Integrating National Research Agendas on Solar Heat for Industrial Processes

Project Deliverable D7.3: Common SHIP RTD strategy doc

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1. Content of deliverable

This report will aid in the definition and structure of a European SHIP Research Programme. The relation to existing research priorities on a national and EU level as well as to national and regional innovations strategies will be addressed. Gaps and Opportunities in R&D for SHIP are identified. Funding possibilities on national and EU levels are discussed. From the collected information, eventually a European RTD Strategy is proposed in this deliverable report.

In addition, and closely linked, based on ongoing activities within EERA JP-CSP, formal and structural relations with national funding agencies and other public bodies relevant will be built at European level with the objective of financing a European SHIP Research Programme. Both parallel initiatives are considered key to lay the Foundations for long lasting Research Cooperation on the topic in Europe.

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2. Relation to Concept Notes

2.1. Alignment of SHIP topics with European Research priorities

2.1.1. Past, present and future topics in Horizon 2020

Horizon 2020 is the flagship research-funding framework of the European commission, and the main pillar of research funding of SHIP-related research in the EU. The following table summarises some of the calls relevant to the topic.

Table 1: SHIP-relevant calls in H2020

Code	Title	Deadline	Relevance
EE-18-2014	New technologies for utilization of heat recovery in large industrial systems, considering the whole energy cycle from heat production to transformation, delivery and end use	2014	Low
LCE-04-2014/2015	Market uptake of existing and emerging renewable electricity, heating and cooling technologies	2014 / 2015	Medium
LCE-18-2014	Supporting Joint Actions on demonstration and validation of innovative energy solutions	2014	Low
EE-14-2014/2015	Removing market barriers to the uptake of efficient heating and cooling solutions	2014 / 2015	Low
LCE-02-2014/2016/2017	Developing the next generation technologies of renewable electricity and heating/cooling	2014 / 2016 / 2017	Low
EE-18-2015	New technologies for utilization of heat recovery in large industrial systems, considering the whole energy cycle from heat production to transformation, delivery and end use	2015	Medium
LCE-02-2015 / 2016 / 2017	Developing the next generation technologies of renewable electricity and heating/cooling	2015	Low
EE-03-2016	Standardised installation packages integrating renewable and energy efficiency solutions for heating, cooling and/or hot water preparation	2016	Low
EE-04-2016-2017	New heating and cooling solutions using low grade sources of thermal energy	2016	Medium
LCE-12-2017	Near-to-market solutions for the use of solar heat in industrial processes	2017	High
FCH-02-4-2018	Thermochemical Hydrogen Production from Concentrated Sunlight	2018	Medium
LC-SC3-RES-11-2018	Developing solutions to reduce the cost and increase performance of renewable technologies	2018	Low
LC-SC3-	Solar Energy in Industrial Processes	2019	High

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RES-7-2019			
Sunfuel-EICPrize-2021	EIC Horizon Prize for 'Fuel from the Sun: Artificial Photosynthesis'	2021	Low

There are many calls that are not directly associated with SHIP, and the strength of association is denoted in the last column. Some however are aimed squarely at SHIP, as LCE-12-2017 (now closed), and LC-SC3-RES-7-2019 (which is forthcoming). This list is not enough on its own to prove or disprove the Commissions' willingness to support SHIP, but it is a strong indication that support at the research level is existent and probably poised to continue.

2.1.2. SET-Plan and EERA

Since the formal launching of the EERA JP-CSP in 2011 and the posterior achievement of STAGE-STE integrated Research Programme (IRP) in 2014, the cooperation and integration of EU R&D community has achieved a remarkable progress up to levels never seen before. Among others, the following main achievements and contributions (achieved during the last 4 years) are considered to adequately justify the added value of the EERA JP-CSP:

1. Greater cohesion in the CSP/STE sector, with stronger links and fruitful communication channels between R&D centres and industry as well as fluent interaction with all sector stakeholders when taking decisions and analysing options, as demonstrated by the quick and effective input provided with regard to the Implementation Plan to SET-Plan CSP/STE defined targets achievement.

