented in Figure 3.5.

Figure 3.5: Impacts of EU-funding based on questionnaire results (out of 34 responses in total)



Note: The impacts were determined from the description of the projects and their reports on results available on Cordis as well as the information they provided in the open questions of the questionnaires and during the interviews where applicable.

The most commonly reported impact is the improvement of existing technologies (27 out of 33). This shows that EU-funded R&D contributes to the continuous improvement of solar thermal technologies, which is of particular relevance for continuity in periods of limited new installed capacities such as currently for CSP (discussed in more detail in chapter 1).

Knowledge transfer across the EU (26 out of 33) and public-private knowledge development (24 out of 33) are also common outputs of EU-funded R&D projects. These outputs result from collaboration between different organisations across the EU within the EU-funded projects, including joint R&D between public research institutes and private companies. This way, the FPs play an important role for increasing collaboration and aligning R&D priorities across the EU and thereby sustaining academic leadership. The ECOSTAR (FP6) and STAGE-STE (FP7) projects are examples of EU-funded projects that brought many stakeholders in the solar thermal energy sector together and thereby contributed to increased knowledge transfer and public-private knowledge development for solar CSP (see also STAGE-STE project spotlight box below).

Finally, improved market access is a commonly reported output of EU-funded R&D projects. This illustrates that several solar thermal technologies are ready for market uptake and that the FPs contribute to this (for instance the EUROSUNMED project which provided access to new markets around the Mediterranean for its consortium members, which is described in the project spotlight box below). Related to this, is the contribution of EU-funded projects to the development of new business models which may open up new markets, such as illustrated by the PIME's project which delivered new Energy Service Company business models (see project spotlight box below).

Apart from these outputs, sector experts describe the role of EU funding as essential for the early development of the CSP sector in the 2000s by supporting various commercial-scale demonstration projects (discussed in more detail in section 5.1). For solar heating and cooling, comparable contributions have been made by supporting demonstrations of integrating the technology into buildings (discussed in section 4.3), integrating solar heating in district heating systems, and applying the technology for industrial process heat generation (discussed in section 5.1).

Project spotlight: STAGE-STE

STAGE-STE (Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy; FP7-ENERGY-2013-IRP/CP-CSA; February 2014 to January 2018; EU funding: EUR 10 million; Coordinator: CIEMAT, Spain) contributed significantly to bringing European CSP research institutes and industry together to set a common research and technology agenda, and align the EU and national level policies in CSP field. The cooperation during the project period contributed to opening-up new markets for the European industry, and has led to many further opportunities to launch new initiatives on a bilateral basis. The project also resulted to over 200 joint publications, more than 4 000 tests carried out at the facilities of the project participants out of which more than 200 were joint tests involving two or more project participants, a web-repository including a description of more than 200 intellectual property assets and more than 100 researchers involved in mobility and exchange programmes.

See annex A for a detailed case study on the STAGE-STE project.

Project spotlight: PIME's

The PIME's project (CONCERTO communities towards optimal thermal and electrical efficiency of buildings and districts, based on microgrids; FP7-ENERGY-2008-TREN-1 – CP; January 2009 to November 2015; EC funding: EUR 10.8 million; Coordinator: Rogaland Fylkeskommune, Norway) was about piloting energy efficient communities. The project is a prime example of a project with a wide range of objectives that are relevant to the sector but that does not lend itself for capturing in concrete statistics. The project contributed to technology advances related to the implementation of large-scale solar thermal generation with associated heat storage, among several other technologies. The concepts were demonstrated at demonstration sites in Hungary and Spain and the project fed into several follow-up projects. Furthermore, several partnerships between the consortium members were created or strengthened, including partnerships with the private sector, and new Energy Service Company (ESCO) models were developed.

Source: EC, 2018, Community Research and Development Information Service; and interviews of the project coordinators.

Project spotlight: EUROSUNMED

The EUROSUNMED project is another example of a project with a wide range of objectives that are relevant to the sector but do not lend itself for capturing in concrete statistics. Apart from 3 patent applications, key outputs of the project include access to new markets around the Mediterranean for several of their consortium members, the development of various optical coatings, an absorber and thermal energy storage materials for use with CSP technology, as well as a several models and algorithms.

Source: project website (http://eurosunmed.cnrs.fr/).

Conclusions

The significant MS and EU budgets for solar thermal have been effective in establishing and maintaining a leading academic position globally. The EU is number 1 in terms of publications and has been able to preserve this leading position irrespective of the strong growth in publications from China. The specific contribution of EU funds is also clearly visible with a contribution to at least 18 % of the EU publications and possible many more.

The conversion of R&D budgets to patents has been less successful with a consistently declining share of the global patents and in recent years also a decline in the absolute number of patents from the EU. This can be partly attributed to the growth in patent applications from China and partly to EU companies making a conscious decision not to patent anymore due to the lack of clear benefits.

Start-ups are a less common direct output of EU-funded research projects. Nevertheless, EU funding supports numerous start-ups through their SME instrument, playing an important role in the development of these start-ups.

Further important outputs of EU-funded R&D include the improvement of technologies, alignment of R&D activities, and increasing knowledge transfer and collaboration across the EU. Moreover, EU-funded R&D contributed to improving market access for EU companies and stimulated market formation by financing the demonstration of various solar thermal technologies.

4 Technology development

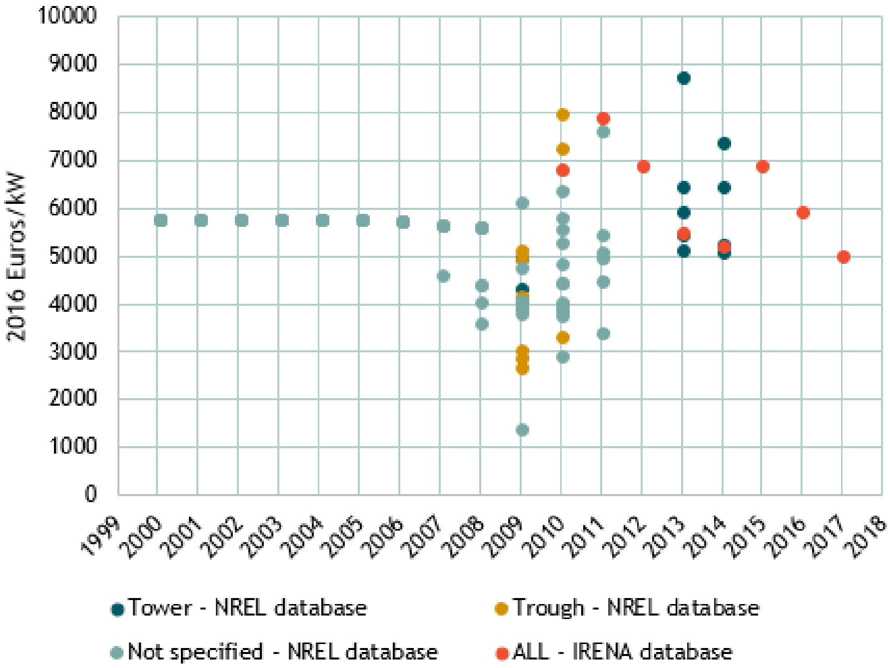
One of the core objectives of R&D funding on RE technologies is to contribute to the development of the technology to make it cost competitive and allow for increased uptake of the technology. The impacts on technology development can be assessed technologically, or from an economic point of view, looking at the costs, performance and competitiveness of the technology. This section focuses on key indicators that assess technology development from an economic point of view: capex, opex and Levelised Cost of Energy (LCOE).

4.1 Capex

Capex (capital expenditure) refers to the initial investment costs of the solar thermal projects. Cost-reducing innovations can contribute to a downward trend in capex, which in turn can make the sector more cost competitive and allow for increased uptake of the technology. One of the main limitations of this indicator is that capex is highly location- and technology-specific, and will therefore vary between projects. To be able to provide an overview of the evolution of the capex over time, we consider global historical estimations of capex, including the estimations of regions outside the EU.

The capex for solar thermal capacities varies greatly for both electricity and heat generation. For CSP, capex for solar tower plants ranges from EUR 4 358/kW to EUR 8 759/kW, while plants based on the older parabolic trough design range from EUR 2 700/kW to EUR 8 012/kW (see Figure 4.1). No clear trend can be discerned from the data, which is due to the costs being location-specific and the lack of a standard design that can be gradually improved. Instead, each plant requires a lot of specific design which adds to the costs. Furthermore, the functionality of each plant differs considerably.

Figure 4.1 Evolution of capex for electricity generation (CSP - Global estimates)

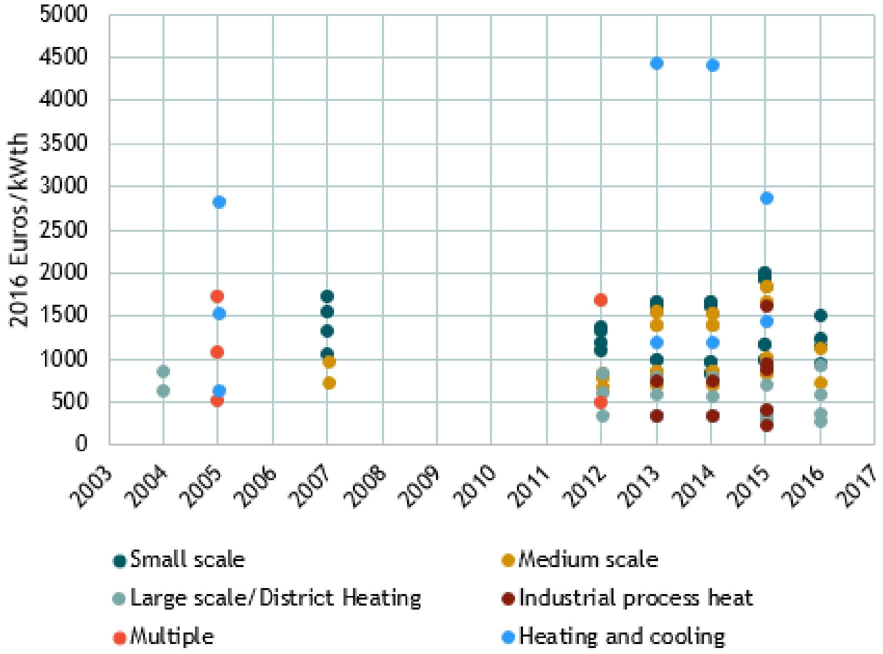


Notes:All figures are global, unless specified otherwise.
For electricity generation, data was taken from NREL database and from IRENA database. IRENA's data is the 'Global weighted average' based on their database with ~15 000 real projects.

Also, the capex for heat generation capacities shows a wide range (see Figure 4.2). Capex for small-scale installations for households can have a capex as low as EUR 100/kW. These are used for hot water and/or heating of buildings. Capex for district heating is higher and ranges from EUR 300/kW to EUR 958/kW with the more expensive installations including seasonal storage. Solar thermal systems for industrial process heat have the largest range, from EUR 239/kW to EUR 1 626/kW. Generally, solar thermal plants used for cooling have the highest capex, ranging from EUR 657/kW to EUR 4 439/kW.

The trends in the capex of solar thermal heat applications are hard to evaluate. The data points with the lowest capex per sub-technology definitely point to reducing capex, for instance visible for large-scale district heating. However, there are also data points that show a higher capex in recent years.

Figure 4.2 Evolution of capex for heat generation (global estimates)



Notes:All figures are global, unless specified otherwise.
For electricity generation, data was taken from NREL database and from IRENA database. IRENA's data is the 'Global weighted average' based on their database with ~15 000 real projects.
For heat generation, data was collected through a desk research. The main sources were REN21 reports (2005, 2007, 2010-2015), OECD/IEA (2007), Solar Thermal World (2016) and Gudmundsson et al (2013). The estimates found for heat were grouped in five categories: Small scale (single-family systems or installed capacity from 0-20 m^2 for hot water only and combi-systems), Medium scale (multi-family systems or installed capacity from 20-100 m^2 for hot water only and combi-systems), Large scale (district heating, block heating systems or installed capacity larger than 100 m^2 for hot water only and combi-systems), Industrial process heat (heat from 50 °C to 400 °C), Heating and cooling (heating and cooling systems, adsorption chillers) and Multiple (solar collectors of unspecified capacity, or with a wide range of capacity).

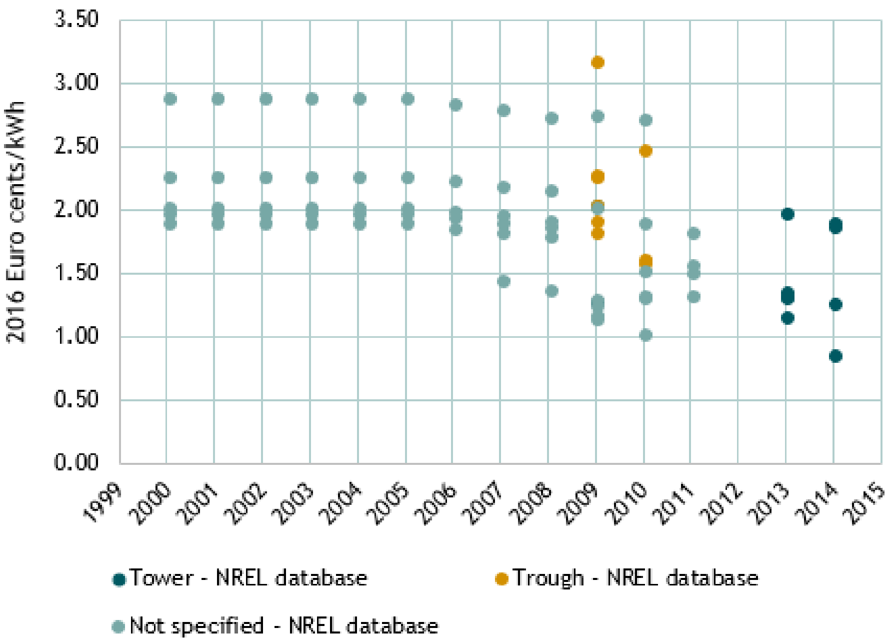
4.2 Opex

Opex (operational expenditure) includes fixed and variable costs for operation and maintenance (O&M) of the plants. Similar to capex, cost-reducing innovations can contribute to a downward trend in opex, which in turn can make the sector more cost competitive. Opex is less location-specific than capex, but can show large variations between sub-technologies. Only global figures were available for the opex.

Figure 4.3 shows the development of the opex for solar thermal electricity generation. The majority of the historical O&M costs do not specify a sub-technology, however by 2014 about 85 % of the global cumulative installed capacity were trough plants.[5] The range of opex for trough plants ranges from 1.401 to 3.201 EURct/kWh. Opex for tower CSP plants has a generally lower range, from 0.861 to 2.047 EURct/kWh. The lowest value for tower CSP plants corresponds to a plant with 18 hours of storage, and a capacity factor of 80 %.

Recent CSP plants built in Spain have lower O&M costs than in the early 1990s. One of the main causes for O&M expenditures is still glass breakage and plant maintenance. Glass breakage requires the replacement of receivers and mirrors, while plant maintenance involves mirror washing (which includes water costs). Advances in materials, design and increased automation of CSP plants have reduced the opex over the last twenty years, but plant insurance (between 0.5 % to 1 % of total capital costs per year) and other potential costs remain significant components in the opex of solar thermal electricity generation.

Figure 4.3 Evolution of opex for electricity generation (CSP - global estimates)



Opex for solar thermal heating generation varies greatly depending on the scale and the type of system. In 2005, opex for direct hot water (DHW), thermo-syphon and combi-systems ranged from 1.21 to 4.53 EURct/kWh. In contrast, solar thermal heating with additional cooling equipment has considerably higher opex, ranging from 1.61 to 7.41 EURct/kWh[6].

In 2016, small-scale installations generating hot water and space heating had an average opex of 2.21 EURct/kWh, medium scale systems had an average opex of 1.73 EURct/kWh, and large-scale systems had an opex of 1.24 to 1.26 EURct/kWh.

[5] IRENA (2015) https://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_2014_report.pdf

[6] *OECD/IEA (2007) Renewables for heating and cooling. Untapped potential. IEA publications. Pg. 125*

4.3 LCOE

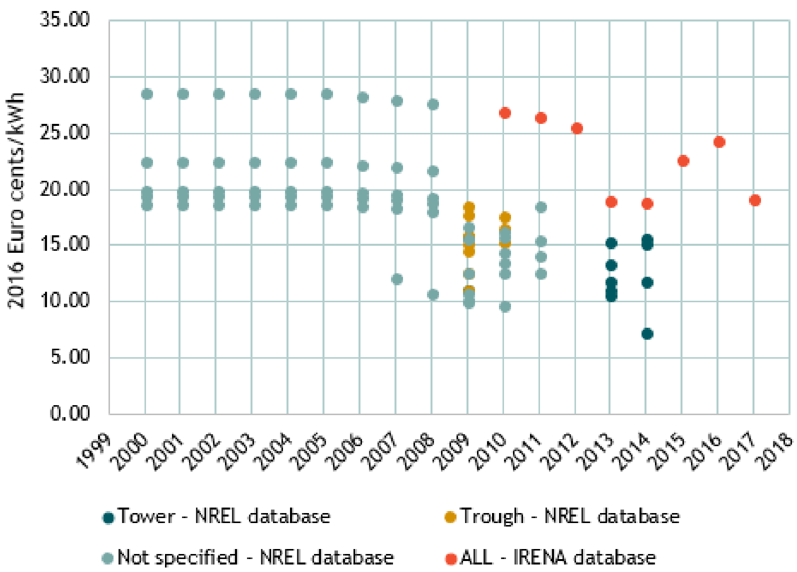
The Levelised Cost of Energy (LCOE) is an indicator to compare the project costs of different energy generation technologies.[7] LCOE is most commonly used in the context of electricity generation, with the 'E' denoting electricity. LCOE can however also be applied to heat generating technologies, sometimes then denoted as Levelised Cost Of Heat. In this document we use LCOE as Levelised Cost Of Energy, specifying per case if this concerns electricity or heat.

