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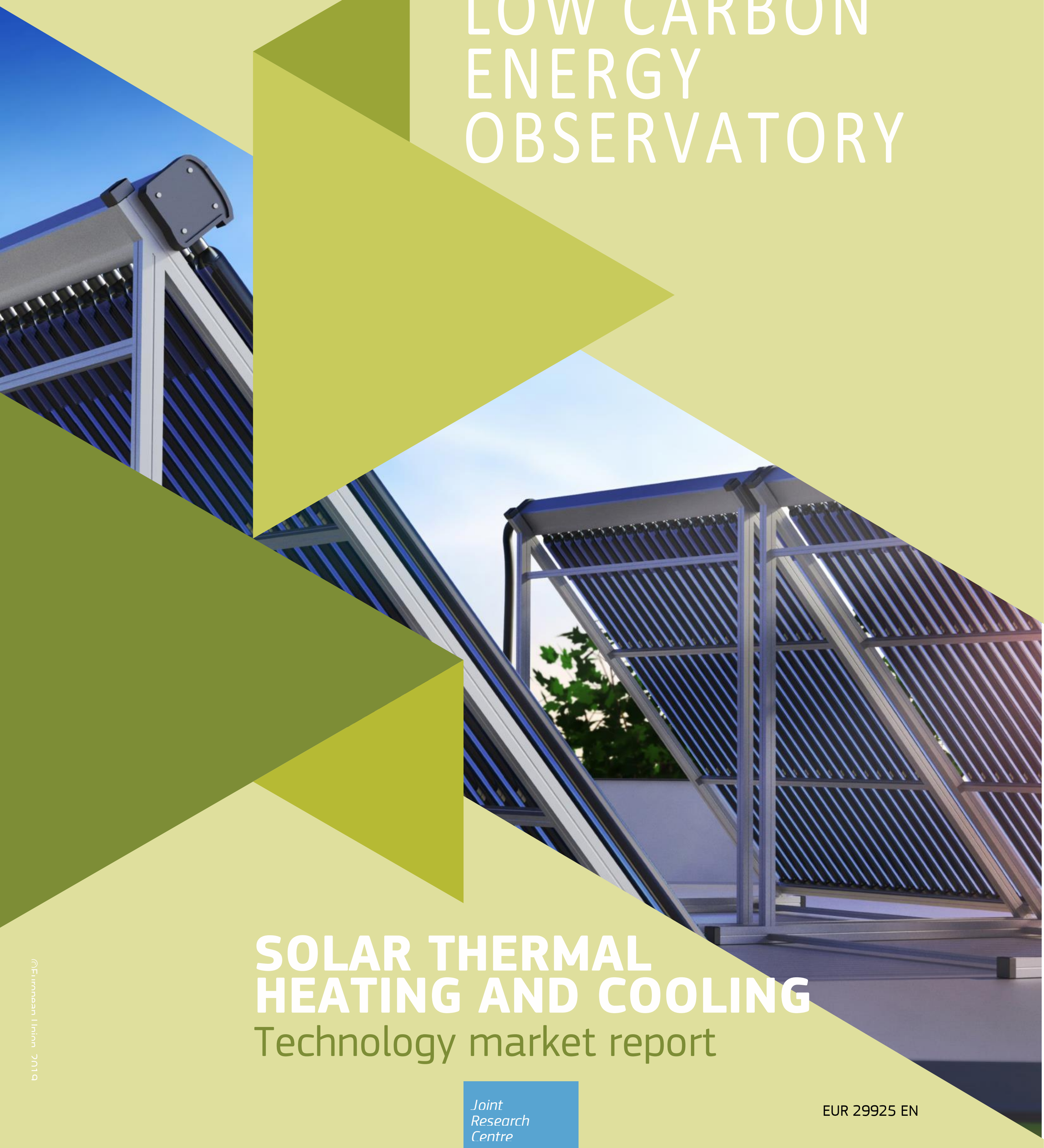

SOLAR THERMAL HEATING AND COOLING

Technology market report

Joint Research Centre

EUR 29925 EN

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Foreword on the Low Carbon Energy Observatory

The LCEO is an Administrative Arrangement being executed by DG-JRC for DG-RTD, to provide top-class data, analysis and intelligence on developments in low carbon energy supply technologies. Its reports give a neutral assessment on the state of the art, identification of development trends and market barriers, as well as best practices regarding use of private and public funds and policy measures. The LCEO started in April 2015 and runs to 2020.

Which technologies are covered?

- Wind Energy
- Photovoltaics
- Solar Thermal Electricity
- Solar Thermal Heating and Cooling
- Ocean Energy
- Geothermal Energy
- Hydropower
- Heat and Power from Biomass
- Carbon Capture, Utilisation and Storage
- Sustainable advanced biofuels
- Battery Storage
- Advanced Alternative Fuels

In addition, the LCEO monitors future emerging concepts relevant to these technologies.

How is the analysis done?

JRC experts use a broad range of sources to ensure a robust analysis. This includes data and results from EU-funded projects, from selected international, national and regional projects and from patents filings. External experts may also be contacted on specific topics. The project also uses the JRC-EU-TIMES energy system model to explore the impact of technology and market developments on future scenarios up to 2050.

What are the main deliverables?

The project produces the following generic reports:

- Technology Development Reports for each technology sector
- Technology Market Reports for each technology sector
- Report on Synergies for Clean Energy Technologies
- Annual Report on Future and Emerging Technologies (this information is also systematically updated and disseminated on the online FET Database).

Techno-economic modelling results are also made available via dedicated review reports of global energy scenarios and of EU deployment scenarios.

How to access the deliverables

Commission staff can access all reports on the Connected LCEO page. These are restricted to internal distribution as they may contain confidential information and/or assessments intended for in-house use only. Redacted versions also are distributed publicly on the SETIS website.

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1 INTRODUCTION

1.1 Scope

This report aims to provide a description of the market status of the solar heating and cooling technology, as well as an insight into its future development, highlighting role of EU stakeholders. It makes use of different data sources including international organization reports, scientific studies, statistical data and JRC own analysis. At the time of preparation, technology and market data was available to the end of 2017.

1.2 Technology overview and market readiness

Solar thermal technologies convert sunlight directly into heat. The primary solar thermal application is domestic hot water heating (DHW) for residential homes, since the temperature level needed is moderate (45 °C to 60 °C) and DHW is needed the whole year round. The residential segment accounted for 63 % of the total installed collector capacity at the end of 2014 (Jakubcionis and Carlsson, 2018).

Solar assisted space heating systems and process heat applications for temperatures up to 95 °C, as well as for medium temperatures up to 250 °C or high temperature up to 400 °C are later developments. In addition, solar thermal heat can be used to drive thermal cooling machines and as an energy source for cooling (Stryi-Hipp et al., 2012).

Solar thermal systems vary according to collector type and mounting, storage volume, control strategy and system configuration. Since solar irradiation is an energy source varying daily and seasonally, the storage volume must be adapted accordingly; usually a back-up heater is included to provide the user with a secure heat supply. Therefore, solar thermal systems must be adaptable to suit different types of applications, taking into account a large number of factors (Stryi-Hipp et al., 2012).