2. Identification of a very large number of relevant R&D organizations in Europe that have actively contributed to the progress of CSP/STE technology, increasing the number of active countries and partners involved in the field beyond the traditional ones.

3. Identification of core capabilities and competences of all previous organizations making possible the starting of a natural process of clustering and specialization around specific technological topics and reinforcing collaboration opportunities between R&D centres and industry.

4. Creation of an efficient collaborative group at the European level in the field of CSP/STE research, with a broad vision and visibility actively supporting and favouring the integration of National and European research efforts and objectives.

5. Creation of a wide network with strong links with industries and international actors to promote synergetic international cooperation and create market opportunities for EU industry.

6. Achievement and successful launching of both IRP and ECRIA initiatives.

All these successful achievements can be translated into the corresponding strengths of the JP-CSP and added to the ones associated to the exchange of knowledge and

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personnel, sharing of resources and infrastructures and definition of the current profile of the community. The JP-CSP has become the reference and representative forum of the whole EU R&D sector on CSP/STE, providing a common voice towards the different stakeholders (industry, Commission, Member States, etc.).

Due to all previous reasons and added value, the EERA JP-CSP is expected to achieve and be recognized as the reference organization to promote and coordinate European R&D cooperation in Solar Thermal Energy.

An important objective for the CSP/STE research community, well and efficiently organized within the EERA Joint Programme on CSP, fully aligned with SET-Plan policy targets, and in particular with SET-Plan targets on CSP is to actively support the execution of the R&D activity of the SET-Plan's CSP Implementation Plan by lobbying the availability of needed financial resources and promoting the creation of consortia to successfully address the development of related projects.

The SET-Plan establishes an energy technology policy for Europe to accelerate the development and deployment of cost-effective low carbon technologies. It establishes as short term strategic target the achievement of cost reductions above 40% in 2020 (taking the 2013 costs as reference), which corresponds to a supply price below 0.1€/kWh (for the typical conditions of southern European countries). For the long term it establishes as target the development of the next generation of CSP technologies. Its implementation plan for CSP is known as Initiative for Global Leadership in Concentrated Solar Power.

In April 2016 a Temporary Working Group (TWG, formed by representatives from a number of SET Plan countries and the stakeholders, both industry and research) was set up, led by Spain as Chair and assisted by the EC, to prepare the CSP Implementation Plan (IP) to previous targets achievement. Such IP was finally approved on September 2017, being the JP-CSP a key actor to its development and successful execution of the IP. To this end, the JP has been recently restructured in the following six Sub-programmes:

- Sub-Programme 1: Line-Focusing CSP systems
- Sub-Programme 2: Point-Focusing CSP systems
- Sub-Programme 3: Thermal Energy Storage
- Sub-Programme 4: Materials for CSP
- Sub-Programme 5: Solar Driven Thermochemical Processes
- Sub-Programme 6: Solar Heat for Industrial Processes and Applications.

2.1.3. SPIRE

On the Industry side, SPIRE is a contractual Public-Private Partnership dedicated to innovation in resource and energy efficiency enabled by the process industries with a mission to ensure the development of enabling technologies and best practices along all

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the stages of large scale existing value chain productions that will contribute to a resource efficient process industry.

It is the European Association committed to manage and implement the SPIRE Public-Private Partnership. It represents innovative process industries, 20% of the total European manufacturing sector in employment and turnover, and more than 130 industrial and research process stakeholders from over a dozen countries spread throughout Europe. SPIRE brings together cement, ceramics, chemicals, engineering, minerals and ores, non-ferrous metals, steel and water sectors, several being world-leading sectors operating from Europe.

It aims for a reduction in fossil energy intensity of up to 30% from current levels through, *inter alia*, introduction of alternative (renewable) energy sources within the process cycle[1]. SPIRE sees a place for renewables, and particularly solar heat for the future, articulated in its roadmap document[2], particularly at high-temperature applications. Moreover, in its 2050 vision SPIRE states that 'Renewable energy generation and industrial processes will be physically and digitally interlinked'[3].