Similar to capex and opex, cost-reducing innovations can contribute to a downward trend in LCOE, which in turn can make the technology more cost competitive. While LCOE is a relatively comprehensive measure of the technology's costs, it does not include all the costs for delivering energy, such as ancillary services and transmission and distribution costs.

Figure 4.4 shows the evolution of the LCOE for solar thermal electricity. The LCOE ranges from 7.2 to 28.6 EURct/kWh. The minimum value represents a Tower CSP system with 18 hr storage and a capacity factor of 80 % and the maximum value is an estimate from an unspecified plant in the NREL database for years 2000 to 2005. On average, estimates from the NREL database have been stable between 2000 and 2006, and show a downward trend afterwards.

The IRENA database also shows a decreasing trend between 2012 and 2014. According to IRENA (2018), the global LCOE range in 2012 widened due to the mix of new projects in Spain, and the commissioning of more competitive plants. On average, the LCOE between 2013 and 2014 was about 20 % lower than between 2009 and 2012. According to IRENA, the main factor behind the downward trend during that period was probably the higher levels of Direct Normal Irradiance (DNI) at the sites of the newly installed plants.

Figure 4.4 Evolution of LCOE for solar thermal electricity generation (CSP - Global estimates)



Notes: For electricity LCOE was calculated for the NREL database values using the market values of NREL (43 % average capacity factor, and 30 years of plant lifetime) when these values were not provided by the original source. A discount rate of 7.5 % was used, taken from IRENA's methodology, and the capex was annualized using the Capital Recovery Factor Method. LCOE from IRENA was taken directly from the database and converted to EUR$_{2016}$.

[7] There are different ways of calculating the LCOE; the method applied here is explained in the methodology document: Trinomics (2018) - Study on impacts of EU actions supporting the development of renewable energy technologies – Literature review and methodology (Deliverables D1.1 and D1.2)

EU-funded R&D projects contribute to important improvements and cost reductions in different CSP components (receiver, collector, heliostat design, turbines etc.), plant construction and operations. Furthermore, EU projects contribute to advances in areas such as heat transfer fluids, thermal energy storage, water consumption management, and hybrid CSP plant solutions have driven the costs of CSP technology further down. Examples include the MACCSOL and WASCOP projects, both of which developed technologies that reduce water consumption and the HYSOL project that demonstrated a solar-biogas hybrid CSP plant (see project spotlight boxes below).

Project spotlight: Air-cooling for CSP plants - MACCSOL

The MACCSOL project (The development and verification of a novel modular air-cooled condenser for enhanced concentrated solar power generation; FP7-ENERGY-2010-1/CP; September 2010 to February 2015; EC funding: EUR 5.1 million; Coordinator: University of Limerick, Ireland) developed, tested and demonstrated a dry cooling technology called Modular Air-Cooled Condenser (MACC) for CSP plants. CSP plants require cooling to condense steam during the power generation cycle. Water is typically used for cooling but as the CSP plants are placed in in high solar radiation areas, water supplies are scarce. The MACC technology developed provides a cost-efficient dry cooling technology based alternative. The modular air-cooled condenser is equipped with speed-controlled fans controlled by sensors that enable the condenser to maintain optimum pressure and temperature regardless of ambient conditions (e.g. temperature, wind). The system enables more efficient condenser unit performance. Based on theoretical models, simulation studies and lab-scale prototypes, the project built an industrial scale prototype installed at a 6 MW CSP plant constructed in Jemalong, New South Wales, Australia. The results showed that the technology enables up to 4 % increase in power plant efficiency, when compared to conventional dry cooling methodologies.

Source: Source: EC, 2018, Community Research and Development Information Service

Project spotlight: Water saving of CSP plants - WASCOP

H2020 project WASCOP (Water Saving for Solar Concentrated Power; H2020-LCE-2015/RIA - Research and Innovation action; January 2016 to December 2019; EC Funding: EUR 5.9 million; Coordinator: CEA, France) focuses on a holistic approach to CSP plants water consumption management. One of the main challenges of CSP is related to elevated water consumption. The CSP plants are typically located to areas with high solar radiation, which in turn often means that these areas suffer from water scarcity. The project is still on-going and develops an effective combination of technologies allowing a significant reduction in water consumption (up to 90 %), and a significant improvement in the water management of CSP plants. This is done e.g. by utilising anti-foiling coatings and dust barriers to avoid the dust to reach and stick in the mirrors, specific foiling sensor systems to clean the CSP plants only when necessary, and cleaning systems using very sour water limiting the water use. The project is also working towards an approach for cold thermal energy storage, with the basic idea to store cool air during the night to be used during the day to assist the cooling system and ease the work of the tanks. The project has led to a follow-up project called SOLWATT (H2020), which aims to demonstrate the water management technology developed during the WASCOP project in commercial CSP plants and it is expected to lead to direct commercialisation of the technology.

Source: EC, 2018, Community Research and Development Information Service; and interview of the project coordinator.

Project spotlight: 100 % renewables based hybrid CSP plant - HYSOL

The HYSOL project (Innovative Configuration for a Fully Renewable Hybrid CSP Plant; FP7-ENERGY-2012-1-2STAGE/CP; May 2013 to July 2016; EC funding: EUR 6.2 million; Coordinator: Cobra Instalaciones y Servicios S.A) developed a commercial scale CSP hybridisation system that combines solar power with biogas in a flexible configuration to ensure reliable energy supply. The system allows optimal electrical production with higher share of solar energy, high conversion efficiency and an excellent flexibility, and energy generation from fully renewable sources. The HYSOL technology integrates the biogas with a CSP system by means of an aeroderivative gas turbine, and the thermal energy from the gas turbine exhaust gases is stored into the molten salts of the CSP storage system. The molten salts heated by the exhaust gases can be used to either generate steam directly or be stored for later use, and the CSP plant achieves electrical generation efficiency similar to combined cycles. The HYSOL demonstrator was installed at the ACS/Cobra power plant in Alcazar de San Juan, Spain, and demonstrated that 100 % renewables based CSP plant is feasible.

Source: Source: EC, 2018, Community Research and Development Information Service; and HYSOL webpage (Available: https://www.hysolproject.eu/)

Technology improvements and learning effects still have significant reduction potentials in CSP. A reduction in electricity generation costs is expected in the coming years, aided by growing markets outside of the EU (see also section 5.1). Particularly when taking into account that the global cumulative capacity of CSP is still limited (+/- 5 GW), and that other technologies such as PV were much more expensive at this point in their development, the sector is optimistic about the possibilities for further cost reductions. EU R&D funding contributes to grasping these opportunities through projects such as NEXT-CSP which aims to make cost reductions up to 25 % and CAPTURE which aims for efficiency improvements of between 5 % and 8 %, and lower costs of electricity generated (see project spotlight boxes below).

The most recent prices offered underline these opportunities for cost reductions. In 2018, for instance, ACWA Power signed an Engineering, Procurement, and Construction (EPC) contract with Shanghai Electric, a major Chinese power company, to install the 700 MW DEWA CSP project in Dubai, Saudi Arabia. The project will consist of three 200 MW parabolic trough systems and a 100 MW central tower plant, summing to a total investment of USD[8] 3.9 billion. The project was awarded at a tariff price of USD 73/MWh (+/- 6.2 EURct/kWh) and includes up to 15 hours of energy storage capacity. Abengoa (Spain) and BrightSource (US) are the respective technology providers for the parabolic trough and central tower plants.[9]

Project spotlight: NEXT-CSP

NEXT-CSP is a project funded under H2020 (LCE-07-2016-2017) and aims to make cost reductions up to 25 % compared to the current CSP plants possible, underlining the significant possibilities for improvement of the technology. The project aims to achieve this by developing the fluidised particle-in-tube concept which is used to achieve higher temperature heat transfer fluids. The technology is currently at technology readiness level (TRL) 4 and the project aims to develop it to TRL 5. The project team estimates that at least 10 more years of development are needed before introducing the technology to the market and consider the EU funding essential for being able to conduct this research.

Source: EC, 2018, Community Research and Development Information Service; and interview with the project coordinator.

[8] Where USD is the US dollar
[9] http://analysis.newenergyupdate.com/csp-today/china-backed-4bn-csp-project-set-financial-close-august

Project spotlight: Combined cycle technology solar thermal power towers - CAPTURE

The CAPTure project (Competitive SolAr Power Towers; H2020-LCE-2014-1/RIA; May 2015 to December 2019; EC funding: EUR 6.1 million; Coordinator: CENER, Spain) aims to introduce the combined cycle technology into solar thermal power towers. The technology presents a clear advance compared to state-of-the-art, in terms of conversion efficiencies but it has not yet been implemented to solar thermal power plants because of complexities related to design and operation. The project develops and tests prototypes of all the key components and so far the main achievement is the development of a solar-driven gas turbine, which can be operated with a solar receiver without using fossil-fuels. The technology is expected to yield much higher efficiency-levels than the current state-of-the-art CSP plants and lower costs of electricity. The project is currently working in the final optimisation of the plant concept and the technology is estimated to yield 5-8 % efficiency increase compared to current state-of-the-art CSP tower plants.

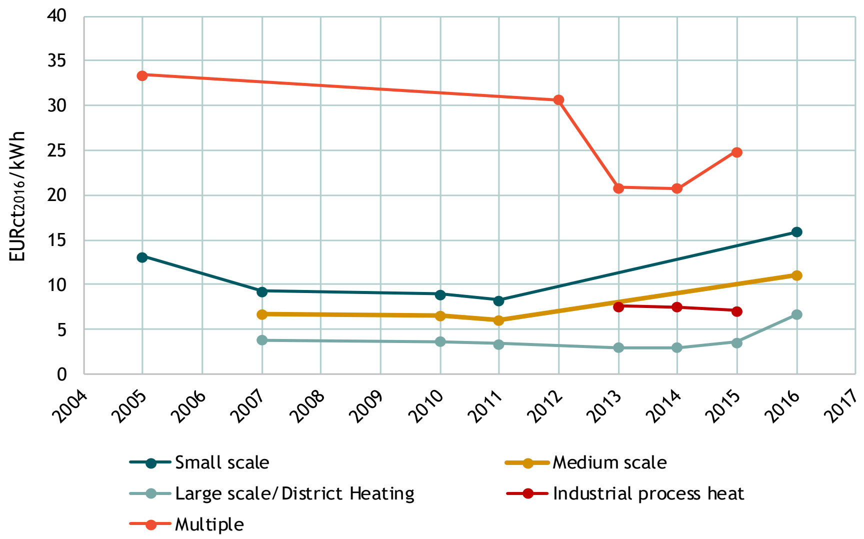
Source: EC, 2018, Community Research and Development Information Service; and interview of the project coordinator.

The development of the LCOE for solar thermal heating and cooling generation can be observed in Figure 4.5. Depending on system size, small-scale solar hot water and heating LCOE ranges from 1.50 to 68.68 EURct/kWh, medium scale from 0.75 to 13.4 EURct/kWh and large scale from 0.75 to 11.2 EURct/kWh.

The LCOE for industrial process heat ranges from 2.4 to 14.5 EURct/kWh, while applications offering both heating and cooling can go from 4.79 up to 134 EURct/kWh.

District heating in Austria, Germany and Denmark, are good examples of the potential for cost reductions thanks to economies of scale. In these regions, the LCOE of a small-scale solar thermal system varies between 13.7 and 18.1 EURct/kWh, and a medium system from 8.9 to 13.4 EURct/kWh. In contrast, the LCOE for a large district heating system is significantly lower, from 3.7 to 4.6 EURct/kWh.

Figure 4.5 Development of LCOE for solar thermal heating and cooling generation (global estimates)



Notes: All figures are global, unless specified otherwise.
For heat generation, data was collected through a desk research. The main sources were REN21 reports (2005, 2007, 2010-2015), OECD/IEA (2007) and Solar Thermal World (2016). The estimates found for heat were grouped in five categories: Small-scale (single-family systems or installed capacity from 0-20 m² for hot water only and combi-systems), Medium scale (multi-family systems or installed capacity from 20-100 m² for hot water only and combi-systems), Large scale (district heating, block heating systems or installed capacity larger than 100 m² for hot water only and combi-systems), Industrial process heat (heat from 50 °C to 400 °C), Heating and cooling (Heating and cooling systems, Adsorption chillers) and Multiple ((solar collectors of unspecified capacity, or with a wide range of capacity).
LCOE for heat generation was taken directly from the desk research data sources and converted to EUR2016.

In Europe the industry is focused on reducing the LCOE of solar heating by technology improvements, facilitating the system installations, and extending the lifetime of the solar thermal collectors (REN21, 2015). EU-funded R&D supports the technology development for instance through demonstration of direct integration of solar systems in residential and non-residential buildings (see project spotlight box on EINSTEIN and CHESS-SETUP below). Such projects have explored new or improved materials and manufacturing processes for solar collectors, sought for novel solutions to reduce complexity and costs of the installation, and advanced the potential for solar hybrid generation and seasonal energy storage solutions. Thanks to the EU FP funding, innovative building-integrated solar thermal (BIST) solutions also have been developed (see project spotlight box on FLUIDGLASS below).

Projects spotlight: Demonstration of solar thermal heating and cooling in buildings
EINSTEIN and CHESS-SETUP

The EINSTEIN project (Effective integration of seasonal thermal energy storage systems in existing buildings; FP7-2011-NMP-ENV-ENERGY-ICT-EeB/CP-IP; January 2012 to December 2015; EC funding: EUR 6.2 million; Coordinator: Tecnalia, Spain) demonstrated how low energy heating systems based on solar thermal energy combined with Seasonal Thermal Energy Storage (STES) - concept, coupled with heat pumps and conventional natural gas boilers, are a feasible solution from a technical and economic point of view. The project developed two full-scale pilot plants: hospital building in Ząbki (Poland) and a cultural centre in Bilbao (Spain).

The CHESS SETUP project (Combined heat system by using solar energy and heat pumps project; H2020-EE-02-2015; June 2016 to May 2019; EC funding: EUR 3.4 million; Coordinator: Agència d'ecologia urbana de Barcelona) was created to respond to the increasing heating and domestic hot water demand in the building sector. The project aim is to design, implement and promote a reliable, efficient and profitable system able to supply heating and hot water in buildings based on an optimal combination of existing technologies such as hybrid photovoltaic-thermal solar panels (PVT), heat pumps and long-term heat storage tanks. The proposed solution is being tested in three pilots: an office block in Manlleu (Spain), 47 new residential houses located in Corby (United Kingdom), and a new sport centre located in Sant Cugat (Spain). All the pilots are expected to be completed by December 2018.

Source: EC, 2018, Community Research and Development Information Service; and interviews with the project coordinators.

Project spotlight: Solar thermal facades - FLUIDGLASS

The FLUIDGLASS project (FP7-ENERGY-2013-1/CP; September 2013 – August 2017; EU funding: EUR 3.7 million; Coordinator: University Liechtenstein) developed an innovative concept of solar thermal façades for use at building and district level, increasing flexibility and energy efficiency. The concept is based on turning glass facades to transparent solar collectors and integrating those to the heating, ventilation and air conditioning system of the building. Testing of the concept was carried out in two locations: Cyprus and Liechtenstein. The project brought a significant cost advantage by increasing the thermal performance of the whole building resulting in an energy savings potential of between 50 % and 70 % for retrofitting, and 20 % and 30 % for new low energy buildings while increasing the comfort for the user, and taking into account the aesthetics of the building.

Source: EC, 2018, Community Research and Development Information Service; Final Report of the project.

Conclusions

The technology development of Concentrated Solar Power has led to clear cost reductions as shown by the downward trend in LCOE. EU-funded R&D has played an important role in enabling these cost reductions by financing research on many components of CSP technology. When interpreting the cost estimates, it is important to keep in mind that the installed capacities have been limited, which has led to limited opportunities for learning-by-doing and economies of scale. As a result, the LCOE is currently at a higher level than wind energy and solar PV, which poses a challenge to the sector. Nevertheless, the sector sees plenty of opportunities to improve the technology and reduce its costs. EU funding continues to play an important role in these developments by offering the necessary funding for promising technologies that are at present still too costly.

The technology development of solar heating and cooling technologies in terms of cost reductions is hard to evaluate due to the large variety of technologies and applications. Still, a downward trend in the capex of the lowest cost installations can be observed and the benefits of economies of scale are clearly visible in district heating applications.

5 Social, economic and environmental impacts

Public R&D funding for RE technologies is justified by several social, economic and environmental impacts. In this section we evaluate a range of indicators that provide insight into these impacts: installed capacity, annual generation, industry turnover, imports/exports, jobs and share of energy consumption.

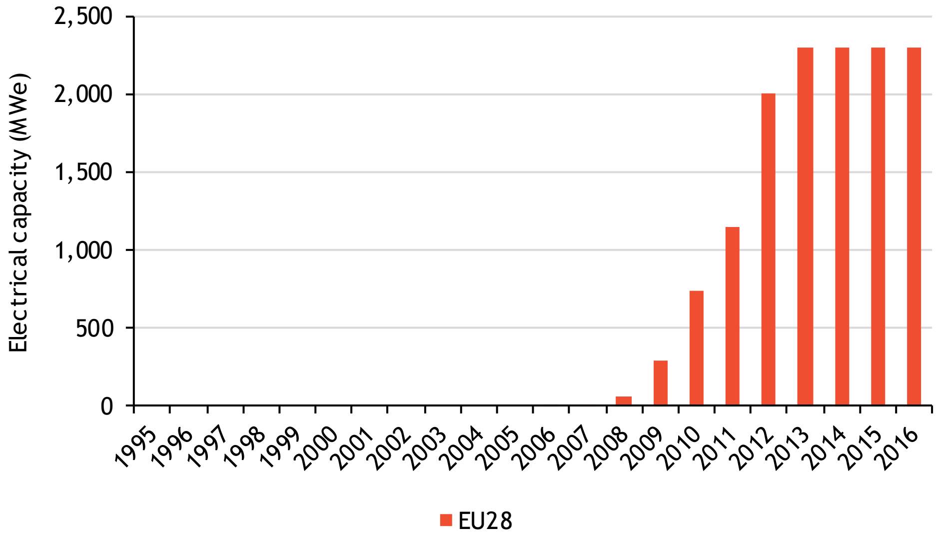
A direct link between these indicators and R&D funding is hard to establish, as the impact of R&D funding is confluent with numerous other factors that drive or prevent deployment. Still, the indicators presented in this section are relevant indicators to assess the evolution of the solar thermal energy sector over time.