The most common types of collectors are flat plate and evacuated tube collectors. Such solar collectors are usually used for DHW and space heating as well as process heat applications, with temperature levels up to 95 °C. For very low-temperature applications, such as swimming pool heating, unglazed plastic collectors can be used. For higher temperature applications, concentrating collectors are the most common option.

In general, solar water heating is a mature technology. It is also facing increasing competition from other renewable energy technologies, especially solar PV powered heat pumps. On the other hand, solar supported district heating and cooling (DHC) systems are gaining increasing interest. In these modern DHC systems solar thermal is often coupled with different technologies and energy sources (e.g. heat pumps, natural gas, biomass, thermal storage) to help ensure a secure supply of heat. By the end of 2017, there were 300 large-scale solar thermal systems with a capacity of more than 350 kWth (equivalent to 500 m² collector area) connected to heating networks and 18 systems connected to cooling networks (Hoogland et al., 2018). The use of solar heat for industrial processes (SHIP) is growing, but for now remains a fraction of that in the building sector, even though the long-term potential for both is similar.

1.3 Current market penetration

Despite the significant contribution of solar thermal technologies to renewable energy generation, the global solar thermal market has faced difficulties in recent years. In particular sales of small-scale solar water heating systems for detached family houses and apartment buildings came under pressure from heat pumps and solar PV systems, especially in the large Chinese and European markets. In contrast, there is increasing interest in large-scale solar-supported DHC systems and in industrial applications although their contribution to market volume is still much lower than that of individual residential installations.

2 TECHNOLOGY TRENDS AND PROSPECTS

2.1 Technology deployment and market trends

The cumulated solar thermal capacity in operation in the world by the end of 2017 was 472 GW_{th} (675 million m² of collector surface). Solar thermal capacity increased by 3.5 % in comparison with 2016. Compared to 2000, the installed capacity has grown by a factor of 7.6. The corresponding annual solar thermal energy yield in 2017 was 388 TWh, which correlates to the savings of 41.7 million tons of oil and 135 million tons of CO_2 (IEA SHC, 2018).

Of the total installed capacity of 472 GW_{th} by the end of 2017, the largest share (324.5 GW_{th}) was installed in China, 51.8 GW_{th} in Europe, North America 18.6 GW_{th}, Asia excluding China 12.1 GW_{th}, Latin America 12.3 GW_{th}, MENA 6.8 GWth, Austrialia and New Zealand 6.5 GW_{th}, Sub-Saharan countries 1.5 GW_{th}, other regions 22.8 GW_{th} (IEA SHC, 2018).

By the end of 2017, 296 large-scale solar thermal systems >350 kWth (500 m²) were in operation worldwide. The total installed capacity of these systems equaled 1.14 GWth (1.74 mill. m²) (IEA SHC, 2018).

There were some changes in the rankings of countries with the highest market penetration per capita compared to 2015, with Denmark replacing Germany. The leading countries were: Barbados (515 kWth/1000 inhabitants), Austria (418 kW_{th}/1000 inh.), Cyprus (399 kW_{th}/1000 inh.), Israel (397 kW_{th}/1000 inh.), Greece (292 kW_{th}/1000 inh.), Palenstinian territories (289 kW_{th}/1000 inh.), Australia (269 kW_{th}/1000 inh.), China (236 kW_{th}/1000 inh.), Denmark (204 kWh/1000 inh.) and Turkey (172 kWh/1000 inh.) (IEA SHC, 2018).

The total overall production of solar thermal energy in EU-28 countries in 2016 was 50.1 TWh (Eurostat, 2017), representing a 2% share renewable energy, a significant increase from 0.6% in 2006 (in comparison, the PV share of renewable energy in 2016 was twice as large at 4.2 %). Spain produced more than of this solar thermal energy (28.9 TWh), however was used for electricity generation. Thus the solar thermal energy available to final users (disregarding solar thermal used as a transformation input) in EU in 2016 was 24.2 TWh. The production of solar thermal energy for direct use in EU-28 countries since 2006 almost tripled (Fig. 1).

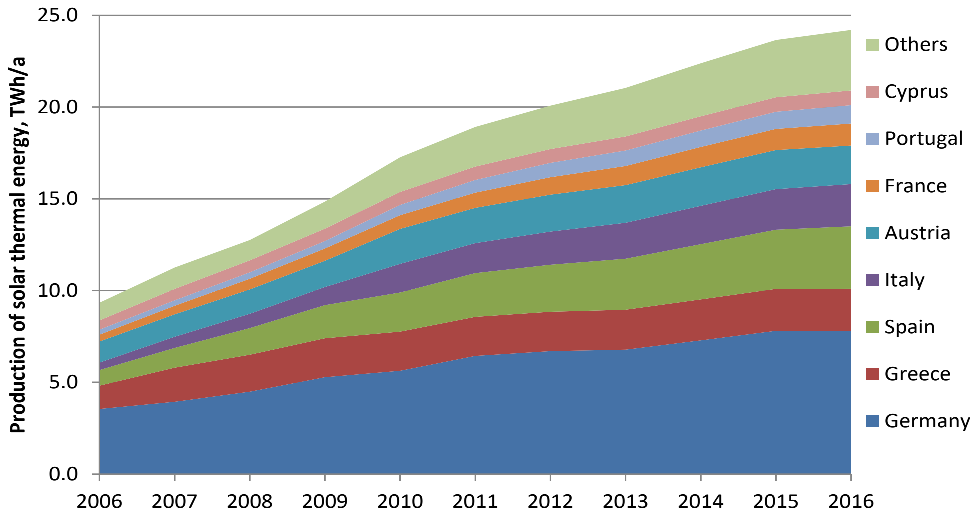

Fig. 1. Production of direct use solar thermal energy in EU-28 countries (Eurostat, 2017)

Worldwide, the negative development in the solar thermal technology sales since 2008 continued in 2017 as well. Compared to 2016, new installations fell by 4.2%. The decline in China continued for the fourth year in a row. After –17 % in 2014 and 2015 and -9% in 2016, 2017 saw a 5% fall, although there are some signs of positive developments as well (IEA SHC, 2018). The Chinese market seems to be stabilizing, while positive tendencies can be seen in solar thermal markets of Europe and the rest of the world. Fig. 2 shows the developments in the global market of glazed water collectors (dominant group of solar thermal technologies).