2.2. Alignment of SHIP topics with national research agendas

The overall picture among the national concept notes is that usually there is no specific regulatory framework in place to support SHIP on a national level. Switzerland and Turkey explicitly say so, but the recurring theme in all concept notes is that there is no specificity in the regulations for SHIP. Some countries however mention indirect regulations that cover some aspects of SHIP, such as standardization and testing regulations (Spain), energy performance of buildings (Cyprus, Portugal), energy efficiency in general and in industrial infrastructure (Austria, Cyprus, Greece, Portugal), renewable generation (France, Italy), emissions reduction frameworks (France), and energy security (France) among others.

An outlier of this rule is Germany: Its involvement with SHIP has been through research centres in and out of Germany itself (Fraunhofer, DLR and University of Kassel for the most part). Recently however, there was a reformulation of the national funding programme for Energy Efficiency in Processes and Installations in Companies[4], and the new programme includes explicitly the use of Renewable Energies (even more explicitly solar heat) in Industrial Processes and Heat distribution networks though unequivocal support schemes. In parallel, the new Energy Research Programme has been developed, defined and

[1] https://www.spire2030.eu/sites/default/files/pressoffice/publication/20131210-spire_brochure_web---final.pdf
[2] https://www.spire2030.eu/sites/default/files/pressoffice/spire-roadmap.pdf
[3] https://www.spire2030.eu/sites/default/files/users/user85/Vision_Document_V5_Pages_Online_0.pdf
[4] https://www.deutschland-machts-effizient.de/KAENEF/Navigation/DE/Foerderprogramme/foerderprogramme-energieeffizienz.html

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eventually published[5] because of a longer consultancy and definition period involving all RTD stakeholders, which contains an explicit mentioning of SHIP as well.

The national research agendas for SHIP on the other hand are (as reported in the country concept notes) practically non-existent at the lower devolution levels (i.e. at regional or local level), and are usually coordinated centrally by federal or national governments through a relevant ministry, usually that of education, environment and/or energy. In some cases (such as in Portugal, Spain and Cyprus) this takes place through Research Foundations, that are arms of the government, but not tied to a ministry. The information collected do not provide a homogenous picture for the countries surveyed; instead, there is a fractured landscape of support for SHIP research usually integrated within renewable energy calls, or within industrial energy efficiency initiatives. As it is a specialised topic, most national research bodies tend to direct interested parties to EU funding instead, without this being an approach with blanket coverage for all countries – several schemes exist for SHIP related research to take place, but the funds allocated to them sometimes go underutilised.

2.3. Previous SHIP research topics

The following table contains a long list of all projects related to solar concentration, both EU and National (denoted 'N'.). The table also contains data for the total budget, the leading institution, and the strength of association to SHIP, in a Low-Medium-High ranking. The ones ranked as 'High' command a total budget of around €20m, which is roughly 8% of the total assigned to all solar thermal projects (including CSP) in a period spanning approximately the 2012-2019 timeframe. This is certainly a significant percentage, and marks SHIP as an active research area, which may be at odds with the niche and relatively disorganised way the topic is being supported at the market level.

Out of those 12 projects marked with high relevance, only four are funded at the EU level and eight at National (or Regional). This trend seems to contradict the norm, but those national projects for which there is data on funding, show a large disparity between funding at EU and National levels, with the lion's share coming from EU projects. It still signifies National interest in SHIP, ostensibly to support the local industry given the applied nature of SHIP.