5.1 Installed capacity

As installed capacities for RE technologies provide (near) carbon free energy that prevents the need for fossil fuel-based energy, they contribute to reducing greenhouse gas emissions and can be considered a measure of the environmental impacts. Installed capacity refers to the maximum installed generation capacity. This is expressed in MWe for electricity and MWth for heat production.

With 2 302 MWe installed by 2016 (see Figure 5.1), CSP is one of the smallest RE sources that produce electricity in the EU. The USA and Spain have been driving technology development and market formation in the CSP sector in the last decade. In the EU, CSP is installed in Spain (2 300 MW) and Germany (2 MW). Two prototype projects exist in France (1 MW) and Italy (5 MW), which are not listed in the Eurostat database. The German plant is built by the German Aerospace Center (DLR) and is only used for research purposes, which makes Spain the only country in the EU with CSP plants at a commercial scale.

Figure 5.1 Installed capacity of CSP plants in the EU



Source: Eurostat (2018)

In 2004, Spain created a policy framework that enabled the construction of CSP plants at a commercial scale. The first plants went into operation in 2007 and the market grew rapidly to 50 plants with a total capacity of 2 300 MW in 2013. The market was aided not only by strong R&D efforts and an abundance of solar radiation, but also by premium feed-in tariffs and the requirement to use renewables. The expansion stopped after 2013 due to amendments to the Spanish remuneration scheme for renewables that were introduced in that year. The measure was retroactive and stopped any new plant development in the country. The technological leadership of several small, but important companies was affected, although the biggest players managed to maintain their position thanks to the development of CSP plants in other regions around the world. Recently, the Spanish Government lost the first ICSID (International Centre for the Settlement of Investment Disputes) arbitration claim over the applied retroactive measures against CSP. There is no indication of new CSP plants being built in the EU in the near future.

EU funding through its FPs is recognised by industry experts as the other main driver of the CSP market development in the EU. The EU supported several demonstration projects in the EU, such as the PS10, Andasol and SOLAR TRES projects in Spain, allowing the technology to be tested at scale (see project spotlight box below). More recently, EU funding also supported demonstration projects outside of the EU such as the MATS and ORC-PLUS projects (see second project spotlight box below), enabling further development of the technology, as well as improving access to foreign markets for EU companies.

As a result of the current lack of policy support in Spain, the evolution of CSP will certainly be different in the next years. Other regions and countries such as China, Morocco, South Africa, Middle East, and India are expected to be the next biggest markets for the sector and predicted installed capacities are very high (IEA, 230GW for 2030). This expected evolution will be linked to the achieved reduction in electricity generation costs in the next years (see section 4.3).

While the lack of policy support in Spain in particular and the EU in general is an important challenge for the European CSP sector, the European industry remains active in projects all around the world thanks to its clear technological leadership. As such, it can be expected to benefit from the anticipated investments in CSP worldwide.

Projects spotlight: CSP demonstration projects PS10, ANDASOL and SOLAR TRES

During the 5th Research and Technological Development (RTD) Framework Programme (1998-2002), the EC supported three major CSP projects, each project receiving an EUR 5 million grant. All the three demonstrations were carried out in South of Spain due to two main reasons: favourable solar radiation conditions and at that time very supportive national policy scheme including feed-in tariffs for electricity produced by the solar thermal power plants. The demonstration projects were aimed to show technological and economic feasibility of the technology.

- PS10 (10 MW solar thermal power plant in Southern Spain) demonstrated the commercial viability of a 10 MW electric generation plant using the central tower receiver approach. The project was led by Abengoa Solar (Spain). The PS10 plant was constructed at Sanlucar la Mayor near Seville and became operational in 2007. The PS10 technology was further used in PS20 plant next to it (20 MWe, operational since 2009).
- ANDASOL (Andasol 50MWe Eurotrough solar thermal plant with thermal storage in the Marquesado Valley) consists of a 50 MW electric generation plant adopting the parabolic trough approach coupled with a molten-salt based storage system. The project was led by Cobra ACS (Spain) and

Solar Millenium (Germany). The Andasol 1 was connected to grid in 2009 and was followed by two other plants (Andasol 2 and Andasol 3).

- SOLAR TRES (Molten salt solar thermal power 15MWe demonstration plant) demonstrated the feasibility of the world's first commercial scale central tower technology plant that utilises a molten salt thermal energy storage system. The Project was led by SENER Ingeneria y Sistemas (Spain). The Gemasolar CSP plant has been operative since 2011 in the Seville province, South Spain, and the technology is further applied in the Noor III plant currently under construction in Morocco *(See also the Case study in Annex A).*

Source: EC, 2018, Community Research and Development Information Service; and interview with the SOLAR TRES project coordinator.

Projects spotlight: ENEA (IT) builds CSP demonstration plants in Egypt and Morocco (FP7-MATS and H2020-ORC-PLUS)

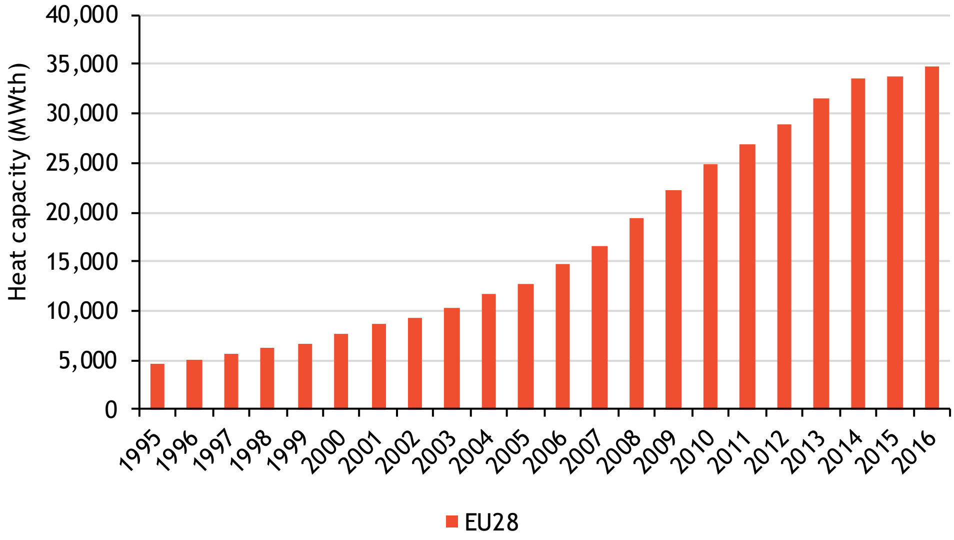
The FP7 project MATS (Multipurpose Applications by Thermodynamic Solar; FP7-ENERGY-2010-2/CP; December 2015 to July 2018; EC funding: EUR 12.5 million; Coordinator: ENEA, Italy) built a CSP demonstration plant in Egypt to demonstrate the potential of CSP technology to dispatch the energy on demand, and how the technology can be applied in small and medium-scale. The plant demonstrates co-generation of electricity and desalinated water to provide fresh water in desert environment. Egypt was chosen as a test location because of optimal radiation condition and being a promising market for European companies. At the moment, the plant is running and each unit is being tested individually.

The focus of the H2020 project ORC-PLUS (Organic rankine cycle - prototype link to unit storage; H2020-LCE-2014-2/IA; May 2015 to April 2019; EC funding: EUR 6.2 million: Coordinator: ENEA, Italy) is to develop a thermal energy storage (TES) system for a small to medium-scale (1-5 MWe) CSP plant. The plan is to couple Fresnel solar collectors, a TES system and an organic rankine cycle (ORC) turbine. The project will be the first thermocline TES system on industrial scale and a demonstration plant is being installed in Ben Guerir (Morocco) and will be completed by end of 2018.

Source: EC, 2018, Community Research and Development Information Service; and interviews of the project coordinators.

Installed capacity for heating and cooling shows a clear upward trend, rising from 5 000 MWth in 1995 to 35 000 MWth in 2016. Germany has the most capacity, accounting for 38 % of the total EU capacity, followed by Austria, Greece, Italy and Spain. Together, these MS account for 73 % of the total installed capacity in the EU.

Figure 5.2 Installed capacity of solar collectors in the EU



Source: Eurostat (2018)

EU-funded R&D contributes to the continued growth of installed capacities in many ways. Noteworthy examples are the development of the district heating and solar process heat sectors, for which the barriers to uptake are not necessarily technological but mainly commercial (payback period) and due to general inertia. The EU has been successful in pushing these markets ahead and is a global leader in district heating enabled by solar thermal technology (Denmark in particular). EU-funded projects that contributed to this leading position in district heating include the three SDH projects (described in the project spotlight box below) and SUNSTORE2 (FP5) which realised additional heat storage and solar collector (greater than 8 000 m^2) capacities in Denmark and improved the efficiency of solar collectors[10]. For solar process heat, EU-funded projects such as SOLARBREW (see project spotlight box below) provide important examples of the application of solar heat in industry and can serve as an example for other companies on how to apply solar process heat, thereby contributing to further growth in installed capacities. The current INSHIP project further underlines the important role that EU funding plays in developing the solar process heat sector (see project spotlight box below).

Projects spotlight: Advances in Solar District Heating market
SDHp2m, SDHplus and SDHtake-off
H2020 project SDHp2m (Solar District Heating from policy to market; H2020-LCE-2015-3; January 2016 to December 2018; EU funding: EUR 1.9 million; Coordinator: Steinbeis Innovation, Germany) has the aim to develop, improve and implement advanced policies and support measures for SDH in 9 participating EU regions. The project activities aim at a direct mobilisation of investments in SDH and hence a significant market rollout. It focuses on Denmark and Sweden, with their advanced district heating and cooling systems, as models. The project builds on the results of the SDHplus and SDHtake-off projects funded through the Intelligent Energy Europe Programme, which resulted in new business models, marketing strategies for SDH and a detailed analysis of market barriers and recommendations for regulations, support schemes, and policy.
Source: EC, 2018, Community Research and Development Information Service; Project webpage (Available: www.solar-district-heating.eu)

[10] http://sunstore4.eu/understand/example-of-sunstore2/

Project spotlight: SOLARBREW

The SOLARBREW project (Solar brewing the future; FP7-ENERGY-2011-2/CP; February 2012 to January 2016; EC funding: EUR 2.6 million, Coordinator AEE INTEC, Austria) designed three solar thermal systems (more than 1 MW each) for the use of solar process heat at different production sites of one of the world-leading brewing companies, Heineken Group. The project has made a significant contribution to the solar heating capacities in the EU by designing over 7 000 m^2 of solar heating capacity of which 1 375 m^2 is already realised. Compared to overall solar heating capacities in the EU of approximately 50 000 m^2, the contribution of SOLARBREW is significant.

The project aimed to develop the use of large-scale solar process heat for the brewing industry in collaboration with the world-leading brewer Heineken. Apart from the planned and installed capacities, the project led to significant improvements in terms of solar process heat integration and technological and economic development of solar thermal systems. Furthermore, the demonstration of a solar process heating technology at a multinational company like Heineken was important for building awareness and further uptake of the industry.

For a detailed case study on the SOLARBREW project, see annex A.

Project spotlight: Towards a common research agenda in solar heat for industrial processes (INSHIP)

The INSHIP project (Integrating National Research Agendas on Solar Heat for Industrial Processes; H2020-LCE-2016-ERA/RIA; January 2017 to December 2020; EC funding: EUR 2.9 million; Coordinator: Fraunhofer, Germany) unifies the key EU actors in the field of solar heat application to industrial processes to arrive with a common research agenda for upcoming years. The project conducts R&I activities such as enhanced integration of solar thermal technologies to different industry requirements, overcoming the barriers related to high temperature solar processes and increasing the connections between industrial parks through centralised distribution networks and the connection with district heating systems and the electricity grid.

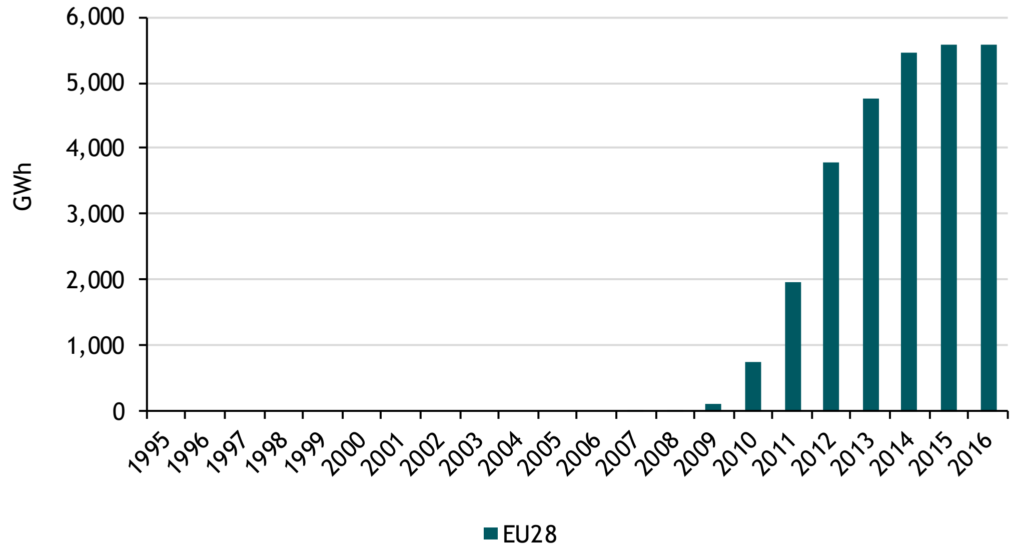
Source: EC, 2018, Community Research and Development Information Service; and INSHIP webpage (Available: www.inship.eu)

5.2 Annual generation

While installed capacities are a commonly used indicator to measure the progress in deploying RE technologies, it can be somewhat misleading due to differences in capacity factors. Annual generation includes the effects of these differences and is therefore a valuable indicator to complement the statistics on installed capacities.

Only Spain had electricity generation from CSP plants for commercial use (the German solar thermal power plant is only for research purposes, which is why no electricity is sold). With the 2 300 MW installed capacity, it generates 5 500 GWh per year.

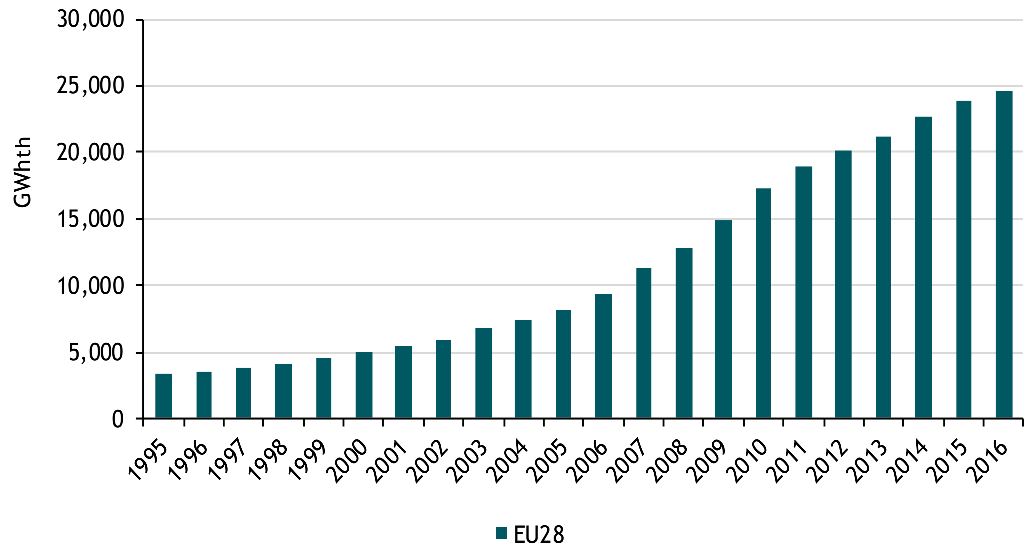
Figure 5.3 Annual electricity generation in the EU from solar thermal (CSP)



Source: Eurostat (2018)

Generation from solar H&C shows an upward trend, similar to its increase in capacity over the years. With 35 000 MWth currently installed, it generates close to 25 000 GWhth per year.

Figure 5.4 Annual heat generation in the EU from solar thermal (solar heating and cooling)



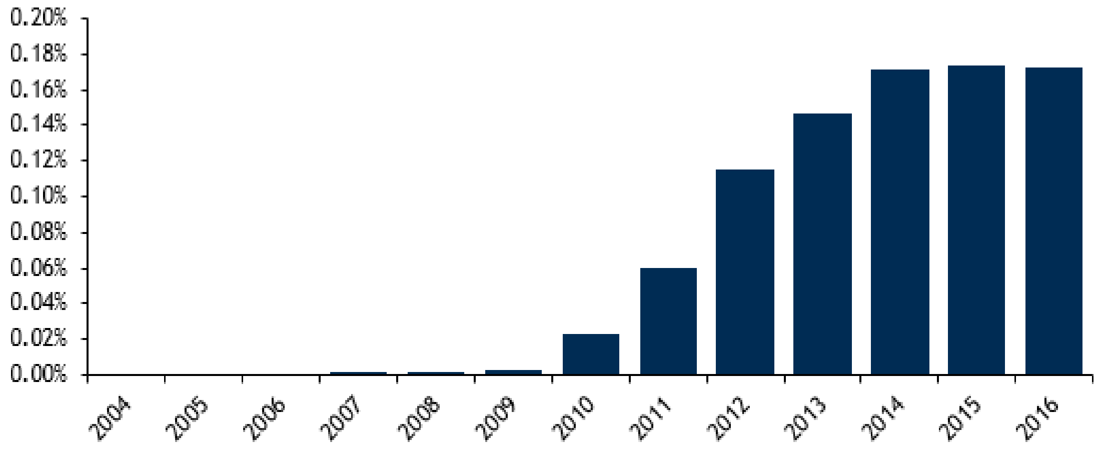
Source: Eurostat (2018)

5.3 Share of energy consumption

Share of energy consumption refers to the participation of solar thermal energy in the gross final energy consumed in each market sector (electricity, heating and cooling, and transport). This indicator allows us to analyse the participation of the solar thermal sector in the overall target of increasing the share of energy from RES in the EU's gross final energy consumption.