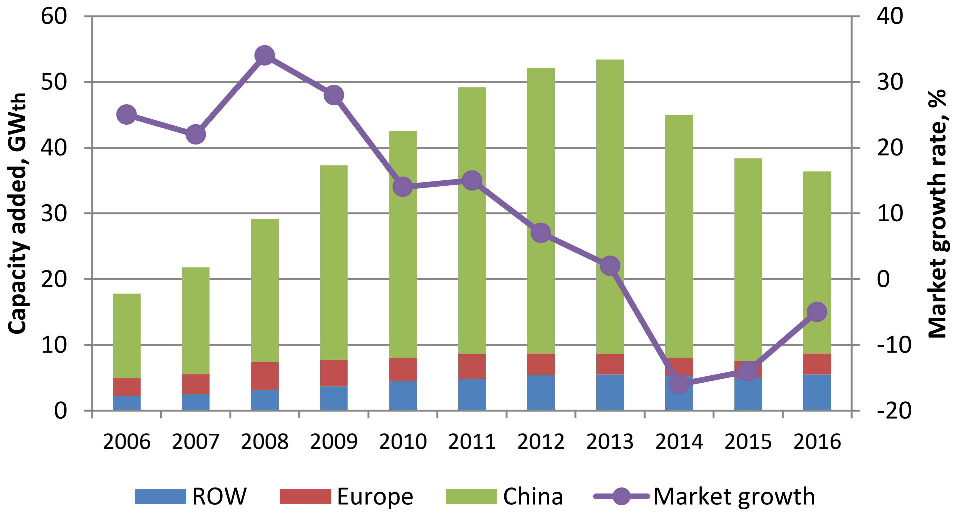

Fig 2. Global development of glazed water collectors market to 2015 (IEA SHC, 2018)

2.2 Deployment projections and current status

The EU-28 2020 projection for solar heating and cooling according to the National Renewable Energy Action Plans (NREAP) is 74 TWh/a (Beursekens & Hekkenberg, 2011). Since the overall target of renewable energy in heating and cooling (RES-H/C) is 1298 TWh/a, this solar contribution represents 5.7 %. The values for the different member state NREAPs range from 0 in Finland to 14.5 TWh/a in Germany and 18.4 TWh/a in Italy (Fig.3). A small minority of NREAPs did not include projections specifically for solar heating.

However, looking at the statistical data on solar heat consumption, it is clear that most of the Member States will come up short of these NREAP values. According to annual energy balances (Eurostat, 2018), in 2016 solar heat consumption (excluding solar heat used for electricity generation) was 24.3 TWh, i.e. only 32.8 % of the projected value. The biggest underperformers are Poland (10 % of the projection achieved), France (11 %), Belgium and Croatia (12 % each) and Italy (13 %). Seven Member States have already reached or exceeded their projections, among them Sweden, UK, the Netherlands and Bulgaria.

In order to reach the NREAPs' 2020 projected level, solar thermal energy production would have to have increased by 32 % annually starting in 2016. Given the current tendencies in the solar heating and cooling market, this does not seem to be realistic (see Fig.1).

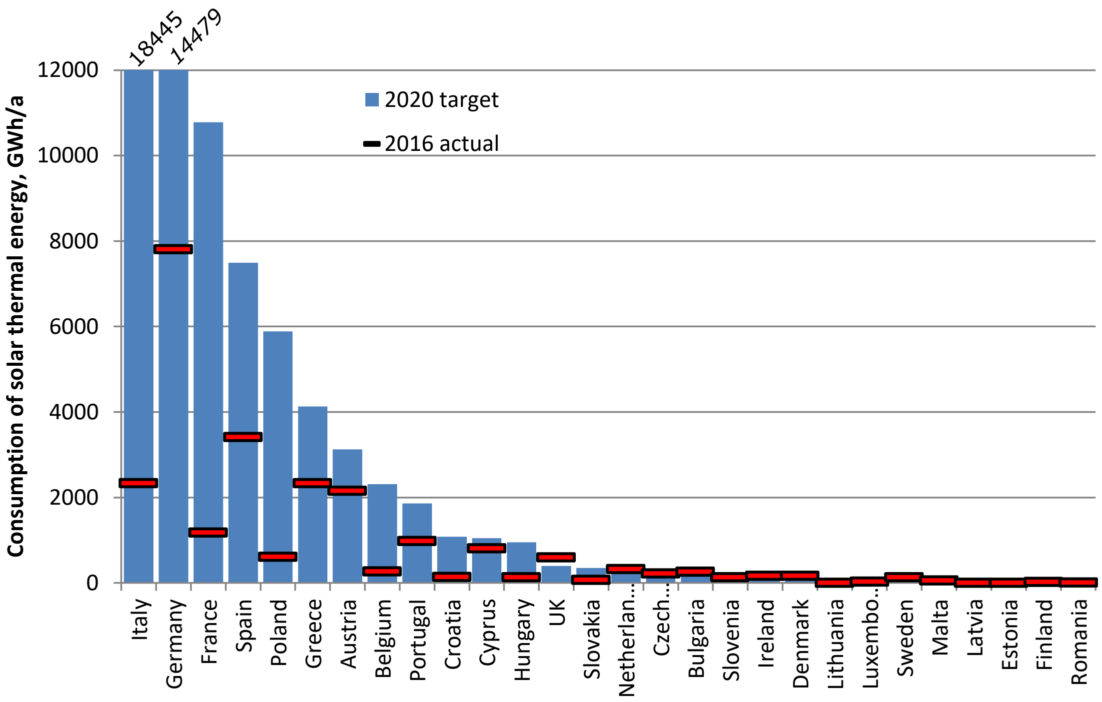

Fig. 3. Comparison of solar heat consumption projections in the NREAPs (Beursekens & Hekkenberg, 2011) in comparison with actual solar heat consumption in 2016 (Eurostat, 2018). The figure is truncated for Germany and Italy to better show the data for other Member States.

2.3 Market mechanisms and support policies

Markets forces alone in most cases are insufficient to deliver the desired level of renewables in the EU, meaning that national support schemes can play an important role. However, such interventions need to be carefully designed to avoid distorting the functioning of the energy market and leading to higher costs for households and businesses (European Commission, 2018).

Global support for heat from renewables represented about 1 % of that for all renewables in 2015. Relative to solar PV, solar heat received a very small amount of support although the capacity additions were about 80 % as large (IEA, 2017).

Each Member State implements a mix of different policies and measures to support the development and deployment of renewables in general and solar heating in particular. The focus of the majority of such instruments is on the power sector, although some also target specific RES shares in heating and cooling. The instruments used include regulatory policies, public financing and fiscal incentives. Fig. 4 provides an overview of policies used in different Member States.

Because of changing market conditions, renewable energy supporting policies in MSs were modified heavily during the last decade. The guidelines adopted in 2014 (European Commission, 2014) create the framework for the ability of MS to grant state aid in this sector until 2020. These guidelines were published in the context of an intense debate on energy prices and the cost of support to RES. The new state aid rules deal with the introduction of competitive bidding processes for allocating public support, while offering MS flexibility to take account of national circumstances (Fruhmann and Tuerk, 2014).