Table 2: Survey of SHIP related calls (though the STAGE-STE project)

N or EU	Project name	Acronym	Total Budget	Leading institution	Relation to SHIP
N	Development of Solar Drying Technologies for the Valorization	…	€100k	METU	High

[5] 7. Energieforschungsprogramm der Bundesregierung (2018), https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/7-energieforschungsprogramm-der-bundesregierung.html

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	of Sludge				
EU	Integrating National Research Agendas on Solar Heat for Industrial Processes	INSHIP	€2.5m	FISE	High
N	GÜNAM 2nd PHASE: Formation of a Global Excellence Center and Interface With The Industry	GÜNAM-2	€4m	METU	Low
EU	SUNlight-to-LIQUID: Integrated solar-thermochemical synthesis of liquid hydrocarbon fuels	SUN-to-LIQUID	€1.7m	Bauhaus	Low
EU	Solar Facilities for the European Research Area - Third Phase	SFERA-III		CIEMAT	Low
N	Multilayer Multifunctional Advanced Coatings	2MAC-CSP	€462k	CNRS-PROMES	Low
N	Optimization of TES thermocline	OPTICLINE	€468k	CNRS-LTEN	Low
EU	High Temperature concentrated solar thermal power plant with particle receiver and direct thermal storage	next-CSP	€5m	CNRS-PROMES	Low
EU	High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates	SOLPART	€4.4m	CNRS-PROMES	Low
EU	Small-Scale Solar Thermal Combined Cycle	POLYPHEM	€5m	CNRS-PROMES	Medium
N	Réacteur solaire pour la gazeification de la biomasse	REACSOL	€402k	CEA	Low
N	Etude du vieillissement accéléré des composants et systèmes solaires photovoltaïques et thermiques et des corrélations climatiques via des plates-formes multi-sites	DURASOL	€6m	CEA	Low
N	Dessalement d'eau de mer par MED utilisant une source solaire à basse température	SOLMED	€1.1m	CEA	Medium
EU	Water Saving for Solar Concentrated Power	WASCOP	€5.9m	CEA	Low
EU	Solar Facilities for the European Research Area-Second Phase	SFERA II	€8.5m	CIEMAT	Low
EU	High temperature thermal energy Storage by Reversible thermochemical Reaction	STORRE	€2.9m	CEA	Low
EU	Multipurpose Applications by Thermodynamic Solar	MATS	€21.9m	ENEA	Medium
EU	Scientific and Technological	STAGE-STE	€21.1m	CIEMAT	Medium

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	Alliance for Guaranteeing the European Excellence in Concentrating Solar Thermal Energy				
EU	Advanced Materials technologies to QUADRUPLE the Concentrated Solar Thermal current POWER GENERATION	INPOWER	€5.8m	LEITAT	Low
EU	Solar Heat for Industrial Process towards Food and Agro Industries Commitment in Renewables	SHIP2FAIR	€10.3m	CIRCE	High
EU	Solving Water Issues for CSP Plants	SOLWATT	€12.6m	TSK	Low
EU	Thermochemical HYDROgen production in a SOLar structured reactor: facing the challenges and	HYDROSOL-beyond	€3m	CERTH	Low
EU	Renewable Power Generation by Solar Particle Receiver Driven Sulphur Storage Cycle	Pegasus	€4.7m	DLR	Low
N	Nachhaltige Düngerproduktion aus Sonne, Luft und Wasser	DÜSOL	€754k	DLR	Low
N	Automatisierung Solar-ThermochemischerKreisprozesse zur Reduzierung von Wasserstoffgestehungskosten	Astor	€1.5m	DLR	Low
N	Indirectly solar heated reformer for production of methanol of CO2 and natural gas	Indiref	€1.5m	DLR	Low
N	On-demand solar power production via sulphur storage technology	Basis	€1.1m	DLR	Low
N	Development and qualification of solar receivers applying transparent ceramics for solar chemical processes	Traksol	€1.4m	SIJ Solar Institute Juelich	Low
N	Solare Kraftstoffe für den Energiemix der Zukunft	SolareKraftstoffe	€1.3m	DLR	Low
EU	SOlar Calcium-looping integRAtion for Thermo-Chemical Energy Storage	SOCRATCES	€5m	USeville	Low
EU	The European SOLAR Research Infrastructure for Concentrating Solar Power (EU-SOLARIS	EU-SOLARIS	€5.9m	CTAER/CIEMAT	Medium
EU	Advanced Multifunctional Reactors for Green Mobility and	ARMOS	€1.7m	APTL-CERTH	Low