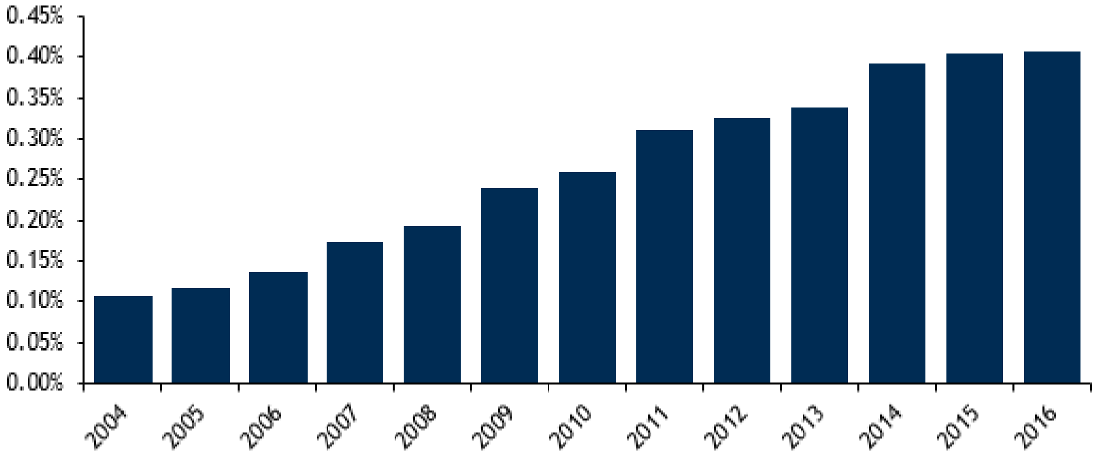
The shares of gross final electricity and heat consumption from solar thermal energy in the EU are 0.17 % and 0.40 % respectively. No new CSP plants are planned currently, therefore it is expected that the share of electricity will remain the same in the coming years. For heat, it is slowly increasing since 2004, which can be attributed to the increasing capacity and generation from solar heat in the EU. This trend is likely to continue.

Figure 5.5 Share of gross final electricity consumption from solar thermal in the EU



Source: Eurostat (2018)

Figure 5.6 Share of gross final heat consumption from solar thermal in the EU



Source: Eurostat (2018)

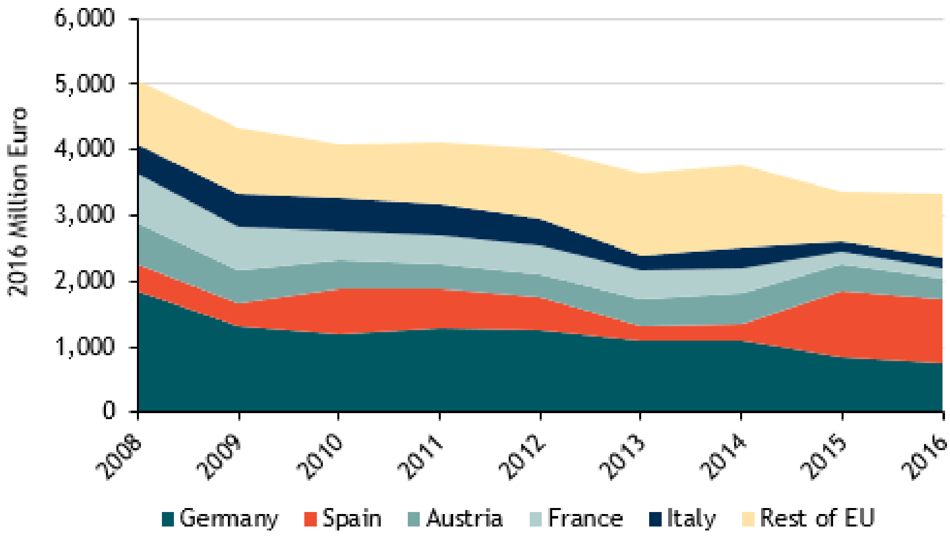
5.4 Industry turnover

Industry turnover is the total amount invoiced from the market sales of goods and/or services supplied to third parties by all sellers in the solar thermal sector. Following the definition in EurObserv'ER, it focuses on the main economic activities of the supply chain including manufacturing, installation of equipment and operation and maintenance (O&M). A growing turnover indicates a growing market.

Industry turnover in the solar thermal sector is estimated at EUR 3.4 billion in 2016. It has declined between 2008-2016, due to various reasons. Generally, the financial crisis and low oil prices affected the market, as well as increased competition from Asian manufacturers and heat pumps becoming an alternative for solar H&C systems.

Some countries such as Austria upheld stable rates, partially thanks to a growing export market for its manufacturers, but overall heating and cooling installations dropped due to stagnation in the building sector. In Italy, a 55 % tax reduction measure gave a boost to the sector in 2011, but the building sector was not able to maintain previous levels in 2012. Italy also implemented a heat feed-in-tariff in 2012, but this only had minor effects on installation rates. Germany also saw declining installation rates, which was offset slightly by large installation parks. Denmark is one of the few exceptions, where turnover grew from an estimated EUR 27 million in 2008 to EUR 521 million in 2016. This success can be ascribed to the installation of numerous solar district heating applications. Spain is the largest player in terms of turnover in recent years, thanks to its strong CSP industry that has retained technological leadership and is active in many global CSP projects.

Figure 5.7 Solar thermal industry turnover in the EU



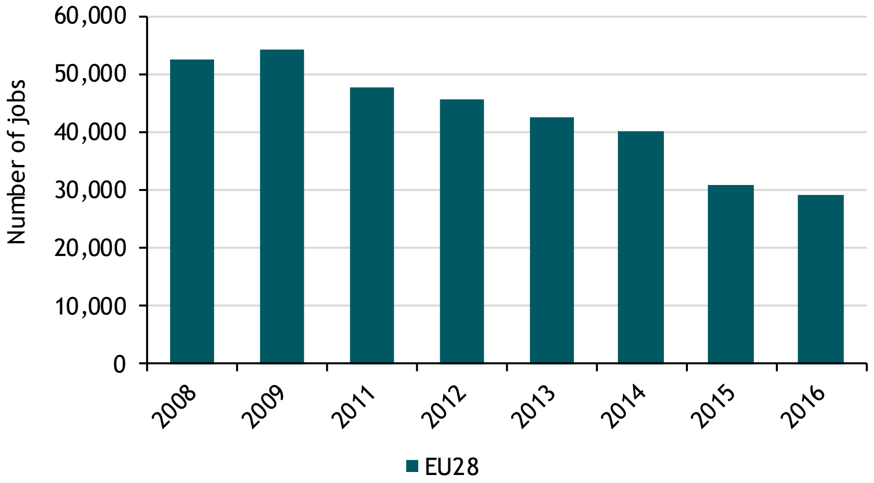
Source: EurObserv'ER reports 2010-2017.
Notes: Data is missing for Croatia on years 2008-2011. It is assumed that the figures of all solar thermal industry turnover include data on the sub-technologies CSP as well as Heating and Cooling. This is explicitly stated in the EurObserv'ER reports from 2013, 2014, 2015 and 2017. It is loosely referred to in the 2011 and 2016 reports, but is not mentioned in 2010.

5.5 Jobs

Employment is an important indicator to understand the socio-economic impact of RE technology deployment. Linking jobs to R&D funding is difficult due to the number of confounding factors, but it is possible to make a connection between RE deployment and jobs. Different methods exist for estimating employment figures. A consistent time-series was only available for 2008-2016.

The solar thermal sector has an estimated 29 000 direct and indirect jobs in 2016. Like industry turnover, the amount of jobs in the solar thermal sector saw a decline from 2008 to 2016. Spain is the largest employer, with an estimated workforce of 8 000 in 2016. A substantial part of this labour force is dedicated to O&M of the existing CSP plants and the development of new CSP plants outside of the EU.

Figure 5.8 Evolution of EU jobs in solar thermal



Source: EurObserv'ER (2010-2017). Data from Croatia is missing for years 2008-2011. Accounts for direct and indirect jobs in solar thermal (aggregating CSP and solar heating and cooling sub-technologies) in the EU MS. It is assumed that the figures of all solar thermal jobs include data on the sub-technologies CSP as well as Heating and Cooling. This is explicitly stated in the EurObserv'ER reports from 2013, 2014, 2015 and 2017. It is loosely referred to in the 2011 and 2016 reports, but is not mentioned in 2010.

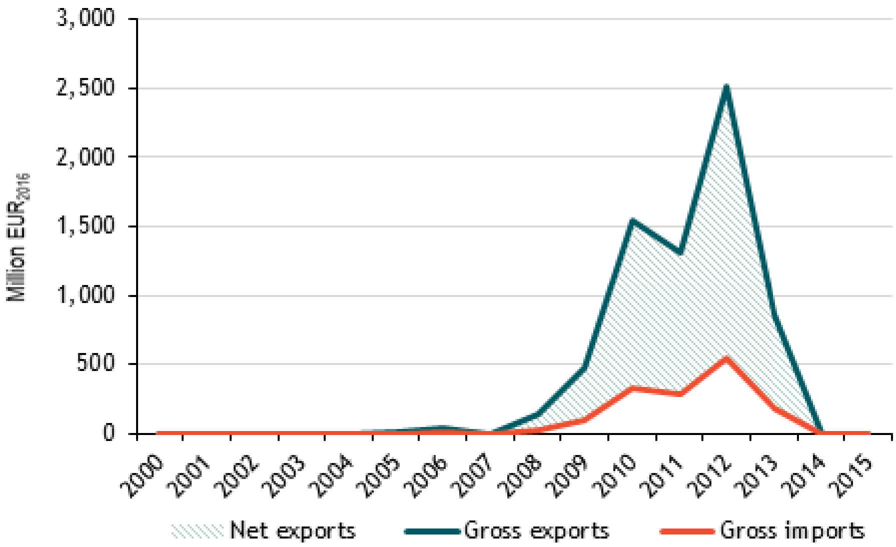
5.6 Imports/exports

International trade can provide a useful measure of the market uptake of solar thermal technologies and development of the solar thermal sector itself. It allows us to examine the extent of the external market for these goods, with increasing exports leading to increased growth of the domestic sector. Similarly, increased activity in the sector will lead to an increase in demand for intermediate goods used in the manufacture of RE technologies, a proportion of which may be imported. Increasing imports of these intermediate goods also provide an indication of the growth within the technology sectors.

Overall the EU exports more than what it imports. For the whole period from 2000 to 2015 taking into account CSP and solar heating and cooling, the total value of exports to non-EU countries was 3 times the total value of imports from non-EU countries.

The gross exports and imports for CSP are shown in Figure 5.9. Exports for CSP components are almost five times to the size of imports for CSP components, indicating that the EU CSP industry is competitive in the global market.

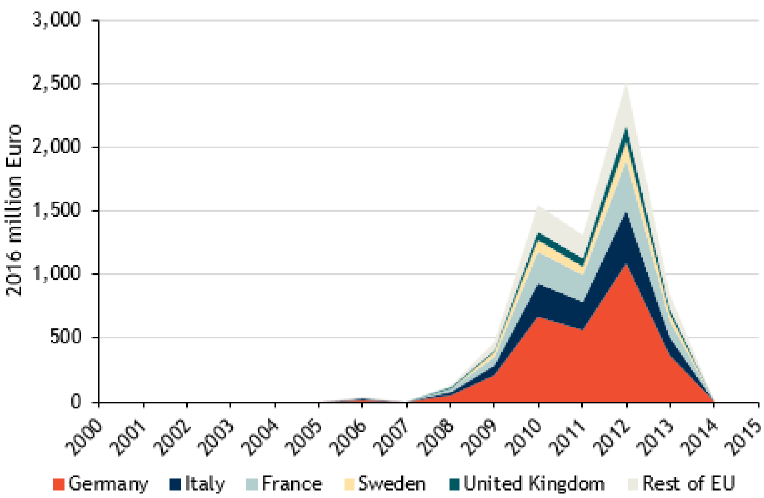
Figure 5.9 Trade balance for CSP



Source: Based on Comext (2018), Lako, P (2008), Eurostat (2018), Wind, I (2009), and Jha, V (2009).
Notes:Data for 1999 and 2016 was 0 for all countries so it was excluded.
For an explanation of the methodology used, see Annex C.

The largest exporter to non-EU countries of CSP components is Germany (see Figure 5.10). Italy, France, Sweden, and the UK make up some of the other large exporters of CSP to non-EU countries. Germany leads the extra EU exports with EUR 2 983 million during the period 2000-2015. Italy and France follow with EUR 1 160 million and EUR 1 079 million each. Sweden has EUR 390 million while the United Kingdom has EUR 332 million. The participation of the rest of the EU MS is minimum, with only EUR 94 million. Important to note is that the import and export volumes only concerns components. Hence, the participation of EU companies as knowledge providers/project managers in international projects is not captured in these statistics, which explains why Spain is for instance not shown as a main exporter, while Spanish companies do export their knowledge.

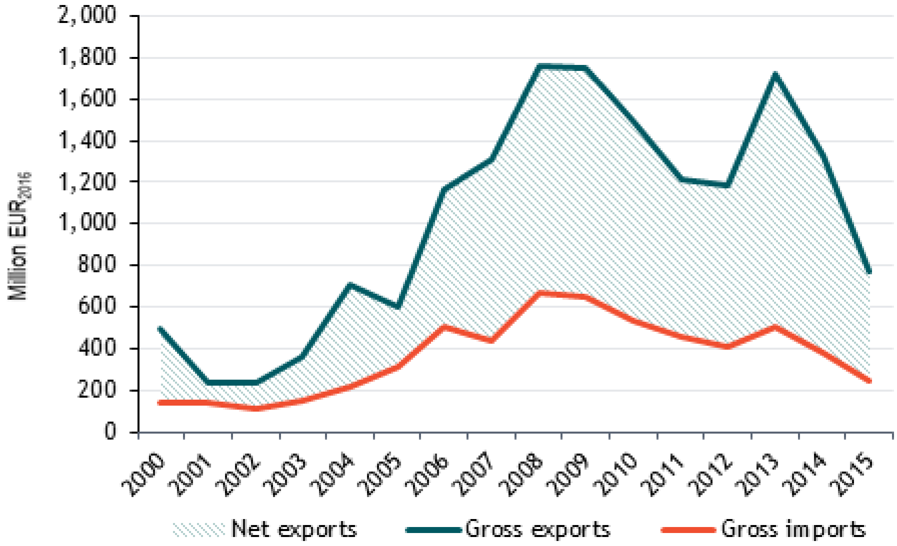
Figure 5.10 CSP exports - extra EU28



Source: Based on Comext (2018), Lako, P (2008), Eurostat (2018), Wind, I (2009), and Jha, V (2009).
Notes:
Values in 2007 are 0 for all MS.
Data for 1999 and 2016 was 0 for all countries so it was excluded.
For an explanation of the methodology used, see Annex C.

Also, for solar H&C, the EU maintained a trade surplus between 2000 and 2015 (see Figure 5.11). The total exports for solar H&C in this time period are more than double the CSP exports, thanks to the consistent demand for solar H&C components.

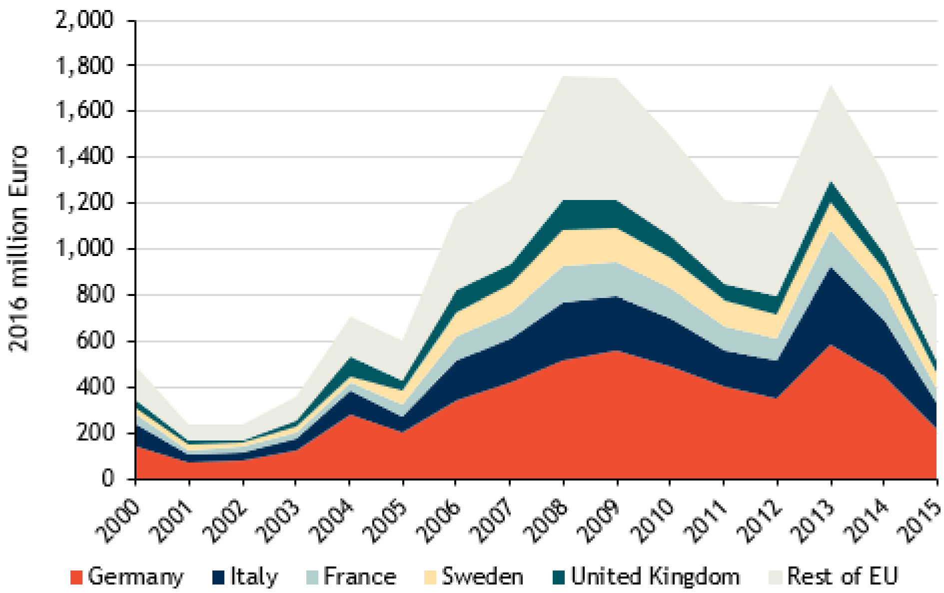
Figure 5.11 Trade balance for solar heating and cooling



Source: Based on Comext (2018), Lako, P (2008), Eurostat (2018), Wind, I (2009), and Jha, V (2009).
Notes:Data for 1999 and 2016 was 0 for all countries so it was excluded.
For an explanation of the methodology used, see Annex C.

The main MS exporting solar H&C outside of the EU are the same as those exporting CSP components. From these, Germany again is leading the exports – exporting EUR 5 232 million worth of components, over the period 2000 to 2015. Italy and France follow with EUR 2 465 million and EUR 1 419 million respectively.