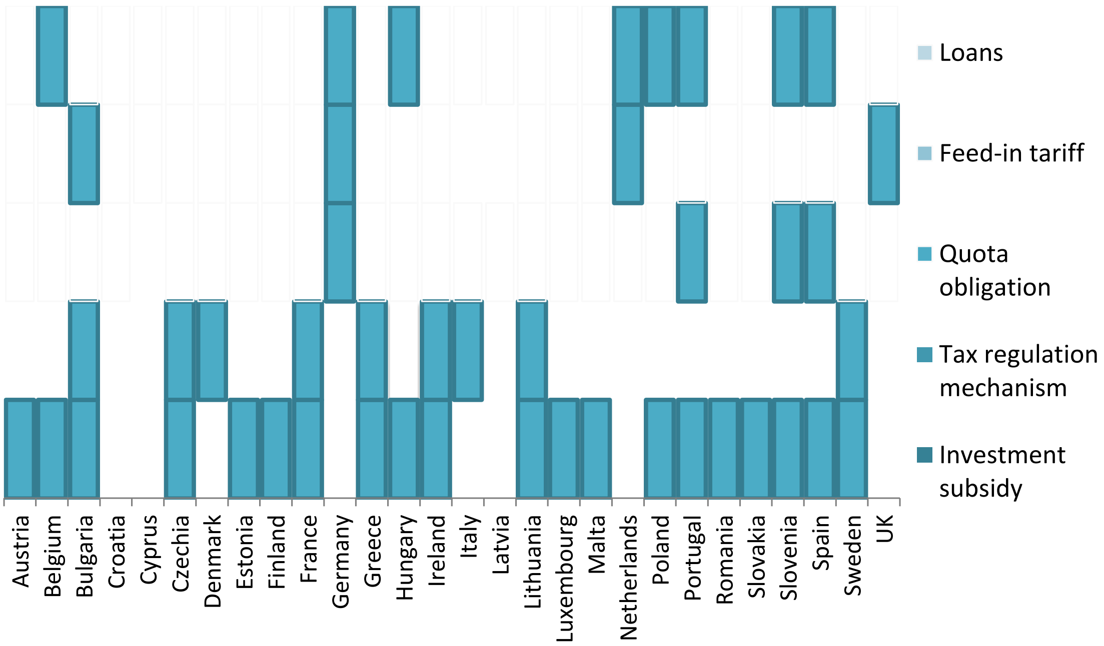

Fig.4 Policy instruments used to support the development and deployment of solar heating and cooling in Member States (Eur'Observer, 2018)

2.4 R&D investments

Solar heating and cooling R&D activities in the EU have been receiving funding from different sources, such as:

- EU research and innovation framework programmes (FP7, H2020 and so on);
- national research programmes of Member States;
- private companies and research institutions.

During the decade from 2004 to 2014, total solar heating and cooling related R&D investments in the EU are estimated at EUR 2.37 billion. The majority of this is attributed to private funding (EUR 2.17 billion or 91.5 %), with the remainder from public sources (source: Joint Research Centre (JRC) based on data from IEA and own estimates).

The total funding, received by solar heating and cooling related research projects under FP5, FP6, FP7 and IEE programmes (i.e. during the period from 1998 to 2013) was approx. EUR 167 million, divided among 79 projects (Hoogland et al., 2018). The total funding under H2020 is not yet known, but the planned EU financial contribution in the eight projects currently running is EUR 22.9 million, while the total costs of these projects is planned at EUR 26.5 million (Jakubcionis, 2018).

R&D funding from Member States has also been a significant financial source. In 2015 the total solar heating and cooling R&D spending in 10 EU Member States[1] was EUR 10.3 million and rose to EUR 11.3 million in 2016 (OECD/IEA, 2018). This represents approximately 1.5% of all renewable energy related R&D funding of those Member States.

As a region, the EU has traditionally invested considerably more into solar heating and cooling R&D than other major economies (Fig.5).

[1] The data is available for Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Slovakia, Sweden and UK (OECD/IEA, 2018).

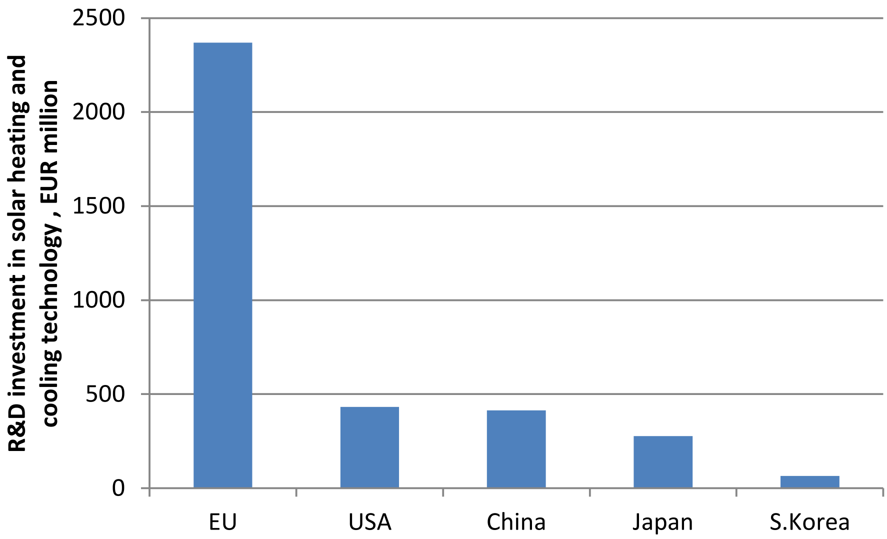

Fig. 5. R&D investment in solar heating and cooling technology in the EU and other regions during 2004-2014. Source: Joint Research Centre (JRC) based on data from IEA and own estimates.

2.5 Patenting activity

The EU has traditionally been a leader in solar heating and cooling related patenting activity. However, this has changed in the recent years (Fig. 6). During the period 2006-2014, EU actors submitted 562 patents (36 %) out of a global total of 1566 patents. This patenting activity peaked in 2009-2010 and then sharply declined. In contrast, patenting in China has steadily increased and overtook that of the EU in 2013. However, it also started to decrease in 2014, as can be seen in Fig. 6. It remains to be confirmed if this is only a temporary dip or reflects a longer-term trend.

The strength of EU research and innovation on this area is also evident from the evolution of the specialisation index values for different regions as shown in Fig. 7. This parameter represents the patenting intensity for a given technology and country relative to the geographical area taken as reference (in this case, the world) (Fiorini et al., 2017). Here it is defined as the share of the number of solar heating and cooling patents in the total number of energy related patents in the EU, divided by the equivalent global number of patents, minus 1. According to this definition, for each country, when SI = 0, the intensity is equal to the world's, when SI < 0, the intensity is lower than in the world and when SI > 0, the intensity is higher than in the world. Fig. 7 shows that in 2014 the EU's had the highest SI for solar heating and cooling patenting compared to other major economies but that its value had more than halved since 2007.

In the case of high value patent families (i.e. patents applied for in more than one patenting office), the EU still clearly dominates (Fig. 8) despite decreasing patent numbers. This shows that the EU companies have a strong international presence in international patenting offices. During the period of 2006-2014, 40 % of EU origin patents were of the high value class. In contrast, despite increasing numbers of Chinese patents (see Fig.6), only 1.4 % of them were submitted to non-Chinese patenting authorities. This shows that Chinese patenting activities are aimed primarily at their internal market.