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	Solar Fuels				
EU	Redox Materials-based Structured Reactors/ Heat Exchangers for Thermo-Chemical Heat Storage Systems in Concentrated Solar Power Plants	RESTRUCTURE	€3m	APTL-CERTH	Low
N	Use of concentrated SOLar radiation in the CEMENT industry: Design of a suitable, integrated and low carbon footprint process for limestone calcination	SOLCEMENT	€900k	APTL-CERTH	High
N	Development of a Mobile system for processing and energy exploitation of recovered industrial materials, Bioliquids, biological resources, waste/rejections utilizing Solar thermochemical technology	MOBISOL	€947k	APTL-CERTH	High
N	Valorization of CARbon DIOxide containing industrial streams via non-conventional catalytic systems and SOLarized processes	CARDIOSOL	€771k	APTL-CERTH	Medium
EU	SSA to cover skills needs through deliver5y and recognition of EU joint CV in CSP	SOLAR CV	€796k	AGENEX	Low
EU	Thermal energy storage systems for energy efficient buidings. An integrated solution for residential building energy storage by solar and geothermal resources	TESSe2b	€4.3m	IPS	Low
EU	Network of Excellence in Solar Thermal Energy Research - NESTER	NESTER	€1.1m	CyI	Low
EU	Cyprus Solar Thermal Energy Chair for the Eastern Mediterranean	CySTEM	€3.5m	CyI	Medium
EU	Small scale thermal solar district units for Mediterranean communities	STS-Med	€4.9m	Consorzio ARCA	Medium
EU	Organic Rankine Cycle - Prototype Link to Unit Storage	ORC-PLUS	€7.3m	ENEA	Low
EU	Advanced Materials technologies to QUADRUPLE the Concentrated Solar Thermal current POWER GENERATION	IN-POWER	€5.8m	ENEA	Low
EU	Advanced materials solutions for next generation high efficiency	NEXT-TOWER	€6.2m	ENEA	Low

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	concentrated solar power (CSP) tower systems				
EU	Turning waste from steel industry into a valuable low cost feedstock for energy intensive industry	RESLAG	€9.7m	CIEMAT	Low
EU	Optimised Microturbine Solar Power system	OMSOP	€5.8m	City Univ. London	Low
N	Solare Termodinamico in aree Urbane	-	€800k	UNINA	Low
EU	Next GenerAtion MateriAls and Solid State DevicEs for Ultra High Temperature Energy Storage and Conversion	AMADEUS	€3.2m	UPM	Low
N	Sviluppo di un ricevitore solare a letto fluidizzato ad irraggiamento diretto	-	€63k	CNR-IRC	Low
N	Solar Steam	Solar Steam	€347k	Lark Energy	Low
N	Small-scale desalination in MENA region using Fresnel lenses	REWARD	€139k	Cranfield Univ.	Medium
N	Plasma CSP	Plasma CSP	€172k	Cranfield Univ.	Low
N	MCG collectors for Solar Heat Industrial Process	MCG-SHIP	€645k	MCG	High
N	Infra-estrutura Nacional de Investigação em Energia Solar de Concentração (Portuguese Science Foundation)	INIESC	€2.7m	UEVORA	Low
EU/N	Fomento de tecnologías innovadoras para la mejora de la eficiencia en el proceso de secado de los lodos de Aguas Residuales y de secado de Residuos Sólidos Urbanos mediante el uso de Tecnologías Solares en Andalucía-Algarve-Alentejo	SECASOL	€783k	Dip. Huelva	Medium
N	LIFESOLAR - Service life of key components for solar thermal energy applications	Lifesolar	€197k	LNEG	Medium
N	Solar Thermochemical Production of Hydrogen based on Cork Ecoceramics	H2CORK	€199k	UAveiro	Low
N	Infra-estrutura Nacional de Investigação em Energia Solar de Concentração	INIESC	€1.8m	UEvora	Low