Figure 5.12 Solar heating and cooling exports - extra EU28



Source: Based on Comext (2018), Lako, P (2008), Eurostat (2018), Wind, I (2009), and Jha, V (2009).
Notes:Data for 1999 and 2016 was 0 for all countries so it was excluded.
For an explanation of the methodology used, see Annex B.

Conclusions

The CSP sector experienced a significant growth in installed capacities from 2008 to 2013, growing from close to zero to more than 2 000 MW, leading to a share of total EU electricity consumption of 0.2 %. The growth has been enabled by the supportive policy framework in Spain as well as EU funding for demonstration projects. From 2013 onwards, no new capacities have been installed in the EU. Spain has been the only real market for CSP plants and the withdrawal of the Spanish support measures for CSP has caused the growth of the capacities to halt. In spite of the lack of a local market, the EU industry has managed to retain industrial leadership and is active in many CSP projects around the world.

The solar heating and cooling sector has experienced a much more gradual growth. In 2004 solar heating provided 0.1 % of EU heat consumption which has grown fourfold to 0.4 % in 2016. Noteworthy developments are the leading position that Denmark has achieved in the large-scale district heating sector, considered the only example of a mature and commercial solar district heating market, and the recent efforts to develop the industrial process heat market. EU funding has contributed to the development of these sectors through demonstration projects and addressing market barriers. The EU solar heating and cooling industry has a strong industrial position with a large trade surplus.

For the solar thermal sector overall, the industry turnover and number of jobs have been in steady decline since 2008, probably largely due to the downturn in CSP capacity additions. O&M to existing CSP capacities and manufacturing for exports still keep the industry alive but have not been able to prevent a steady decline.

6 Conclusions

Solar thermal energy technologies have received 11 % of EU R&D funds and 13 % of MS R&D funds for RE technologies over the past 20 years. Internationally, the EU has a strong academic position with leading R&D budgets and the number 1 position in terms of publications worldwide. The EU Framework Programmes made a clear contribution to the EU's academic leadership by funding projects that delivered many publications and stimulating collaboration and alignment of R&D agendas across the EU.

For Concentrated Solar Power (CSP), one of the key impacts of EU funding has been its contribution to the scale-up and market uptake of the technology, by funding several demonstration projects. Together with the policy support of Spain, this created strong growth in installed capacities and enabled the development of a globally leading EU industry. Furthermore, EU-funded R&D contributed to technology improvements and cost reductions for CSP technologies that facilitate the continued global competitiveness of the EU CSP industry.

The EU solar heating and cooling capacities have grown steadily over the past 20 years. EU-funded R&D has contributed to achieving cost reductions, improving technologies and facilitating market uptake. Noteworthy examples include the EU contribution to the development and demonstration of building-integrated solar heating and cooling technologies and the efforts to increase the uptake of solar process heat by the industry. Furthermore, EU-funded projects have contributed to the development of world-leading solar district heating infrastructures (Denmark in particular). Thanks to the efforts of the EU and MS, the EU solar heating and cooling industry has a strong global position with a significant trade surplus.

Annex A - Case studies

Case study: SOcool

Author:	Hanna Kuittinen Iñigo Iparraguirre	Approver:	Dr. Carsten Corino
Project title:	SunOyster cooling (SOcool)		
Lead partner:	SunOyster Systems GmbH Poststrasse 46 25469 Halstenbek Germany		
Project location*:	Germany		
Technology area/s:	Solar thermal		
Start and end date**:	Phase 1: August 2016 to January 2017 Phase 2: September 2017 to August 2019		
Project cost:	Phase 1: EUR 71 429 Phase 2: EUR 1 997 825	EC funding:	Phase 1: EUR 50 000 Phase 2: EUR 1 398 477.50
Other funding sources:	Private investments		
Quantifiable outputs and impacts:	The second phase of the project is still on-going and to be finalised in August 2019. The company has estimated that, by 2021, the SunOyster SoCool product could lead to: Annual installed capacity: 50 MW electric capacity + 75 MW thermal capacity Systems sold: 10 000 per year Turnover: EUR 66 million Job creation: 140		
Further information***:	Project website General Manager (GM) - Dr Carsten Corino, SunOyster Systems GmbH. Visiting address, Poststrasse 46, 25469 Halstenbek, Germany. T +49 4101 80 87 67. E carsten.corino@sunoyster.com		

Project description

SunOyster Systems, the single beneficiary of the SOcool project, is a SME established in 2011, based in Halstenbek, near Hamburg, Germany. The company is focused on developing and commercialising concentrating solar technology, and has developed its own technology including a highly efficient solar collector, which produces simultaneously electricity and high-grade heat. Technologically it is based on a large parabolic mirror on one line (16 m^2) concentrating the solar energy on a receiver, which uses PV cells to covert the solar radiation directly into electricity. These cell assemblies also produce heat, and conduct the heat through a receiver tube into a thermal fluid, which is transporting the heat to storage or direct usage. This technology is highly efficient, achieving from serial production an electric efficiency of up to 30 % and a thermal efficiency of 45 %, both in relation to direct normal irradiance. In this system, heat is a cheap by-product of electricity generation. SunOyster has applied for three international patents for the company's main innovations related to the above-mentioned technology.

The objective of the SOcool project is to use a concentrating photovoltaic/thermal (CPVT) system combined with chillers to provide cost-efficient solar energy in forms of electricity, heat and cold. The project is based on the premise that cooling and refrigeration cause nowadays 7 % of the worldwide greenhouse gas (GHG) emissions, and their market demand is expected to increase during the next decade. As cooling is mainly required when the sun is shining, the basic idea of the SOcool project is to use solar energy to generate cooling. The proprietary technology of SunOyster can generate at the same time electricity and heat with a very high efficiency, and the idea of SOcool project is to combine this technology with thermal chillers, readily available on the market, and to offer integrated and standardised solar cooling packages. These can be directly used for the air-conditioning of residential or commercial buildings, cool storage or other industrial purposes. The SOcool project aims to develop the technology further, to easily scalable, adaptable and standardised solar cooling product packages for the supply of electricity, cooling and heat. This will be achieved by building-up a production pilot, testing and certifying the packages, carrying-out a demonstration project, and launching large-scale commercialisation. The focus is on three applications areas, which have demonstrated to have the highest market potential:

- SOcool Hotel: covering the large heating and cooling demands of hotels;
- SOcool Office: where the cooling demand corresponds well with the sunshine hours ;and
- SOcool Pool: for villas with a pool, where the pool is used as the heat sink for the SunOyster in spring and autumn, when the building needs less heating or cooling.

Outputs and impacts

Before the SOcool project started, the technology had already reached TRL 6-7, and SunOyster had applied for intellectual property (IP) rights protection (patents, utility model) in its main markets (USA, EU, India and China). The first phase of the SOcool project was successfully finalised in January 2017. It was focused on a feasibility study laying the foundations for the development of the SOcool packages, including a preliminary supply chain mapping, and a market analysis. The second phase of the project is still on-going and is planned to be finalised in August 2019. The project is advancing as scheduled, and so far, it has not encountered any major drawbacks or deviations from the planned schedule. The company has first prototypes and the first zero and pre-series machines installed, and is setting-up a pilot production plant in Germany and is looking forward to upscale the manufacturing in near future. The SOcool packages are in testing phase.

The company has estimated that, by 2021, the annual installation of SOcool is expected to rise to 50 MW electric and 75 MW thermal capacity, corresponding to 10 000 sold systems per year, generating EUR 66 million turnover and creating 140 green jobs in the EU. This will contribute to carbon dioxide (CO_2) emission reductions, and enhance the living standards of people suffering from hot climate.

Outlook and commercial application of the outputs

The technology has different advantages such as a larger energy generation capacity thanks to the hybridisation in relation to the occupied roof surface when compared to energy generation of conventional photovoltaics and low-medium temperature solar thermal collectors. The main challenge is related to production costs and the company is currently discussing with potential component suppliers to bring down costs.

The company considers China and India as its main markets, and especially Chinese market shows currently high potential. The company also sees market potential in EU countries, including in SunOyster System's home country Germany. European policies are considered to have been very focused on renewable electricity generation while they have neglected the role of heating and cooling. According to the SunOyster System CEO Dr. Carsten Corino 'Heat is the sleeping giant in Europe and to achieve the ambitious climate change targets, the sector should be better activated'.

The role of EU funding

The SOcool project received funding from the European Union's Horizon 2020 Programme for Research and Innovation (H2020). Horizon 2020 funds high-potential innovation developed by SMEs through a dedicated programme called SME Instrument, targeted to support close-to-market activities and boost the SMEs to reach global markets with their highly innovative ideas. The funding programme is organised in two phases: Phase 1 for feasibility assessment (lump sum of EUR 50 000, for a period of 6 months), and Phase 2 for innovation development and demonstration purposes (up to EUR 2.5 million grant with duration 1-2 years). SunOyster Systems successfully finalised the Phase 1 project and competed and received funding for the Phase 2 in 2017. The EU contribution for the Phase 1 SOcool project was EUR 50 000, whereas the Phase 2 grant is significantly larger EUR 1 398 477.50. For both phases, the EC contribution corresponds to 70 % of the projects' total costs. Winning the SME Instrument grant was an important milestone for SunOyster Systems, and it allowed the company to enlarge its personnel and consolidate activities. The company had accomplished a private investment prior to receiving the SME Instrument grant. The private investor was encouraged to increase its investment after SunOyster got the Phase 2 EU funding. The SME Instrument grants have contributed to an increased visibility of SunOyster Systems.

Full project participant list

Organisation	Country	Type
SunOyster Systems GmbH	Germany	Private company (SME)

The case study authors would like to express their acknowledgements to Dr. Carsten Corino, General Manager of SunOyster Systems, for his kind support and participation in a telephone interview on 14 May 2018.

Case study: SOLARBREW

Author:	Hanna Kuittinen Iñigo Iparraguirre	**Approver:**	Wolfgang Glatzl Christoph Brunner
Project title:	Solar brewing the future (SOLARBREW)		
Lead partner:	AEE - Institute for Sustainable Technologies (AEE INTEC) Feldgasse 19 8200 Gleisdorf Austria		
Project location:	Austria		
Technology area/s:	Solar thermal		
Start and end date:	February 2012 to January 2016		
Project cost:	EUR 4 894 032.80	**EC funding:**	EUR 2 628 572.00
Other funding sources:	-		
Quantifiable outputs and impacts:	Design of three large-scale solar thermal systems for three different brewing plants of the world-leading brewing company Heineken, with a total planned capacity of 5.08 MWth corresponding to a 7 270 m^2 solar collector area. One of the plants was built during the course of the project in Göss, Austria with a capacity 1 MWth, corresponding to 1 375 m^2 collector area.		
Further information:	Project website Project Manager - DI Christoph Brunner, Industrial Processess and Energy Systems, AEE - Institute for Sustainable Technologies (AEE INTEC) Visiting address, Feldgasse 19, A-8200 Gleisdorf. T +43 (0)3112-5886. E c.brunner@aee.at		

Project Description

The SOLARBREW project aimed at developing the use of solar process heat in the brewing industry by designing three large-scale solar thermal systems (more than 1 MW each) at different production sites of one of the world-leading brewing companies, Heineken Group. The coordinator of the project AEE INTEC had worked several years on so called green brewery concept together with a local Göss Brewery in Leoben. Göss Brewery is one of the largest and most-well known breweries in Austria, whose majority shareholder is the Dutch brewing company Heineken. As a result of this local collaboration, the Heineken Group became interested to explore further energy-efficiency applications in the brewing processes.

The objective of the project was to demonstrate the technical and economic feasibility of large-scale solar thermal system integration in the brewing industry for the first time. Enhanced utilisation of thermal energy available from heat recovery combined with integration of solar heat supply was expected to reduce exergy losses and fossil fuel based CO_2 emissions of the brewing process. Brewing industry processes are especially suitable to be supplied by solar thermal systems, since they require optimal temperature range (between 50 °C and 100 °C) for advanced medium temperature solar collectors. The project aimed at designing solar thermal systems in three demonstrations in Heineken Group plants located at Göss, Austria; Valencia, Spain; and Vialonga, Portugal. The project was an important milestone for brewing and solar thermal industry, by demonstrating in real-scale how solar thermal energy applications can be used in key-processes of brewing industry.

The project was coordinated by AEE INTEC, which is a non-university research institute located in Gleisdorf, Austria. AEE INTEC is specialising in thermal energy technologies and hybrid systems, building and renovation, as well as industrial processes and energy systems. The partners of the project involved one of the world-leading brewery companies Heineken Supply Chain BV from the Netherlands; GEA Brewery Systems GMBH, a brewery sector process engineering specialist from Germany, and Sunmark AS, a solar engineering company from Denmark.

Outputs and impacts

The project designed three demonstrator plants with a total planned solar thermal energy capacity of 5.08 MWth, corresponding to 7 270 m² of collector area. The three demonstrations involved different brewing industry processes (mashing, pasteurisation and drying malt), and different climatic zones (Austria, Spain and Portugal), in orto evaluate the performance of the plants under different solar radiation conditions. One of the three designed solar thermal plants was built during the course of project in Göss, Austria with a capacity 1 MWth, corresponding to 1.375 m² collector area. The solar thermal system Göss implies several innovative approaches: Two steam supplied vessels (mash tuns) were retrofitted by especially designed internal plate heat exchanger templates, which enabled a supply system based on hot water instead of steam. The new hot water supply is fed by waste heat from a nearby biomass CHP plant as well as by a large-scale ground mounted solar thermal system, which is hydraulically connected to a solar energy storage tank. As a result, approximately 20 % of the thermal process energy demand previously supplied by steam can be supplied by the solar thermal system, leading to reduced CO_2 emissions.

The project led to a significant improvement of solar process heat integration and a technological and economic development of solar thermal systems.

- Compared to the state of art, the most important technological results achieved included improved hydraulic concepts and stagnation behaviour control of large-scale solar thermal systems, and the development and application of advanced flat-plate collectors, utilising, among other features, a second transparent cover and advanced insulation, allowing more efficiency on higher temperature levels;
- The project also developed new solutions for the adaptation and optimisation of the machinery and processes involved in brewing and malting processes to solar energy supply (e.g. matching the time-dependency of the solar energy supply and the heat demand of the processes);
- In addition, the project enhanced the usage of the synergies of converting the heat supply system of the related processes from a steam based heat supply system to a hot water based supply system, enabling efficient integration of the solar thermal systems;
- The project resulted to one peer-reviewed journal article and to a number of conference presentations, press releases, newspaper and magazine articles;
- Most importantly, the project showcased how the large-scale application of solar thermal energy is a viable and economically feasible solution for brewing industry energy supply, even competitive compared to fossil fuels in short term. Present investment costs for solar thermal systems range from 400 to 500 €/m² (corresponding to 250-1 000 €/kW of thermal power) leading to average energy costs in Southern Europe from 2 to 5 cent/kWh for very low temperature applications and from 5 to 15 cent/kWh for medium temperature systems;

- Finally, the project developed a comprehensive 'Green Brewery' sector concept, including a guideline and calculation tool, which serves as basis for a broad European wide training and dissemination programme, and supports energy managers, solar thermal experts and consultants to reduce the fossil CO_2 emissions in breweries and malting plants.

Outlook and commercial application of the outputs

The project was finalised in January 2016, but the work continues. The demonstrations carried-out in SOLARBREW project can be considered as best practice example for the brewing sector, and can act as a catalyser for the market uptake of the solar thermal energy in the whole food and drink industry resulting to important boost for the solar thermal industry and significant reductions of CO_2 emissions in the brewing industry. The results of the project are not only useful for the broad market deployment in the brewing industry, but they are also of high relevance for food and beverage industry in general, as many of the brewing industry processes (pasteurising, drying) are common also in the food and beverage industry.

The project results and the Green Brewery concept have been further developed by AEE INTEC in 5-6 new projects with Göss Brewery and other major breweries such as Carlsberg. They have also conducted an Intelligent Energy Europe co-funded project called GREENFOODS[11] aimed to lead the European food and beverage industry to high energy efficiency and reduction of fossil carbon emissions. Also, Heineken Group continues their efforts towards sustainability, and has announced goals to reduce CO_2 emissions of their production process by 40 % by 2020 (compared to 2008 level)[12]. The Göss Brewery where the demonstration plant was built, is fully carbon-neutral, and its energy supply is 100 % based on RE, including solar thermal energy[13].

The role of EU funding

The SOLARBREW project received funding from the European Union's Seventh Framework Programme for Research and Innovation (FP7). Energy was one of the thematic areas under the Cooperation programme, and provided project funding for collaborative research. The SOLARBREW project received the funding under the specific call topic: Low/Medium temperature solar thermal systems for industrial process heat, aimed at demonstrating large-scale integration of solar collectors into existing industrial process heat demand. The FP7 has since been replaced by the Horizon 2020 programme, which continues to fund near-to-market solutions for the use of solar heat in industrial processes (e.g. topic LCE-12-2017).

The EU contribution of the SOLARBREW project yield to 54 % of the project total cost, and the funding rates varied by participant types; research organisation AAE Intec and SME Sunmark had a higher funding rate 75 %, whereas the large companies, Heineken Group and GEA Brewery Systems, had a funding rate of 50 %. The project necessitated contractual changes and amendments due to a bankruptcy and later merger of project partner Sunmark in 2015.

According to the project coordinators, the EU support was essential for the project, and the demonstration would not have taken place without EU funding, not at least at the same scale or

[11] http://www.green-foods.eu/objectives/
[12] http://www.theheinekencompany.com/heinekens-view-on-renewable-energy
[13] http://www.theheinekencompany.com/media/features/goss-brewery-celebrates-becoming-carbon-neutral

timetable. In addition, the EU funding ensured significant visibility and enhanced the awareness of RE and sustainable brewing within the sector.

Full project participant list

Organisation	Country	Type
Arbeitsgemeinschaft - Erneuerbare Energie - Institut Fur Nachhaltige Technologien (AEE INTEC)	Austria	Research institute
Heineken Supply Chain B.V.	The Netherlands	Private company
GEA Brewery Systems GMBH	Germany	Private company
Sunmark AS (later Arcon-Sunmark)	Denmark	Private company (SME)

The case study authors would like to express their acknowledgements to Mr. Wolfgang Glatzl and Mr. Christoph Brunner from AEE-INTEC for their kind support and participation in a telephone interview on 14 May 2018.