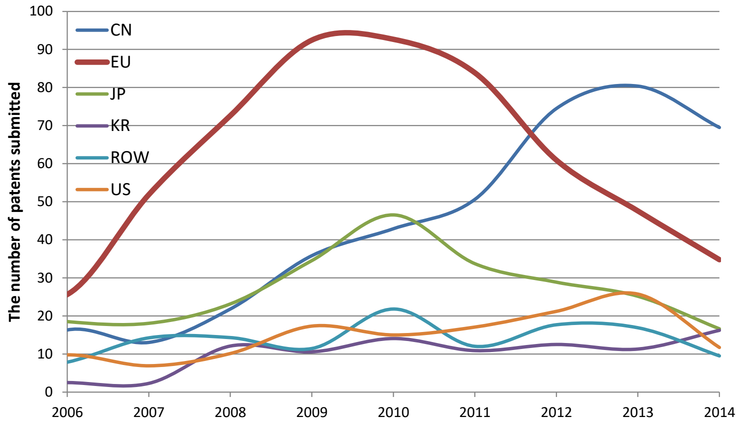

Fig. 6. Global patenting trends in solar heating and cooling technologies. Source Joint Research Centre (JRC), based on data the European Patent Office (EPO)

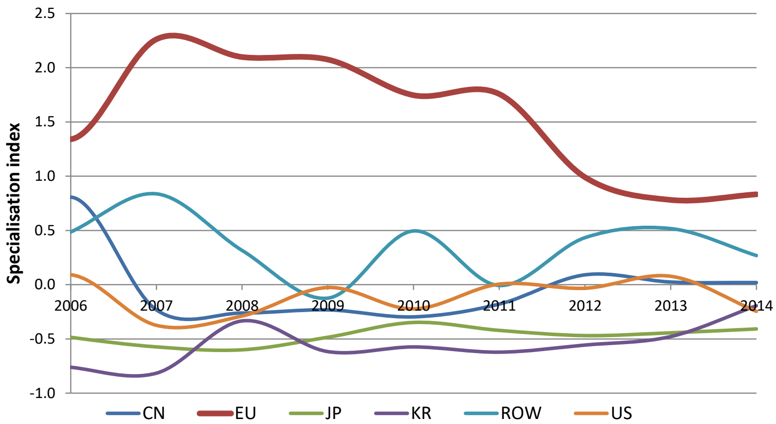

Fig. 7. Specialisation index in solar heating and cooling technologies in the EU and the rest of the world. Source: Joint Research Centre (JRC) based on data from the European Patent Office (EPO)

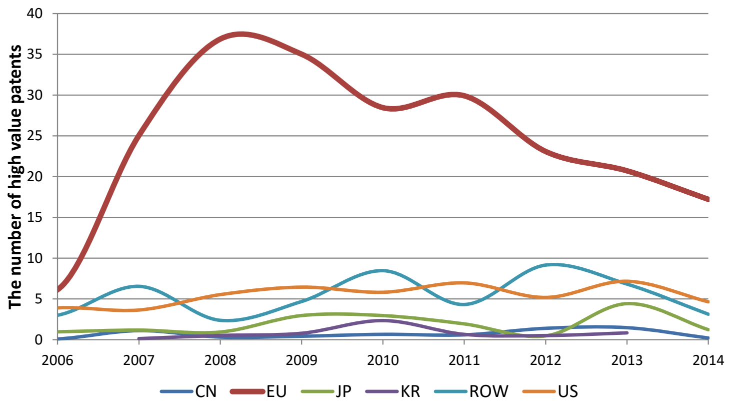

Fig. 8. Global trends in high value patents for solar heating and cooling technologies. Source Joint Research Centre (JRC) based on data the European Patent Office (EPO)

The most active patenting entity during 2006-2014 was Robert Bosch Gmbh (Germany) with 23 inventions in total as shown in the list of top-20 patenting entities in solar heating and cooling in Table 1. It is interesting to note that Japanese companies dominate (11 out of 20). The composition of the top-20 list has changed significantly over time. The most active in 2012-2014 were Chinese companies and institutions (10 out of 20). However, I the same period the most active companies were Robert Bosch Gmbh (EU) and Yazaki Energy System Corp. (Japan) with the 5 patents each.

Overall, however, patenting activities are well dispersed since the share of top-20 in the total number of patents is just 9%.

Table 1. Most active patenting entities during 2006-2014. Source: Joint Research Centre (JRC) based on data from IEA and the European Patent Office (EPO)

Company	Region	Total number of inventions, 2006-2014	Most active year
Robert Bosch Gmbh	EU	23	2008
OTIS ELEVATOR JAPAN	JP	11	2009
Vaillant Gmbh	EU	8	2009
NORTIZ CORP	JP	7	2010
GANTAN BEAUTY KOGYO KK	JP	7	2009
SEKISUI CHEMICAL CO LTD	JP	7	2011
MISAWA HOMES CO	JP	6	2009
ASAHI KASEI HOME PRODUCTS KK	JP	6	2009
Panasonic Corporaiton	JP	6	2010
KOREA ENERGY RESEARCH INST	KR	6	2010
SHARP CORPORATION	JP	6	2008
UNIV CHONGQING	CN	6	2012
YAZAKI ENERGY SYSTEM CORP	JP	5	2012
UNIV SOUTHEAST	CN	5	2014
Schueco International Kg	EU	5	2010
UNIV SHANGHAI SCIENCE & TECH	CN	5	2013
DAIWA HOUSE IND	JP	5	2005
UNIV TIANJIN	CN	5	2006
MATSUSHITA ELECTRIC IND CO LTD	JP	4	2006
Fraunhofer Society	EU	4	2008

3 MARKET OVERVIEW

3.1 Market description, structure and segmentation

Since 2009 the European Union's solar thermal market (i.e. new additions) has been contracting an annual average rate of 6.9%. The total surface area installed in 2017 was 2.2 million m² compared to 4.6 million m² in 2008. Flat plate collectors accounted for 93% of the installed surface area followed by vacuum collectors with 5% (EurOBserv'ER, 2018).

In 2016, 37 large-scale solar thermal systems with close to 0.5 million m² (0.35 GWth) were installed (IEA SHC, 2018). The world's largest plant in Silkeborg, Denmark accounted for about 30 % of this new collector area. Silkeborg has an installed capacity of 110 MWth (156,694 m² flat plate collectors). DH networks with solar energy as heat source also started operation in Sweden, Germany, France and Austria. In total there were 290 large-scale solar thermal installations in Europe at the end of 2017.

Table 2 shows the figures for installed solar thermal collectors per EU Member State in 2017 (EurOBserv'ER, 2018). Almost 30 % of the newly installed collector area was in Germany (EurOBserv'ER, 2018). However, the solar thermal market in Germany suffered a decline of 15 %. The second largest addition of solar collectors occurred in Greece, but the market there decreased even more (34%).

One of the main reasons for the weak solar thermal market is the strong competition from other renewable technologies, mainly heat pumps and solar PV. The Levelized Cost of Heat of SWH is some 15-20 % higher compared to solar PV (more details on the costs of solar heating technologies are provided in Table 3). The relative financial attractiveness still depends on other factors, such as feed-in-tariffs or the local cost of electricity (IEA, 2017). Historically low oil and gas prices has have a negative effect.

For buildings with swimming pools or high hot water demand, such as hotels or hospitals, solar thermal systems are usually more financially attractive. It is also more cost effective in large applications, e.g. district heating systems, due to lower losses and the more constant level of heat demand (IEA, 2017).

3.2 Global market trends by the type of solar thermal application

3.2.1 Small-scale solar water heating systems

Small systems for providing hot water in single-family homes comprise most of the world's solar thermal cumulative installed capacity. These systems are facing challenging times. This is reflected in the continuous shrinking of annual added collector capacity in the world in general and in the EU in particular (Fig. 9), which declined from 18 % in 2010/2011 to 5 % in 2015/2016 (IEA SHC, 2018).

3.2.2 Large-scale solar heating systems

Recent trends show that the deployment of large scale systems is accelerating due to the more favourable economic indicators achieved with larger heat demands such as for commercial hot water, space and water heating combined, industrial process heat and district heating. Combined, these systems made up more than half (56%) of the world's newly installed collector capacity in 2015 (OECD/IEA, 2017).