Case study: STAGE-STE

Author:	Iñigo Iparraguirre Hanna Kuittinen	**Approver:**	Dr. Julián Blanco Galvez, Director, Almería Solar Platform, CIEMAT
Project title:	Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy (STAGE-STE)		
Lead partner:	CIEMAT - Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas Avenida Complutense 40 28040 Madrid Spain		
Project location:	Spain		
Technology area/s:	Solar thermal		
Start and end date:	February 2014 to January 2018		
Project cost:	EUR 21 134 658.37	**EC funding:**	EUR 9 997 207.00
Other funding sources:	In-kind contributions		
Quantifiable outputs and impacts:	Selected key performance indicators (KPIs) of the project[14]: • More than 200 joint publications accepted/published in academic peer-reviewed journals during the project lifetime • More than 4 000 tests carried out at the facilities of the project participants out of which more than 200 were joint tests involving two or more project participants • A web-repository including a description of more than 200 IP assets • More than 100 researchers involved in mobility and exchange programmes		
Further information:	Project website Project Coordinator – Dr. Julián Blanco Gálvez, Director, Almería Solar Platform, CIEMAT. Avenida Complutense 40, 28040 Madrid, Spain. T +34 950387800. E julian.blanco@psa.es		

Project description

The Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy (STAGE-STE) project started from three premises: 1) Solar energy offers the highest RE potential to our planet; 2) Solar thermal electricity (STE) can provide dispatchable power in a technically and economically viable way, by means of thermal energy storage and/or hybridisation, e.g. with biomass; 3) Significant research efforts are still needed to realise the full potential and benefits of the technology. Keeping this in mind, the STAGE-STE project was set to accomplish the following general objectives:

- Convert the consortium into a reference institution for concentrated solar power (CSP) research in Europe, creating a new entity with an effective governance structure;

14 The project has altogether 47 KPI to assess the progress made.

- Enhance the cooperation between European research institutions participating in the project to create European added value;
- Synchronise the different national research programmes to avoid duplication and to achieve better and faster results;
- Accelerate the transfer of knowledge to industry to maintain and strengthen the existing European industrial leadership in STE;
- Expand joint activities among research centres by offering researchers and industry a comprehensive portfolio of research capabilities, bringing added value to innovation and industry-driven technology;
- Establish the European reference association for promoting and coordinating international cooperation in solar thermal electricity research.

To achieve the above listed objectives, the project was organised into two modules:

- *Coordination and support*: Six groups of activities aimed to intensify the cooperation between institutes. The objective was to more efficiently coordinate, complement and reinforce the activities of the European research institutes active in the STE field;
- *Research and innovation*: Another set of six activities related to STE technology development (covering topics such as central receiver systems, line-focusing systems, thermal energy storage (TES), materials for solar receivers and STE components, solar thermochemical fuels, and CSP and desalination).

The STAGE-STE project joined forces of the leading European and international research centres (23 European and 9 international) in the CSP field together with industrial companies, including also the European Association of Solar Thermal Industries (ESTELA).

Outputs and impacts

The project made a considerable progress towards a benchmark institution for CSP/STE research in Europe. Although the project did not create a new legal entity, a concrete plan, endorsed by all the partners, was made to concentrate the efforts on further development of the EU-SOLARIS initiative[15]. The project enabled collaboration and mutual learning among the partners thanks to the intensive technical and scientific cooperation in research activities and the extensive staff exchange programme. STAGE-STE also achieved significant progresses in terms of alignment of national research programmes and EU programmes. The project engaged with key persons in the respective government ministries of participant countries (Spain, Portugal, France, Germany, Italy, Switzerland, United Kingdom, Cyprus and Turkey), and a roadmap was proposed to align national research programmes.

In respect to knowledge transfer to industry, the most relevant achievement of the project was the development of a web-based IP repository. The repository contains descriptions of more than 200 relevant IP assets (foreground and background), which can be used to share knowledge, foster alignment of research, and create a basis for new collaboration and knowledge exploitation opportunities[16]. The IP repository remains operational and in use within the European Energy Research Alliance CSP Joint Programme. The project also contributed towards the development of several

[15] EU-SOLARIS (http://eusolaris.eu/) initiative engages all the major European research institutes, with relevant activities on CSP/STE, into an integrated structure to ensure the continuation of the ongoing networking activities. EU-SOLARIS should be fully implemented and operative by 2019.
[16] A public showcase of the repository is available on the European Energy Research Alliance (EERA) webpage: https://www.eera-set.eu/eera-joint-programmes-jps/about-jps/ip-assets/

International Energy Committee (IEC) standards, created a publicly available database[17] on technical characteristics of line-focus solar collectors as well as guidelines for reflector measurement.

STAGE-STE was highly successful in establishing linkages between European and international CSP/STE communities. Relevant organisations from leading countries and regions (North Africa, Middle East, South Africa, Australia, China, India, Chile, Mexico and Brazil), were involved in the networking and research activities of STAGE-STE.

The project made advances in several different areas of research and the partners contributed to critical technological achievements that are reported in academic journal articles and conference presentations. Among others:

- Thermal energy storage (TES) for STE plants: New approaches for TES systems such as identification of barriers that may limit the commercial use of innovative heat exchangers, research on compatibility of solar salt with industrial waste, concrete fillers for thermocline tanks, and improved models of TES systems;
- Materials for solar receivers and STE components: development of three guidelines/standards characterising the aging behaviour of reflectors and new knowledge of the aging behaviour of several absorber materials. The developed methods and tools will help plant developers and investors to reduce the risk linked to the aging behaviour of materials;
- Solar fuels: Improvements of many solar thermochemical processes, e.g. improved design of solar reactors and basic studies of innovative solar fuel processes;
- STE and desalination: analysis of the feasibility of a solar thermal cogeneration scheme compared to the separate generation of electricity with a solar plant and the use of part of such electricity to drive a desalination process like reverse osmosis;
- CSP and tower technology: Development of test procedures for durability testing of key components, innovations in absorbers, heliostats and heliostat fields including analysis and testing of new receiver structures;
- Line-focus technologies: A new procedure to monitor the status of the vacuum level in linear receivers utilising infrared images, a system for off-line monitoring of thermal oil degradation and a dynamic solar field testing procedure for assessing solar collectors' performance in commercial plants.

Outlook and commercial application of the outputs

As a result of over a decade of supportive policies at European and national levels, the European industry has become a global leader in STE technologies. However, the competition has increased in recent years, and the countries traditionally strong in the STE technologies (e.g. the USA) but also emerging countries (e.g. China, India) are challenging the European leadership. STAGE-STE contributed significantly to bringing European research institutes and industry together to set a common research and technology agenda. 'This is essential for maintaining the competitiveness of the European STE industry', Julian Blanco, coordinator of the STAGE-STE project highlighted.

Despite the fact that Europe is at the forefront of STE research, industrial exploitation is currently rather limited. The future deployment of the technology will largely take place outside the EU. The STAGE-STE project successfully integrated partners from four continents – Australia, Latin-America

[17] The database is available at http://stage-ste.eu/keydocuments/solar_collectors/index.php/SolarCollectors

(Chile, Brazil, and Mexico), Asia (India, China), as well as countries from Middle East and North Africa (Libya, Morocco and Saudi Arabia). The cooperation during the project period contributed to opening-up new markets for the European industry, and has led to many further opportunities to launch new initiatives on a bilateral basis. 'While the STAGE-STE project provided a framework and initial boost for international cooperation, the network is now a well-established community with strong links between the research organisations, and drawing an increasing interest from industry due to the opportunities to access new international markets' Julian Blanco explained.

The role of EU funding

STAGE-STE project was supported by the European Union's Seventh Research and Innovation funding programme (FP7) that was in place in 2007-2013. The FP7 Energy programme launched Integrated Research Programmes (IRPs) as an instrument combining research and coordination and support actions. The aim of the instrument was to increase European coherence among national research operators through pooling of research resources in RE technologies, including CSP. The STAGE-STE project had a total budget of more than EUR 21 million, out of which 47 % came from the EU. The project started in February 2014 and ran for four years, celebrating the final conference in January 2018.

The project contributed significantly to future research and innovation policy in Europe. It acted as a 'nexus' between the research community, national authorities and funding agencies, the industry, and the European Commission. This collaboration and intensified knowledge flows supported the work of the SET Plan[18] temporary working group on CSP, and led to successful drafting of the SET Plan CSP Implementation Plan in 2017. 'EU funding has been essential for research and development in the field, especially in terms of facilitating collaborative research and innovation between the different European and international actors', Julian Blanco concluded.

Full project participant list

Organisation	Country	Type
Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas	Spain	Research institute
Deutsches Zentrum fuer Luft - und Raumfahrt EV	Germany	Research institute
Paul Scherrer Institut	Switzerland	Research institute
Centre National de la Recherche Scientifique	France	Research institute
Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V	Germany	Research institute
Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile	Italy	Research institute
Eidgenoessische Technische Hochschule Zurich	Switzerland	Academic institute
Commissariat à l'Energie Atomique et aux Energies Alternatives	France	Research institute
The Cyprus Institute Limited	Cyprus	Industry association
Laboratorio Nacional de Energia e Geologia I.P.	Portugal	Research institute
Fundacion Centro Tecnologico Avanzado de Energias Renovables de Andalucia	Spain	Research institute
Consiglio Nazionale delle Ricerche	Italy	Research institute
Fundacion Cener-Ciemat	Spain	Research institute
Fundacion Tecnalia Research & Innovation	Spain	Research institute
Universidade de Evora	Portugal	Academic institute
Fundacion Imdea Energia	Spain	Academic institute
Cranfield University	United Kingdom	Academic institute
Fundacion Tekniker	Spain	Research institute
Universita Degli Studi di Palermo	Italy	Research institute

[18] Strategic Energy Technology Plan, https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan

Organisation	Country	Type
Centro di Ricerca, Sviluppo e Studi Superiori in Sardegna	Italy	Research institute
INESC ID - Instituto de Engenhariade Sistemas e Computadores, Investigacao e Desenvolvimento em Lisboa Associacao	Portugal	Research institute
Associacao do Instituto Superior Tecnico para a Investigacao e Desenvolvimento	Portugal	Research institute
Sener Ingenieria y Sistemas S.A.	Spain	Private company
HSE Hitit Solar Enerji AS	Turkey	Private company
Acciona Energia S.A.	Spain	Private company
Schott Solar CSP GmbH	Germany	Private company
Archimede Solar Energy SRL	Italy	Private company
European Solar Thermal Electricity Association	Belgium	
Abengoa Solar New Technologies SA	Spain	Private company
King Saud University	Saudi Arabia	Academic institute
Universidad Nacional Autonoma de Mexico	Mexico	Academic institute
Stellenbosch University	South Africa	Academic institute
Centre for Solar Energy Research and Studies	Libya	Research institute
Commonwealth Scientific and Industrial Research Organisation	Australia	Research institute
Fundacao de Apoio a Universidade De Sao Paulo	Brazil	Academic institute
Institute of Electrical Engineering Chinese Academy of Sciences	China	Research institute
Universidad de Chile	Chile	Academic institute
Universite Cadi Ayyad	Morocco	Academic institute
Fondazione Bruno Kessler	Italy	Research institute
Cobra Instalaciones y Servicios S.A	Spain	Private company
Suncnim	France	Private company
Universidad de Sevilla	Spain	Academic institute

The case study authors would like to express their acknowledgements to Dr Julián Blanco for his kind support.

Case study: SOLAR TRES

Author:	Hanna Kuittinen Iñigo Iparraguirre	**Approver:**	Juan Ignacio Burgaleta, CSP Consultant, SOLAR TRES Project Coordinator, former CTO of Torresol Energy
Project title:	Molten salt solar thermal power 15MWe demonstration plant (SOLAR TRES)		
Lead partner:	SENER Ingenieria y Sistemas, S.A		
Project location:	Spain		
Technology area/s:	Solar thermal		
Start and end date:	December 2002 - December 2008		
Project cost:	EUR 15 343 220	**EC funding:**	EUR 5 000 000
Other funding sources:	Private investments		
Quantifiable outputs and impacts:	Gemasolar CSP plant, with a registered electrical power capacity of 19.9 MW, 80 GWh production per year, generating electrical power to supply 27 500 households and reducing CO_2 emissions by more than 28 000 tons per year.		
Further information:	Project website Project Coordinator – Sener Ingenieria y Sistemas, S.A., Avda. Zugazarte, 56 -Las Arenas, Getxo, Spain.		

Project description

The objective of the SOLAR TRES project was to demonstrate the technical and economic viability of the world's first commercial-scale concentrated solar power (CSP) plant that applies a central tower receiver technology combined with thermal storage including a single thermal fluid (molten salts). The demonstration project led to building of Gemasolar CSP plant in Fuentes de Andalucía, Seville, Spain. The project presented a milestone of the sector by building and demonstrating operations of a CSP plant with technology that allows dispatchable power generation.

The SOLAR TRES project was encouraged by the experience of the former Solar One and Solar Two demonstration projects, built in California, USA in the 1980s and 1990s with the support of Department of Energy (DOE)[19]. The Solar Two was a 10 MWe demonstration project operated from 1997 to 1999, successfully demonstrating advanced molten salt power technology and a storage system allowing solar energy to be collected during the sunlight hours and dispatched as high-value electric power at night or when demanded by the utility.

The SOLAR TRES project was led by SENER, an engineering company based in Getxo, Spain. Initially, the demonstration initiative following the Solar Two experience was promoted by Nexant (USA), Boeing (USA) and GHER (Spain)[20], and the group had carried-out preliminary design of the plant in 2000. SENER joined the team in 2001. Later on, for different reasons, Nexant and Boeing left the project in 2004,

[19] http://www.solaripedia.com/13/31/solar_one_and_two_(now_defunct).html
[20] Gould, W. et al. (2000) Solar Tres 10 MWe Central receiver Project. In Energy 2000: The Beginning of a New Millennium. P.394 - 399. Ed. Catania, P.

and SENER assumed the responsibility to lead the SOLAR TRES project in 2005, after renewed negotiations with the European Commission. SENER had made the decision to invest in CSP technology development, also due to favourable conditions imposed by the Spanish legislation of solar thermal power. Spain was the first European country to introduce a feed-in tariff funding system for solar thermal power in 2002[21]. The conditions related to these support mechanisms were changed in 2004, 2007 and 2008, and were finally withdrawn in 2012.

SENER developed its own state of the art solar thermoelectric facilities, allowing the company to carry-out commercial scale testing. SENER collaborated closely with the Spanish National Research Centre for Energy, Environment and Technology (CIEMAT - Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) and CIEMAT's Solar Energy Platform (PSA - Plataforma Solar de Almería) to develop the plant concept and component design and signed an agreement for the development and evaluation of new heliostat and molten salt receiver concepts and a prototype with better thermal performance.

The European Union Fifth Framework Programme for Research (FP5) supported the SOLAR TRES project with a EUR 5 million grant for further development of the technology and carrying out a demonstration. Apart from SENER (coordinator of SOLAR TRES FP5 project) and CIEMAT, the project consortium was formed by Saint Gobain S.A, a French specialised material company responsible for the solar mirrors, Siemens, a German conglomerate, which developed the steam turbines and Gher, S.A., a Spanish research laboratory.

Outputs and impacts

The SOLAR TRES demonstration project led to the Gemasolar thermosolar power plant in Fuentes de Andalucía, Seville province in Spain. In 2007, after successful experimental validation of the prototype receiver and molten salt loop, and testing carried out at PSA, SENER decided to develop a CSP plant that is now called Gemasolar. SENER had already accomplished the needed permissions, environmental impact studies and financing necessary. In 2007, the detailed engineering of the main components was completed including: design of heliostats, receiver and thermal storage system; turbine selection; electrical tracing; instrumentation and plans for the civil engineering work; and selection of mirrors for the heliostats. As a result of development work carried out in the SOLAR TRES project, SENER applied for two patents for its proprietary central tower receiver technology. In 2008 Torresol Energy Investments was founded for constructing and operating the plant. Torresol Energy is a joint venture between SENER (60 %) and Masdar (40 %), a RE company located in Aby-Dhabi, United Arab Emirates. The plant construction took two years and the investment costs were approximately EUR 230 million[22]. The plant started its operations in 2011.

Gemasolar is a 19.9 MWe thermosolar power plant, which uses central tower receiver technology with a thermal energy storage system. The central receiver is surrounded by thousands of sun-tracking heliostats, forming a solar field of 310 000 m^2 mirror surface, which reflect the sun light directly to a receiver located on top of a 140 metres high tower. Within the tower receiver there is an innovative heat transfer system based on molten salts. The heat is collected by the molten salts, which can reach very high temperatures (over 500 C°), which flow through a heat exchanger to generate steam. The steam is directed to a turbine for producing electricity. The solar thermal energy collected and stored

[21] https://www.solarpaces.org/csp-technologies/csp-potential-solar-thermal-energy-by-member-nation/spain/
[22] https://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=40

in the molten salt tank allows for 15 hours of production and thus ensures dispatchable solar electricity generation.

Gemasolar typical net electricity output to the grid reaches 80 GWh per year and it has the capacity to produce electric power 24 hours a day as the thermal storage system allows for power generation autonomy for up to 15 hours without sunlight. The record for continuous operation is 36 days. The plant supplies energy to 27 500 households and reduces CO_2 emissions by more than 28 000 tonnes per year. After nearly seven years since its official opening, the plant has an excellent operational record and it has exceeded all the expectations. The Gemasolar plant is still a global benchmark in the CSP sector. Others have intended to build a plant with similar characteristics but without succeeding' Mr. Juan Ignacio Burgaleta, the Coordinator of the SOLAR TRES project, explained.

Outlook and commercial application of the outputs

The Gemasolar plant is still a landmark of the industry. It paved the way for building the first utility-scale CSP plant with molten salt storage in Tonopah, Nevada, USA, which started operations in 2015. SENER is currently building the Noor III plant in Morocco with a capacity of 150 MW. The Noor III project is based on the experiences and learning achieved in constructing and operating the Gemasolar plant. It features certain improvements, such as a larger receiver, improved heliostat reflective surfaces and a more precise solar tracker system. Noor III presents a step change also in terms of reduction of CAPEX, leading to a cost reduction of the electricity[23] of approximately 40 %. This is partially explained by economies of scale as Noor III has a 600 MW thermal receiver compared to the 120 MW receiver used in Gemasolar. In addition to the difference in scale, other factors such as continuous R&D activities of SENER, lessons learned with Gemasolar, efficiency gains and industrialisation of component manufacturing play also a key role. Although Noor III is SENER's 29th CSP project, it is only the second to feature a CSP tower plant with molten salts storage. In general, the central tower technology still presents a niche market within the CSP technology, parabolic through comprising 90 % of the CSP deployed. The CSP parabolic trough levelized cost of electricity (LCOE) has decreased considerably over the last decade through scale-up and enhanced efficiency. Although tower technology is still in its infancy, the last project auctions have showed remarkable cost reductions. 'There is still lot of potential for cost reductions in central tower technology, but this will be achieved only by constructing more plants', Mr. Burgaleta pointed out. The central tower technology combined with molten salts energy storage is seen as the future of CSP: 'Dispatchability is a large advantage and it is a great value added of CSP technology compared to other renewable energy technologies' Mr. Burgaleta concluded.

Thanks to Gemasolar plant, SENER has been awarded the European Business Awards (EBA) for Innovation in 2011[24] and the USA CSP Today awards in the categories of 'Engineering Firm of the year 2011' and 'Commercialized Technology Innovation of the year 2011', and 'Solutions for improving manageability capacity' in 2012, 2013 and 2015. The company was also awarded the DESERTEC Foundation 2014 Award for pioneering and replicable solutions for clean energy supply in deserted areas. The company represented Spain in the European Union campaign 'Together for the climate' in COP21, the Paris Conference on Climate Change in 2015[25].

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[23] http://www.solarpaces.org/moroccos-noor-iii-solar-tower-csp-deliver-power-october/
[24] https://www.businessawardseurope.com/download/EBA_case_study_SENER_61.pdf
[25] http://www.engineeringandconstruction.sener/press-releases/gemasolar-is-the-project-that-represents-spain-in-the-european-campaign-together-for-the-climate-cop21

The role of EU funding

The SOLAR TRES project received funding from the European Union's Fifth Framework Programme for Research and Innovation (FP5). Under FP5, the EU contributed to research projects intended to develop CSP technologies, notably components, storage, solar-hybrid co-generation, and solar chemistry including hydrogen production. The activities included three major CSP demonstration projects that received a total EU contribution of EUR 15 million. These projects were aimed to validate the full-scale application of different technological approaches and their economic viability under market conditions. SOLAR TRES received EUR 5 million, while the total costs of the demonstration project were EUR 15 345 000. The EU support was only a modest fraction of the total costs of the construction of the Gemasolar plant. In the scope of the SOLAR TRES project, only the costs for the innovative parts of the project were eligible, and e.g. civil works and the turbine-electricity generation assembly were not eligible for EU funding. For the construction of the Gemasolar plant, Torresol Energy received financial support from the European Investment Bank with a EUR 80 million loan[26]. The EU support was important for the demonstration phase of the Gemasolar technology, and allowed SENER to build CSP central tower technology capacities and mitigate the risks of investing in early-phase technology. The demonstration and building of the plant would not have taken place in the same timetable without the EU support.

Full project participant list

Organisation	Country	Type
Sener Ingenieria y Sistemas, S.A.	Spain	Private company
Centro de Investigaciones Energeticas, Medioambientales Y Tecnologicas	Spain	Research institute
Compagnie de Saint Gobain S.A.	France	Private company
Gher, S.A.Spain	Spain	Private company
Siemens Aktiengesellschaft	Germany	Private company

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[26] http://europa.eu/rapid/press-release_BEI-09-224_en.htm

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Annex C - Methodological note on imports and exports

The value of the following components was assessed for solar thermal:

Table A.1 HS6 product codes relevant to the solar thermal sector

HS6 code	Brief product description
700991	Glass mirrors, unframed
700992	Glass mirrors, framed
711590	Other articles of precious metal or of metal clad with precious metals, other
732290	Radiators for central heating, air-heaters, hot air-distributors non-electric, other
830630	Photograph, picture or similar frames, mirrors; and parts thereof
841280	Other engines and motors
841919	Instantaneous or storage water heaters, nonelectric
841989	Other machines and mechanical appliances for the treatment of materials by a process involving a change of temperature: other
841990	Other machines and mechanical appliances for the treatment of materials by a process involving a change of temperature: parts
850239	Other generating sets: other
900190	Other (including lenses and mirrors)
900290	Other optical elements (including mirrors)
900580	Other instruments

Source: Comext database and Jha (2009)

Annex D – List of EU-funded projects

Table 0.1 Solar thermal EU funded projects

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
AIRCOOL	54437	Adsorption cooling of buildings with integrated pv/solar air heating facades ('AIRCOOL')	787328	FP5-EESD	1.1.4.-6.
ALONE	90321	Small Scale Solar Cooling Device	2565949	FP7-ENERGY	ENERGY-2007-4.1-02
ANDASOL	70424	Andasol 50 MWe Eurotrough Solar Thermal Plant with Thermal Storage in the Marquesado Valley (Granada, Spain)	6305350	FP5-EESD	1.1.4.-5.2.4
ANDASOL	86905	Andasol 50MWe Eurotrough solar thermal plant with thermal storage in the Marquesado Valley (Granada, Spain)	5919597	FP5-EESD	
ARCHETYPE SW550	103634	Demonstration of innovating parabolic solar trough using an alternative heat transfer fluid producing electricity and fresh water: ARChimede Hot Energy TYPology Enhanced Water Solar 550	30382871	FP7-ENERGY	ENERGY.2010.2.9-1
ARTISC	86865	Refrigeration, heating and air-conditioning using an absorption refrigeration system heated by transparent insulated solar collectors	507582	FP5-EESD	
ASFIC	60074	Advanced solar facades with integrated collectors-accumulators for domestic hot water and space heating applications (ASFIC)	547207	FP5-EESD	1.1.4.-6.
a-Si PVT-ORC	201177	A novel amorphous silicon cell-based solar cogeneration system using the coupled thermal storage/organic Rankine cycle as an alternative to battery	192158	H2020-EU.1.3.2.	MSCA-IF-2015-EF
ASODECO	57661	Advanced Solar Driven Desiccant Cooling Systems for Central European and Mediterranean Climates	925288	FP5-EESD	1.1.4.-6.1.3
BIONICOL	90331	Development of a bionic solar collector with aluminium roll-bond absorber	1182198	FP7-ENERGY	ENERGY-2007-4.1-01
BIOSTIRLING-4SKA	108900	A cost effective and efficient approach for a new generation of solar dish-Stirling plants based on storage and hybridization	3460027	FP7-ENERGY	ENERGY.2012.2.5.1
BIPV-PCM-COGEN	103335	A Novel BIPV-PCM Heat and Power Cogeneration System for Buildings	285238	FP7-PEOPLE	FP7-PEOPLE-2011-IIF
BRESAER	193471	Breakthrough solutions for adaptable envelopes for building refurbishment	5863730	H2020-EU.2.1.5.2.	EeB-02-2014
CAPTure	193759	Competitive SolAr Power Towers – CAPTure	6119293	H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-02-2014
CESAR	101325	Cost-Effective Solar AiR conditioning	705751	FP7-SME	SME-2011-1
CHESS-SETUP	203231	Combined HEat SyStem by using Solar Energy and heaT pUmPs	3364315	H2020-EU.3.3.1.	EE-02-2015
COLOURFACE	61368	Coloured collector facades for solar heating systems and building insulation (COLOURFACE)	1020286	FP5-EESD	1.1.4.-6.
COMPACT	86995	Low-cost compact solar heaters made of plastic materials and composites	663206	FP5-EESD	
CompoSol	101548	Fibre Reinforced Composite Reflectors for Concentrated Solar Power Plants	1129462	FP7-SME	SME-2011-1
COMTES	103641	Combined development of compact thermal energy storage technologies	4844227	FP7-ENERGY	ENERGY.2011.4.1-4
COOLSUN	101033	Development of a tri-generation solar heating and COOLing System including the Use of the heat extracted from the adsorptioN chiller re-cooling circuit	1185304	FP7-SME	SME-2011-1

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
CSP2	100979	Concentrated Solar Power in Particles	2376507	FP7-ENERGY	ENERGY.2011.2.5-2
CySTEM	197312	Cyprus Solar Thermal Energy Chair for the Eastern Mediterranean	2506250	H2020-EU.4.c.	WIDESPREAD-2-2014
DEARSUN	93078	DEvelopment of a direct solAR heating System capable of covering a full-year thermal load UsiNg high temperature thermal storage	1186469	FP7-SME	SME-1
DESICCANT COOLING	73573	Dehumidification and cooling driven by solar/waste heat using liquid desiccants	262281	FP6-MOBILITY	MOBILITY-2.2
DESOL	75030	Low cost low energy technology to desalinate water into potable water	638472	FP6-SME	SME-1
DESSHC	57484	Demonstrating the Efficiency of Solar Space Heating and Cooling	1609795	FP5-EESD	1.1.4.-6.1.3
DIGESPO	93421	Distributed CHP generation from Small Size Concentrated Solar Power	3548995	FP7-ENERGY	ENERGY.2009.2.5.1
DIMONTEMP	200028	Distributed Monitoring of HTF Temperature at Solar Thermal Power Plants	50000	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015-1
DISTOR	73986	Energy Storage for Direct Steam Solar Power Plants (DISTOR)	2755567	FP6-SUSTDEV	SUSTDEV-1.2.6
DNICAST	109593	Direct Normal Irradiance Nowcasting methods for optimized operation of concentrating solar technologies	3018242	FP7-ENERGY	ENERGY.2013.2.9.2
E2PHEST2US	93225	Enhanced Energy Production of Heat and Electricity by a combined Solar Thermionic-Thermoelectric Unit System	2141110	FP7-ENERGY	ENERGY.2009.2.5.1
ECOSTAR	73988	European Concentrated Solar Thermal Road-Mapping (ECOSTAR)	281402	FP6-SUSTDEV	SUSTDEV-1.2.6
EFISOL	93398	Solar Thermal Cogeneration Plant based on Organic Rankin Cycle	1254173	FP7-SME	SME-1
EINSTEIN	102067	EFFECTIVE INTEGRATION OF SEASONAL THERMAL ENERGY STORAGE SYSTEMS IN EXISTING BUILDINGS	6302072	FP7-NMP	EeB.NMP.2011-2
EUPRES	86842	A cross-European city partnership with large-scale realisation of innovative renewable energy schemes in the tertiary, industrial, public and private sectors	3150452	FP5-EESD	
EUROTROUGH II	54438	Euro trough ii - extension, test and qualification of a full scale loop of eurothrough collectors with direct steam generation	1337272	FP5-EESD	1.1.4.-6.
EU-SOLARIS	106231	THE EUROPEAN SOLAR RESEARCH INFRASTRUCTURE FOR CONCENTRATED SOLAR POWER	4550505	FP7-INFRASTRUCTURES	INFRA-2012-2.2.1.
EXPERT SYSTEM LSSH	54402	Development of an expert system to analyse/optimise the technical/economic feasibility or performance of hybrid large-scale solar heating (lssh) systems (expert system lssh)	546346	FP5-EESD	1.1.4.-5.
FLUIDGLASS	110009	FLUIDGLASS - SOLAR THERMAL FAÇADES	3896366	FP7-ENERGY	ENERGY.2013.4.1.1
FOCALSTREAM	204183	Breakthrough high performance cost competitive solar concentration system for combined heat and power generation	1018752	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015
freescoo	205111	Low temperature heat/solar driven air conditioning system for heating, cooling, dehumidification and ventilation of buildings	50000	H2020-EU.2.3.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
FRESH NRG	107423	FREsnel for Solar Heat with New Receiver and Geometry	2519045	FP7-ENERGY	ENERGY.2012.4.1.1
FRIENDS2	194373	Framework of Innovation for Engineering of New Durable Solar Surfaces	347366	H2020-EU.1.3.3.	MSCA-RISE-2014
GLASUNTES	196681	Innovative high temperature thermal energy storage concept for CSP plants exceeding 50 % efficiency	259558	H2020-EU.1.3.2.	MSCA-IF-2014-GF

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
GREEN SOLAR REGIONS	57556	Optimised Solar Assisted Heating and Ventilation Design in Copenhagen, Piemonte and Poland as Part of European Green Sol	670748	FP5-EESD	1.1.4.-6.1.3
helioSTEAM	197461	A novel concentrated solar steam system for industrial applications with a high degree of pre-manufacturing at extremely low prices.	50125	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015-1
HELIOtube	199275	Inflatable solar collectors for a low cost CSP Plant with irreducibly small carbon footprint	1847660	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015
HELITE	200412	High precision and performance heliostat for variable geometry fields of Thermosolar Plants	50000	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015-1
HIGH-COMBI	85696	High solar fraction heating and cooling systems with combination of innovative components and methods	1324178	FP6-SUSTDEV	SUSTDEV-1.1.1
HITECO	95892	New solar collector concept for high temperature operation in CSP applications	3570784	FP7-ENERGY	ENERGY.2010.2.5-2
HP-LP-SOLAR-FACADE	99062	A Novel Heat Pump Assisted Solar Façade Loop Heat Pipe Water Heating System	214938	FP7-PEOPLE	FP7-PEOPLE-2010-IIF
HYBRID-CHP	52904	Hybrid solar collector/CHP system (HYBRID-CHP)	677241	FP5-EESD	1.1.4.-5.
HYDRA	70393	Hybrid latent/sensible compact storage Devised for combined thermal solar energy applications: Refrigeration, heating and Air-conditioning	450740	FP5-EESD	1.1.4.-5.3.2
HYSOL	108326	INNOVATIVE CONFIGURATION FOR A FULLY RENEWABLE HYBRID CSP PLANT	6213605	FP7-ENERGY	ENERGY.2012.2.5.2
INDITEP	70234	Integration of dsg technology for electricity production - (INDITEP)	3470409	FP5-EESD	1.1.4.-5.
Innova MicroSolar	205663	Innovative Micro Solar Heat and Power System for Domestic and Small Business Residential Buildings	3999384	H2020-EU.3.3.1.	EE-04-2016-2017
IN-POWER	207407	Advanced Materials technologies to QUADRUPLE the Concentrated Solar Thermal current POWER GENERATION	4914608	H2020-EU.2.1.3.;H2020-EU.2.1.2.	NMBP-17-2016
INSHIP	207022	Integrating National Research Agendas on Solar Heat for Industrial Processes	2456515	H2020-EU.3.3.5.;H2020-EU.3.3.3.;H2020-EU.3.3.2.;H2020-EU.3.3.4.	LCE-33-2016
INSUN	103644	Industrial Process Heat by Solar Collectors	4230542	FP7-ENERGY	ENERGY.2011.4.1-2
INTERSOLAR	110019	Development and demonstration of intelligent non-contact inspection technology for concentrated solar power plants	1071336	FP7-SME	SME-2013-1
ISSA	81749	Construction and field test activities of an innovative single-room solar driven air-conditioning system	48401	FP6-MOBILITY	MOBILITY-4.1
JORDAN , ULRIKE	71086	Experimental and Computational Analysis of Flow Patterns at Inlet Devices of Solar Water Stores	185174	FP5-EESD	1.1.4.-6.
LARGE SCALE SOLAR CO	54165	Air conditioning based on thermal solar energy- development of a low temperature absorption chiller for larger scale solar cooling in the building sector (large-scale solar cooling)	524414	FP5-EESD	1.1.4.-6.
LCSAC	198914	Low cost solar absorption cooling	50125	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015-1
LIGHTHOUSE	205077	LIGHTHOUSE: concentrated thermal solar power directly connected to the heating and cooling systems of buildings at the local level.	50000	H2020-EU.2.3.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
MACCSOL	95857	The development and verification of a novel modular air cooled condenser for enhanced concentrated solar power generation	4426315	FP7-ENERGY	ENERGY.2010.2.5-1
MACSHEEP	101598	New Materials and Control for a next generation of compact combined Solar and heat pump systems with boosted energetic and exergetic performance	2311115	FP7-ENERGY	ENERGY.2011.4.1-1