Worldwide, 15 large-scale solar thermal systems were added in 2017 (Fig. 10). Of these, 9 systems with about 35000 m² (24.5 MWth) were installed in the EU. 46% of new collector area was installed in Denmark. The largest system is 110 MWth (Silkeborg) (IEA SHC, 2018)

Table 2. Annual installed surfaces in 2017 per type of collectors and power equivalent (EurOBserv'ER, 2018)

Country	Flat plate collectors m^2	Vacuum Collectors m^2	Unglazed collectors m^2	Total m^2	Equivalent capacity, MW_{th}
Germany	573000	57000	20000	650000	455.0
Greece	312840	3160		316000	221.2
Spain	190666	7187	3652	201505	141.1
Denmark	173387	0		173387	121.4
Italy	159666			159666	111.8
France	114591		5500	120091	84.1
Poland	115000			115000	80.5
Austria	99770	1060	630	101460	71.0
Portugal	55105			55105	38.6
Belgium	30200	5200		35400	24.8
Netherlands	21150	6162	2621	29933	21.0
United Kingdom	28000			28000	19.6
Bulgaria	24000			24000	16.8
Czechia	16500	7500		24000	16.8
Slovakia	24000			24000	16.8
Croatia	22700			22700	15.9
Ireland	11254	9049		20303	14.2
Cyprus	18000	860		18860	13.2
Romania	6800	11000		17800	12.5
Hungary	12000	5000	180	17180	12.0
Finland	5000			5000	3.5
Luxembourg	3600			3600	2.5
Sweden	2867	341		3208	2.2
Slovenia	2300	400		2700	1.9
Lithuania	800	1400		2200	1.5
Estonia	1000	1000		2000	1.4
Latvia	1500	300		1800	1.3
Malta	518	130		648	0.5
	2026214	**116749**	**32583**	**2175546**	**1523**

3.2.3 Solar Heat for Industrial Processes (SHIP)

Solar process heat installations make up only a small fraction of the total installed solar heating and cooling capacity. However, this market segment experienced positive developments in recent years, with new systems installed in different regions of the world (OECD/IEA, 2017).

Flat plate and evacuated tube collectors are usually used for temperatures up to 100 °C and concentrating solar thermal collectors up to 400 °C. 88 % of the installed systems are non-concentrating (IEA SHC, 2018)

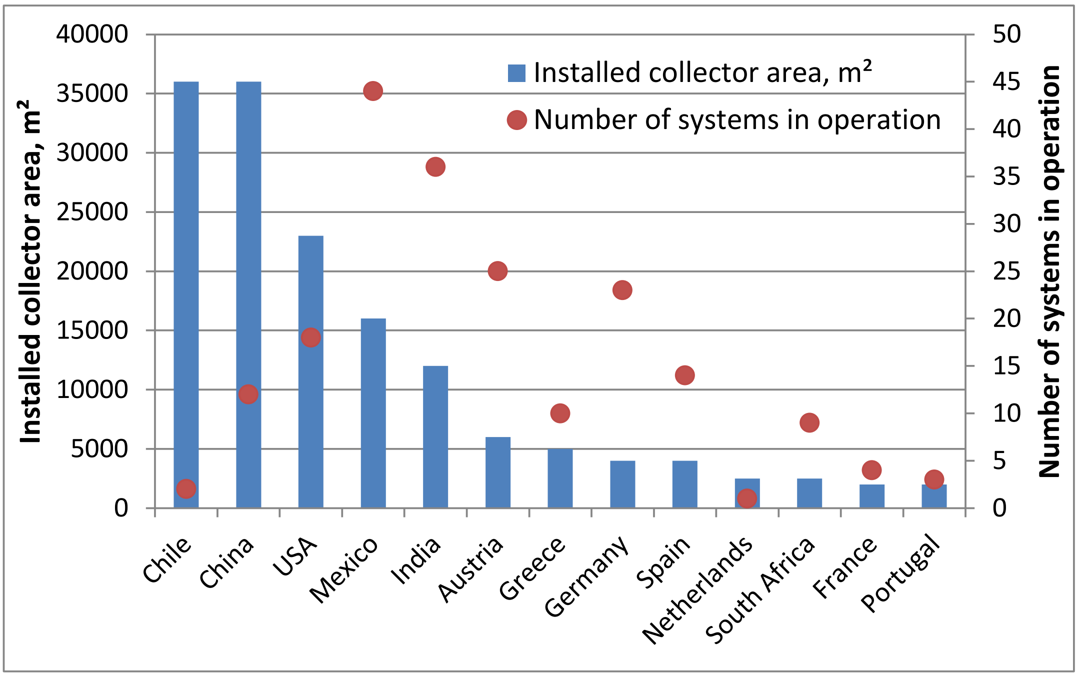

Fig. 9. Solar process heat applications in operation in selected countries at the end of 2016 (IEA SHC, 2018)

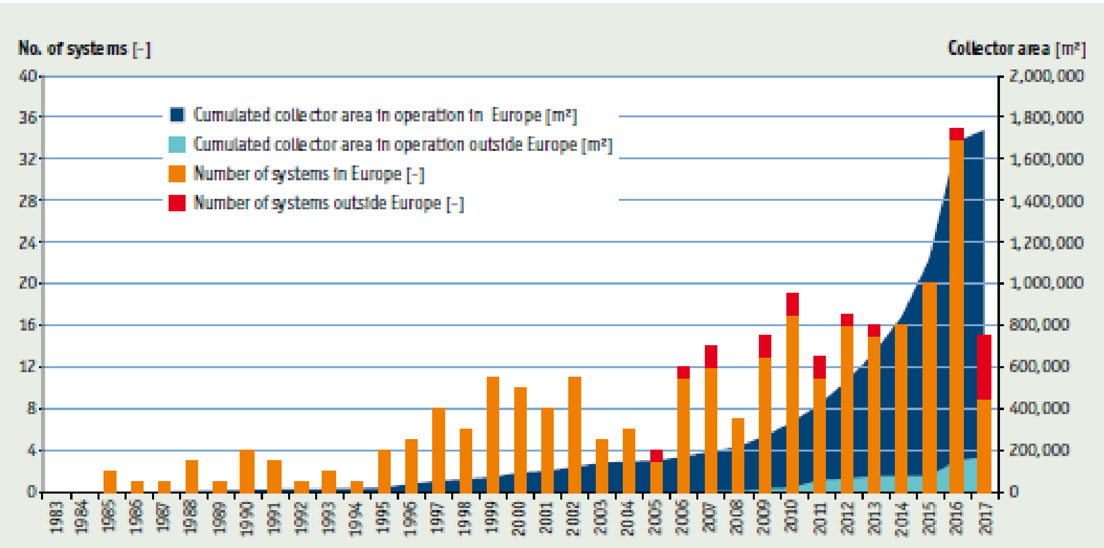

Fig. 10 IEA SHC assessment of large-scale solar district heating and cooling systems – annual installations and cumulative area in operation (source IEA SHC, 2018)

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3.2.4 Solar air conditioning and cooling

In the medium-sized capacity installations segment, the deployment has stagnated due to the relatively high system costs, space requirements and complexity. Absorption chillers account for about 71 % of the capacity in operation.