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
MARIO MOTTA	65205	Thermodynamic design and optimisation of advanced solar assisted desiccant cycles for mediterranean climates	189544	FP5-EESD	1.1.4.-6.
MATS	100479	Multipurpose Applications by Thermodynamic Solar	13142182	FP7-ENERGY	ENERGY.2010.2.9-1
MED-CSD	87801	Combined solar power and desalination plants: technico-economic potential in Mediterranean Partner countries	1116076	FP7-ENERGY	ENERGY-2007-2.5-02
MEDISCO	80017	MEDIterranean food and agro industry applications of Solar COoling technologies	1657612	FP6-INCO	INCO-2004-B1.5;INCO-2002-B1.5
MEDITERRANEAN-AIRCON	81326	An advanced solar-driven air conditioning system for Mediterranean climate	1328159	FP6-INCO	INCO-2004-B.3
MEEFS RETROFITTING	102074	Multifunctional Energy Efficient Façade System for Building Retrofitting	7492975	FP7-NMP	EeB.NMP.2011-3
MEMDIS	86935	Development of stand-alone, solar thermally driven and Pv-supplied desalination system based on innovative membrane distillation	1239043	FP5-EESD	
MERITS	107963	More Effective use of Renewables Including compact seasonal Thermal energy Storage	4669705	FP7-ENERGY	ENERGY.2011.4.1-4
MinWaterCSP	200380	MinWaterCSP - Minimized water consumption in CSP plants	5861372	H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-02-2015
MOSAIC	205864	MOdular high concentration SolAr Configuration	5077734	H2020-EU.3.3.2.	LCE-07-2016-2017
MSLOOP 2.0	206074	Molten Salt Loop 2.0: key element for the new solar thermal energy plants.	2243085	H2020-EU.3.;H2020-EU.2.	FTIPilot-01-2016
MUSTEC	211264	Market uptake of Solar Thermal Electricity through Cooperation	2356102	H2020-EU.3.3.7.;H2020-EU.3.3.3.;H2020-EU.3.3.2.	LCE-21-2017
NANODAOHP	186337	Nanoparticle based direct absorption oscillating heat pipes for solar thermal systems	222138	FP7-PEOPLE	FP7-PEOPLE-2013-IIF
NanoDAOHP	190981	Nanoparticle based direct absorption oscillating heat pipes for solar thermal systems	15000	FP7-PEOPLE	FP7-PEOPLE-2013-IIF
NECSO	106941	Nanoscale Enhanced Characterisation of SOlar selective coatings	1869617	FP7-NMP	NMP.2012.1.4-3
NEGST	87883	New generation of solar thermal systems	1093079	FP6-SUSTDEV	SUSTDEV-1.1.1
NESTER	199326	Networking for Excellence in Solar Thermal Energy Research	1060798	H2020-EU.4.b.	H2020-TWINN-2015
NEXT-CSP	205807	High Temperature concentrated solar thermal power plan with particle receiver and direct thermal storage	4947420	H2020-EU.3.3.2.	LCE-07-2016-2017
NEXTOWER	207409	Advanced materials solutions for next generation high efficiency concentrated solar power (CSP) tower systems	4915443	H2020-EU.2.1.3.;H2020-EU.2.1.2.	NMBP-17-2016
OMSOP	106967	Optimised Microturbine Solar Power system	4457501	FP7-ENERGY	ENERGY.2012.2.5.1
OPICS	70374	Optimised Integrated Collector Storage: low-cost solar thermal systems for houses and offices	463573	FP5-EESD	1.1.4.-5.2.4
OPICS	86883	Optimized integrated collector storage: low-cost solar thermal systems for houses and offices	463573	FP5-EESD	
ORC-PLUS	195491	Organic Rankine Cycle - Prototype Link to Unit Storage	6264940	H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-03-2014
PEGASUS	205804	Renewable Power Generation by Solar Particle Receiver Driven Sulphur Storage Cycle	4695365	H2020-EU.3.3.2.	LCE-07-2016-2017

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
PIME'S	94484	CONCERTO communities towards optimal thermal and electrical efficiency of buildings and districts, based on MICROGRIDS	11963822	FP7-ENERGY	ENERGY.2008.8.4.1
PITAGORAS	186981	Sustainable urban Planning with Innovative and low energy Thermal And power Generation from Residual And renewable Sources	8430379	FP7-ENERGY	ENERGY.2012.8.8.2
Polarsol Phase One	197421	Disrupting the energy market with the innovation in solar heating	50125	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015-1
Polarsol Phase Two	204995	Polarsol - a disruptive hybrid heat management solution for global markets	2059050	H2020-EU.2.3.1.;H2020-EU.2.1.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
POLYSOL	98108	Development of a modular, all-POLYmer SOLar thermal collector for domestic hot water preparation and space heating	1171358	FP7-SME	SME-1
POSHIP	87135	The potential of solar heat in industrial processes	471178	FP5-EESD	
POWERSOL	81331	Mechanical power generation based on solar Thermodynamic Engines	1214801	FP6-INCO	INCO-2004-B1.5
PreFlexMS	195027	Predictable Flexible Molten Salts Solar Power Plant	14398100	H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-03-2014
Prisma	211295	Innovative and highly-efficient solar thermal collector for Building façades	49157	H2020-EU.2.3.1.;H2020-EU.2.1.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
PROTEAS PS SYSTEM	67935	Triple hybride concentrating pv system for the co-generation of electricity, heat and cooling power	1003875	FP5-EESD	1.1.4.-6.
PS10	57595	10 Mw Solar Thermal Power Plant in Southern Spain		FP5-EESD	1.1.4.-6.5.2
PV-TE-MCHP	209530	A Novel Hybrid Photovoltaic–Thermoelectric Power Generation System Employing the Flat-plate Micro-channel Heat Pipe	192158	H2020-EU.1.3.2.	MSCA-IF-2016
RAISELIFE	200815	Raising the Lifetime of Functional Materials for Concentrated Solar Power Technology	9291723	H2020-EU.2.1.3.	NMP-16-2015
Re-Deploy	199520	Re-deployable solar boilers based on concentrating solar collectors for ESCO type sale of thermal energy to industrial processes.	2025207	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015
RESTRUCTURE	100980	Redox Materials-based Structured Reactors/Heat Exchangers for Thermo-Chemical Heat Storage Systems in Concentrated Solar Power Plants	2220366	FP7-ENERGY	ENERGY.2011.2.5-1
ROCOCO	85644	ROCOCO - Reduction of costs of solar cooling systems	585466	FP6-SUSTDEV	SUSTDEV-1.1.1
RO-SOLAR-RANKINE	107610	Development of an Autonomous Low-Temperature Solar Rankine Cycle System for Reverse Osmosis Desalination (RO-SOLAR-RANKINE)	1406646	FP6-SME	SME-1
SACE	61352	Solar Air Conditioning in Europe	417987	FP5-EESD	1.1.4.-6.1.1
SACPEH	86884	Solar air conditioning system using very low cost variable plastic ejector, with hybrid potential for different markets	826527	FP5-EESD	
SARTEA	196113	SOLAR ADSORPTION REFRIGERATOR WITH THIN-LAYER/ENHAMCED ADSORBENT	195455	H2020-EU.1.3.2.	MSCA-IF-2014-EF
SCOOP	101374	Solar Collectors made of Polymers	3268726	FP7-ENERGY	ENERGY.2011.4.1-1
SDHp2m	199617	Advanced policies and market support measures for mobilizing solar district heating investments in European target regions and countries	1919298	H2020-EU.3.3.7.;H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-04-2015
SECESTTP	85691	Supporting the development of a European solar thermal technology roadmap	374812	FP6-SUSTDEV	SUSTDEV-1.1.1
SEFI	197585	Solar Energy for Food Industry	50125	H2020-EU.2.3.1.;H2020-EU.3.2.	SFS-08-2015-1

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
SESPer	211753	Solar Energy Storage PERovskites	235157	H2020-EU.1.3.2.	MSCA-IF-2016
SFERA	91047	Solar Facilities for the European Research Area	8174729	FP7-INFRASTRUCTURES	INFRA-2008-1.1.2
SFERA-II	110563	Solar Facilities for the European Research Area-Second Phase	7015861	FP7-INFRASTRUCTURES	INFRA-2012-1.1.17.
SHINE	109061	Solar Heat Integration Network	3488705	FP7-PEOPLE	FP7-PEOPLE-2012-ITN
SmartHeat	205134	SmartHeat - An eco-innovative solution towards zero-carbon household heating	50000	H2020-EU.2.3.1.;H2020-EU.2.1.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
SOCOLD	72253	Development and implementation of a cost effective adsorption refrigeration system utilising high temperature (120 °C) solar Compound Parabolic Collectors (CPC) (SOCOLD)	1252983	FP6-SME	SME-1
SOcool	205130	SunOyster cooling	50000	H2020-EU.2.3.1.;H2020-EU.2.1.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
SOcool	211760	SunOyster cooling (SOcool)	1374888	H2020-EU.2.3.1.;H2020-EU.2.1.1.;H2020-EU.3.3.	SMEInst-09-2016-2017
SOLABS	67210	Development of unglazed solar absorbers (resorting to coloured selective coatings on steel material) for building facades, and integration into heating systems (solabs)	1366856	FP5-EESD	1.1.4.-6.
SOLAC	80860	Investigations of the absorber component of a solar desiccant air conditioning system	48401	FP6-MOBILITY	MOBILITY-4.1
SOLAIR	69263	Advanced solar volumetric air receiver for commercial solar tower power plants ('SOLAIR')	2008343	FP5-EESD	1.1.4.-6.
SOLAR LOUVRE	54164	Solar louvre building integrated collector (SOLAR LOUVRE)	400613	FP5-EESD	1.1.4.-6.
SOLAR TRES	86841	Molten salt solar thermal power 15MWe demonstration plant (target action ‘C’)	5784766	FP5-EESD	
SOLARBREW	103642	Solar Brewing the Future	2689196	FP7-ENERGY	ENERGY.2011.4.1-2
SOLARCLIM	57667	Solar Air-Conditioning for Buildings, Demonstration, Analysis and Assessment	939047	FP5-EESD	1.1.4.-6.1.3
SOLARIS	91806	A novel modular solar air source heat pump system	1179532	FP7-SME	SME-1
SOLARPEMFC	83087	Power generation from solar energy based on PEM fuel cell	265321	FP6-MOBILITY	MOBILITY-2.3
SOLARSTORE	89222	Improvement of the efficiency of a solar thermal system by integration of a thermochemical storage process	1103753	FP5-EESD	
Solar-Store	208562	Solar Powered Thermochemical Heat Storage System	192158	H2020-EU.1.3.2.	MSCA-IF-2016
SOLATERM	90568	Promotion of a new generation of solar thermal systems in the MPC	947207	FP6-SUSTDEV	SUSTDEV-2005-1.1.1-2
SOLEGLASS	100221	All Glass Mid Temperature Direct Flow Thermal Solar Vacuum Tube	2237089	FP7-SME	SME-2011-2
SOLERA	85693	Integrated small-scale solar heating and cooling systems for a sustainable air-conditioning of buildings	925563	FP6-SUSTDEV	SUSTDEV-1.1.1
SOLFACE	73803	High flux solar facilities for Europe		FP6-INFRASTRUCTURES	INFRASTR-1
SOLGATE	54153	Solar hybrid gas turbine electric power system (SOLGATE)	1967420	FP5-EESD	1.1.4.-5.

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
SOLHYCARB	78505	Hydrogen from Solar Thermal Energy: High Temperature Solar Chemical Reactor for Co-production of hydrogen and carbon black from natural gas cracking	2364820	FP6-SUSTDEV	SUSTDEV-1.2.6
SOL-MBDI	87167	Widening the use of European solar thermal technologies in Mediterranean countries following the successful model of Greece and Cyprus. Part A: Spain, Portugal	226101	FP5-EESD	
SOL-MED II	70471	Widening The Use Of European Solar Thermal Technol In Mediterranean Countries Following The Successful Model Of Greece. Part B: I, F, Ro, Bg, Tr	592748	FP5-EESD	1.1.4.-5.3.3
SOL-MED II	86979	Widening the use of European solar thermal technol in Mediterranean countries following the successful model of Greece.part B: I, F, Ro, Bg, Tr	592748	FP5-EESD	
SOLNET	87530	Advanced solar heating and cooling for buildings	2110488	FP6-MOBILITY	MOBILITY-1.2
SOLPART	199440	High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates	4366563	H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-02-2015
SOLPCM	185764	Solar Collector and PCM Thermal Façade for Low Carbon Buildings	309977	FP7-PEOPLE	FP7-PEOPLE-2013-IIF
SOLUGAS	90333	Solar Up-scale Gas Turbine System	6694218	FP7-ENERGY	ENERGY-2007-2.5-04
SOLZINC	59848	Solar carbothermic production of Zn from ZnO (SOLZINC)	1685862	FP5-EESD	1.1.4.-6.
STAGE-STE	111484	Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy	10021198	FP7-ENERGY	ENERGY.2013.10.1.10
STATIC-2	60073	Stagnation proof transparently insulated flat plate solar collector (STATIC-2)	636302	FP5-EESD	1.1.4.-6.
STOLARFOAM	103583	Thermochemical Storage of Solar Heat via Advanced Reactors/Heat exchangers based on Ceramic Foams	229639	FP7-PEOPLE	FP7-PEOPLE-2011-IEF
STORRE	103961	High temperature thermal energy Storage by Reversible thermochemical Reaction	2255345	FP7-ENERGY	ENERGY.2011.2.5-1
SUNSTORE2	89232	Solar thermal and long term heat storage for district heating systems	1063277	FP5-EESD	
SWITCH	57574	Switch Solar Water Integrated Thermal Cooling and Heating Systems	214639	FP5-EESD	1.1.4.-6.1.3
TCSPower	100642	Thermochemical Energy Storage for Concentrated Solar Power Plants	2991896	FP7-ENERGY	ENERGY.2011.2.5-1
TENCENT	198896	The next generation of Hybrid Concentrating Solar Power Plants	50125	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2015-1
TERMISOL	80004	New Low-Emissivity the Long Lasting Paints for Cost-Effective Solar Collectors	1036007	FP6-INCO	INCO-2004-B1.5;INCO
THERMALCOND	96989	Polymeric composite materials with enhanced thermal conductivity properties for heat exchangers applications	1143413	FP7-SME	SME-1
THERMOTEX	96632	The development of a new more efficient and easy to install high strength solar collector withstanding high temperature (120°)and operating pressures form circulating water and externals	907343	FP7-SME	SME-1
THESEUS	57691	Theseus-50 MWe Thermal Solar European Station of Frangokostello Crete - Implementation Phase	632682	FP5-EESD	1.1.4.-5.2.4
TRANSREGEN	196298	Portable thermal fluid regeneration system for Solar Thermal Plants	50125	H2020-EU.2.3.1.;H2020-EU.3.3.	SIE-01-2014-1
TRANSSOL	57008	Transnational access to the 'plataforma solar de almería' : the european solar thermal test centre (1° phase)	2132979	FP5-HUMAN POTENTIAL	1.4.1.-2.
TRANSSOL-II	58557	Transnational access to the 'plataforma solar de almería' : the european solar thermal test centre (2° phase)	665461	FP5-HUMAN POTENTIAL	1.4.1.-2.

Acronym	Rcn	Project title	EC funding (2016 EUR)	Programme	Topic
WASCOP	199297	Water Saving for Solar Concentrated Power	5941608	H2020-EU.3.3.2.4.;H2020-EU.3.3.2.2.;H2020-EU.3.3.2.1.	LCE-02-2015
No acronym	61561	Thermal conditioning of buildings by solar roof, and radiant floor, including displacement ventilation and natural skyligh	29299	FP5-EESD	1.1.4.-5.
No acronym	56930	Air-cooled, solar (gas) -driven nh3-h2o absorption system for air conditioning and other cooling applications using a compound parabolic collector	30184	FP5-EESD	1.1.4.-5.
No acronym	61364	Solar space conditioning with a chemical heat pump	30184	FP5-EESD	1.1.4.-5.

Table 0.2 EU funded projects of multiple RES technologies, where solar thermal is one of the funded technologies

Acronym	Rcn	Project title	EC funding (2016 EUR)	Framework Programme	Topic	RE technologies
BIOSOD	86964	Development of an autonomous biomass-solar thermally driven distillation system	1097073	FP5-EESD		Solar Thermal, Bioenergy
BIODISH	51191	Development of a ceramic hybrid receiver for biogas fired dish-stirling-systems for electric power supply ('BIODISH')	587161	FP5-EESD	1.1.4.-5.	Solar Thermal, Bioenergy
REMAP	84048	Action plan for high-priority renewable energy initiatives in Southern and Eastern Mediterranean area	451194	FP6-POLICIES	POLICIES-3.2	Wind, Solar Thermal
EUROCARE	52230	Infrastructure co-operation network in area of combustion and solar energy	201224	FP5-HUMAN POTENTIAL	1.4.1.-2.	Solar PV, Solar Thermal
EUROSUNMED	109592	EURO-MEDITERRANEAN COOPERATION ON RESEARCH & TRAINING IN SUN BASED RENEWABLE ENERGIES	5302986	FP7-ENERGY	ENERGY.2013.2.9.1	Solar PV, Solar Thermal
GREEN SOLAR CITIES	85686	Global renewable energy and environmental neighbourhoods as solar cities	7294590	FP6-SUSTDEV	SUSTDEV-1	Solar Thermal, Bioenergy
INTENSOL	97198	Transparent Fresnel Based Concentrated Photovoltaic Thermal System	1019607	FP7-SME	SME-1	Solar PV, Solar Thermal
PV/HP GENERATION	92655	A Micro-generation System Using PV/heat-pipe Roof Modules	200424	FP7-PEOPLE	FP7-PEOPLE-IIF-2008	Solar PV, Solar Thermal
REELCOOP	109511	Research Cooperation in Renewable Energy Technologies for Electricity Generation	5211510	FP7-ENERGY	ENERGY.2013.2.9.1	Solar PV, Solar Thermal, Bioenergy
RESSOL-MEDBUILD	93381	RESearch Elevation on Integration of SOLar Technologies into MEDiterranean BUILDings	1082554	FP7-REGPOT	REGPOT-2009-2	Solar PV, Solar Thermal
SECRHC-PLATFORM	100483	Support to the activities of the European Technology Platform on Renewable Heating and Cooling	1049463	FP7-ENERGY	ENERGY.2010.4.5-1	Geothermal, solar thermal, bioenergy
SOLAR-ERA.NET	105893	ERA-NET on Solar Electricity for the Implementation of the Solar Europe Industry Initiative	2046115	FP7-ENERGY	ENERGY.2012.10.1.2	Solar PV, Solar Thermal
SOLAR-ERA.NET Cofund	200090	SOLAR-ERA.NET Cofund	5930150	H2020-EU.3.3.3.;H2020-EU.3.3.2.;H2020-EU.3.3.4.	LCE-18-2015	Solar PV, Solar Thermal
SOLEURAS	67851	European-central asian solar energy conference tashkent may 2003	25218	FP5-INCO 2		Solar PV, solar thermal, wind
SOLFORRENEW	99608	A comprehensive framework for high-resolution assessment and short-term forecasting of the solar resource for renewable energy applications	223528	FP7-PEOPLE	FP7-PEOPLE-2010-IOF	Solar PV, Solar Thermal
SUNSTORE 4	94908	Innovative,multi-applicable-cost efficient hybrid solar (55%)and biomass energy(45%) large scale (district) heating system with long term heat storage and organic Rankine cycle electricity production	6633766	FP7-ENERGY	ENERGY.2009.4.5.1	solar thermal, bioenergy

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