By the end of 2015, an estimated 1350 solar cooling systems were installed worldwide. More recent data is not available as data collection is difficult with more and more players entering the market. In 2015 the number of installed systems increased by 20-30 % with the largest growth happening outside Europe. About 70 % of all installed systems are still in Europe (e.g. Spain, Germany and Italy) (IEA SHC, 2018).

Drivers for solar cooling include the increasing demand for cooling in general and the potential to reduce peaks electricity demand.

3.3 Technology market shares

Globally, the evacuated tube collectors (71.5%) were the predominant solar thermal collector technology followed by flat plate collectors with 22.0 %, unglazed water collectors 6.2 % and glazed and unglazed air collectors with 0.3 %.

In contrast, in Europe 72.3 % of all solar thermal systems installed are flat plate collectors. Evacuated tube collectors are however becoming more popular and their market share increased from 15.6 % in 2011 to 26.1 % in 2015. The installed solar thermal capacity increased 5% in 2015. This is significantly behind solar PV (+33 %), and wind (+12 %) (IEA SHC, 2018).

Economic analysis based on 2016 costs shows that there is a very broad range in system costs and - subsequently - the levelized cost of solar heat (LCOH). These costs are dependent on the system type and the application, such as small DHW systems for single-family homes, large DHW systems for multi-family homes, small combined DHW and space heating systems and swimming pool heating systems with unglazed water collectors.

Collector production costs in Europe have shown a learning curve of 23 %. Standardized hydraulic components, connections and plug and function concepts have the potential to improve the installation practices, reducing costs and improving systems reliability (Ramos et al., 2017).

Table 3. Main characteristics of different solar thermal systems (IEA SHC, 2018)

System	Typical collector area, m²	Typical water storage, ltr	Service lifetime, years	CAPEX, EUR/m²	CAPEX (Europe) EUR/m²	LCOH, EUR/kWh[2]
Small pumped DHW	2.2-6	120-300	15-25	240-1760	440-1760	0.07-0.19
Small thermosiphon DHW	2-4	150-400	10-15	100-1240	-	0.02-0.12
Large pumped DHW	20-75	1000-6000	15-25	140-1240	520-1240	0.02-0.14
Small combined DHW and heating	2.2-55	120-2000	15-25	200-1380	400-1180	0.03-0.19
Swimming pool heating	24-480	-	25	20-260	-	0.01-0.02

3.4 Major players in terms of market share

German flat plate collector manufacturers continued to dominate the ranking of the world's largest manufacturers in 2015, among them Bosch, Viessmann, Vaillant, Thermosolar and Wolf. China ranked second for number of manufacturers with four, i.e. Five star, Prosunpro, BTE solar, and Sunrain. Turkey is placed third with three producers. A Polish company was among the top 20 for the first time (Hewalex). The three largest vacuum tube collector manufacturers are all based in China (Sunrise East Group, Himin, Linuo-Paradigma) (Sawin et al., 2016).

[2] Using discount rate of 3%

The EU solar heating and cooling sector employed (directly and indirectly) 21900 people in 2017 (decrease of 25% compared to 2016). The turnover of the sector in 2017 was EUR 2.41 billion (decrease of 29% compared to 2016) (EurObserv'ER, 2018).

Table 4. Representative European solar thermal collector manufacturers (EurOBserv'ER, 2018)

Company	Country	Solar Collector Activity	Production 2015 (m^2)
GREENoneTEC	Austria	Flat plate and vacuum tube collectors	540 000
Bosch Thermotechnik	Germany	Heating equipment supplier/ Flat plate collector manufacturer	280 000
Arcon-Sunmark	Denmark	Flat plate collectors manufacturer for large plants	215 000
Viessmann	Germany	Heating equipment/ solar thermal	190 000
Hewalex	Poland	Flat plate and vacuum tube collectors	140 000
Dimas	Greece	Flat plate collectors manufacturer	140 000
Thermosolar	Germany	Flat plate and vacuum tube collectors	130 000
Vaillant	Germany	Heating equipment supplier/ solar thermal	120 000
Nobel	Bulgaria	Flat plate collectors manufacturer	110 000
Delpaso Solar	Spain	Flat plate collectors manufacturer	80 000
Wolf	Germany	Flat plate and vacuum tube collector manufacturer and heating equipment supplier	80 000
Cosmosolar	Greece	Flat plate collectors manufacturer and heating equipment supplier	80 000

3.5 Emerging markets and players

Globally China is the primary manufacturer and installer of solar heating systems with over 5000 manufactures, but only 10 operate at a larger scale (IEA-ETSAP, 2015). India has over 100 approved solar heating system manufacturers (Forsyth et al., 2015).

At present there is significant production overcapacity in much of Europe and China. The Chinese industry was troubled by a second year of significant market contraction, driving consolidation at all levels of the supply chain. Some high-profile European companies experienced significant financial troubles. However, new innovative business models in Europe somewhat counteracted the problems, e.g. focus on public tenders for social housing or innovative financing schemes. In Mexico, there are 2 factories under construction, one for polymer collectors and one for vacuum tubes. Turkey's three vacuum tube manufacturers extended their production capacities in 2015 (Sawin et al., 2016).

3.6 Market outlook

Solar heating and cooling technologies already have a strong global presence. Global solar thermal energy consumption is expected to increase during 2017-22 by over a third, growing from 1.4 EJ in 2016 to 1.9 EJ by 2022 (OECD/IEA, 2017). While the buildings sector drives most of the increase, a slower pace can be expected compared to the previous years due to the expectation of a continued decline in small domestic systems for hot water in China, a market which largely influences the global totals.

However, solar thermal consumption is accelerating in district heating systems and industry due to increasing cost-effectiveness of large scale solar heat supply systems. Most of the growth is expected to happen in applications where significant heat demands, currently supplied by fossil fuels, coincide with suitable climatic conditions. One of such countries is, for instance, India, which leads the growth in industrial solar thermal consumption over the next five years (OECD/IEA, 2017).

As the example of Denmark shows, the successful deployment of high capacity solar heating and cooling applications heat largely depends on the availability of new business models as well as legislative and public support. The economic attractiveness of solar energy in Denmark is the main driver due to taxes on fossil-fuelled heating, affordable land and compatibility with operating temperatures of pre-existing district heat networks (REN21, 2017).

The future of solar heating and cooling technologies will depend on how the industry will utilise drivers and overcome challenges for technology expansion (Table 5).

Uncertain market conditions for some industries, cause limited insights into future heat demand, leaving them hesitant to commit to the long-term contracts. It is forecasted that solar heating and cooling market in the EU will continue to decline due to many reasons, such as ineffective policy support and high installation costs comparing to competing technologies (OECD/IEA, 2017). Over 2017-22, solar thermal energy consumption in Europe will depend on the dynamics of growth of different market segments in warmer versus colder climates.

Since colder climates require more expensive solar thermal systems, deployment of solar thermal systems will depend on the extent to which policy support can improve solar thermal's economic attractiveness across different market segments in buildings and industry. High upfront costs, complex installations and a lack of consumer awareness about the technology or available incentives remain key barriers for the small domestic segment, while larger systems for industrial process heat or district heating have strong potential (OECD/IEA, 2017).

Their role could be significantly expanded using proper policy incentives and measures. Major barriers to greater uptake of solar heating and cooling, in particular in the building sector, are high capital investments needed and long payback time expected. Moreover, the cost-competitive employment of solar heating and cooling is hindered by technical bottlenecks. Heat storage is considered to be the most important of them for further expansion of solar heating and cooling market. Other major bottleneck is the unavailability of commercialised cooling machines for solar cooling applications. A sustained further effort in R&D to address these issues is needed.

Table 5. Drivers and challenges for solar thermal heating market development

Drivers	Challenges
1. Low-carbon source of heat. 2. Attractive in markets where the building stock is well insulated and the electricity prices are high, **3.** Low OPEX, especially in the case of thermosiphon systems or large-scale solar thermal installations.	1. The lack of consistency in support schemes, which depend on fluctuating annual budgets. 2. High investment costs compared to alternative renewable technologies, such as solar PV or heat pumps. 3. Energy yield highly dependent on proper design and installation of solar collector panels. Lack of qualified installers leads to lower than promised and expected energy yield, and consequently, bad image of the technology. 4. Limited public awareness about the environmental and economic benefits of solar heating and cooling.

3.7 Energy systems models

In general, energy system studies do address deployment of solar heating and cooling technologies in less detail compared to other low carbon energy technologies (Tsiropoulos, 2018). This also reflects the inherent complexity of the potential applications that include consideration of the following factors:

- Scale: residential, commercial, industrial, district heating
- End use: sanitary hot water, heating/cooling system (or both), process heat
- Hybridisation: combinations with gas, heating oil, biomass, heat pumps, electrical resistance heaters

The LCEO project has used the JRC-EU-TIMES model to analyse the EU energy system (Nijs, 2018). However the results for the solar heating and cooling were deemed to be less accurate and contain a lower level of detail compared to other technologies, and therefore are not discussed here.

Specific projections for solar thermal are however available from the recent IRENA REmap analysis of the EU, conducted in collaboration with the European Commission and national and international experts (REmap, 2018). It considered two forward looking scenarios. The first one, the "Reference Case", was a baseline featuring current national energy plans and goals to 2030; the second, "REmap", is an accelerated renewable energy scenario to 2030.

Based on the energy mix projected in the Reference Case, the REmap analysis focused on identifying cost-effective alternatives to supply energy with renewables instead of conventional technologies. These alternatives are named "REmap Options", and are intended to reflect realistic estimates of renewable energy potential at the sector and technology levels for 2030. Two options for solar thermal were analysed: solar thermal in buildings and solar thermal in industry. The results of the modelling (Fig. 11) identified a significant and cost-effective potential to increase the use of solar thermal, to account for more than 3% of the final heat demand in the EU in the Remap 2030 scenario, compared to the 2010 level of less than 0.5%. The largest potential continues to be in buildings, but industry applications can also be significant.

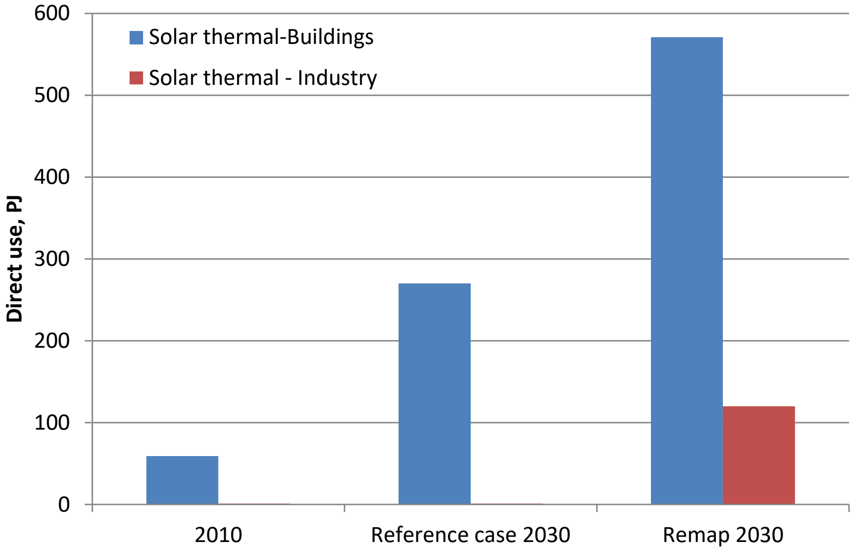

Fig. 11. Solar thermal consumption in the EU-28 in 2010 and in 2030 under the Reference case and Remap scenarios (REmap, 2018)

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4 SUMMARY AND CONCLUSIONS

The cumulated solar thermal capacity in operation in the world by the end of 2017 was 472 GWth (675 million m² of collector surface). Solar thermal capacity increased by 3.5 % in comparison with 2016.

The largest share (324.5 GWth) is installed in China, while Europe takes second place with 51.8 GWth. Total production from solar thermal heating and cooling systems in EU-28 countries in 2016 was 24.2 TWh.

Worldwide, the negative trends in the solar thermal technology sales continued. Compared to 2016, new installations in 2017 declined by 4.2%. However, the solar heating and cooling market showed positive signs as well. The Chinese market seems to stabilise itself while positive tendencies can be seen in solar thermal markets of Europe and the rest of the world.

According to the National Renewable Energy Action Plans, the EU-28 projection for solar heating and cooling energy consumption is 74 TWh/a by 2020, but it does not seem that this will be achieved – as mentioned above, the 2017 consumption is only 33% of the projected 2020 value.

The EU's leading role in this technology sector has been underpinned also by research and innovation activities. From 2004 to 2014 total solar heating and cooling related R&D investments in the EU were estimated at EUR 2.37 billion. The majority of this come from to private funding, with the public share at 8.5 %.

During the period 2006-2014, EU actors submitted 562 solar heating and cooling related patents, i.e. 36% of total worldwide. The patenting activity in the EU peaked in 2009 and 2010 and since then sharply declined, while patenting in China was growing continuously up to 2013, when it overtook that of EU. However, compared to their Chinese counterparts, the EU companies have a strong interest in international markets: 40% of EU origin patents are considered high value i.e. submitted to more than one patenting office. In contrast only 1.4% of the Chinese patents were submitted to patent offices outside China.

In 2017 the EU solar heating and cooling sector employed (directly and indirectly) 21 900 people, with a turnover of EUR 2.41 billion, although this is decreased significantly compared to 2016 and reflecting the market contraction in the same period.

IRENA's 2018 REmap study for the EU identifies significant potential to upscale the use of solar thermal, both for buildings and industry, and to account for more than 3% of direct heat demand by 2030 in the accelerated renewables scenario. However, in light of the continuing solar thermal heating and cooling market decline, such a projection might prove to be too optimistic, given a lack of policy support and high installation costs compared to competing technologies. The future of solar heating and cooling technology depends on how the industry and authorities can address these challenges.

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ACRONYMS AND ABBREVIATIONS

DHC – district heating and cooling;

DHW – domestic hot water;

MS – member state;

NREAP – national renewable energy action plan;

R&D – research and development;

ROW – the rest of the world;

SHIP – solar heat for industrial processes;

SI – specialisation index;

SWH – solar water heater;

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