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N	DURASOL - Durability of Solar Thermal Collectors	Durasol	€426k	UAveiro	Low
EU	Competitive Solar Power Towers	CAPTURE	€6.4m	CENER	Low
N	Nuevos Desarrollos para una Tecnología Termosolar más Eficiente	DETECSOL	€363k	CIEMAT	Medium
N	Predicción de la radiación solar en el receptor de una planta termosolar de torre central	PRESOL	€273k	UAL	Low
N	Almacenamiento y conversión de la energía solar térmica de concentración	ALCONNES	€787k	IMDEA	Low
N	Soluciones termosolares para integración en procesos industriales	SOLTERMIN	€278k	CIEMAT	High
EU	Solar dryer based on Fresnel concentration system	SIROCCO	€1.2m	AQYLON	Medium
N	Desarrollo de códigos y algoritmos numéricos paralelos de altas prestaciones para la mejora de la eficiencia en los sectores eólico, solar térmico y edificación	ANUMESOL-1	€100k	CTTC-UPC	Low
N	Algoritmos numéricos avanzados para la mejora de la eficiencia energética en los sectores eólico y solar-térmico. Desarrollo/adaptación a nuevas arquitecturas computacionales	ANUMESOL-2	€151k	CTTC-UPC	Low
N	Storage and conversion of concentrated solar power	ALCCONES	€768k	IMDEA	Low
N	Multidisciplinary analysis of indirectly-heated particles receivers/reactors for solar applications in extreme conditions	ARROPAR-CEX	€335k	IMDEA	Low
EU	Concentrating solar thermal energy in the transport sector and heat and electricity production.	ACES2030-CM	€963k	IMDEA	Medium
EU	MOdular high concentration SolAr Configuration	MOSAIC	€5.1m	IK4-TEKNIKER	Low
R	Hydrogen Sensor for Concentrated Solar Power	SEHICET	€389k	CENER	Low
N	On-line concentrated solar flow measurement system for solar tower plants	EFECTO	€1.1m	ACS-COBRA	Low

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R	Development of high temperature and low cost advanced thermal storage systems	HTSTORAGE	€490k	CENER	Low
EU	Sustainable Production of Industrial Recovered Energy using energy dissipative and storage technologies	SUSPIRE	€3.7m	PRECICA ST	High
N	Recubrimientos Innovadores para Espejos Solares de Alta Reflectancia (INNSOLAR)	INNSOLAR	€676k	RIOGLASS Solar SA	Low
N	Desarrollo de actividades de investigación fundamental; estratégica en almacenamiento de energiá electroquímica y térmica	CICe15-18	€6.6m	CIC-Energigu ne	Low
N	Diseño de sistemas eficaces de almacenamiento de energía y medios de transferencia para aplicaciones específicas	cice8		CIC-Energigu ne	Low
N	Konzeptentwicklung zur Implementierung nachhaltiger Energiesysteme in Städten am Beispiel von Gleisdorf und Salzburg	EnergyCity Concepts	€849k	AEE Intec	Low
N	Solar process heat for the automotive industry	SolarAutomoti ve	€462k	AEE Intec	High
N	Thermal Energy Storage for Sustainable Energy Technology	Tes4seT SToreITup	€4.1m	AEE Intec	Low
N	Sondierung prozessorientierter Konzeptentwicklung solarer Reaktoren und deren Einsatzpotentiale	SolarReaktor	€74k	AEE Intec	Low
N	Solar energy in industrial water and wastewater management	IEA SHC Task 62	€239k	AEE Intec	High
EU	Innovative market based Trust for Energy Efficiency investments in industry	TrustEE		AEE Intec	High
N	IEA-IETS Annex 15/2 Industrielle Abwärmenutzung (Industrial Excess heat Recovery)	Annex 15		Chalmers	High

2.4. Long term energy projections

The EU member states are bound by several targets for their energy futures, mostly related to restricting their Greenhouse Gas Emissions (GHG). Their immediate, 2020 goals had

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been set a number of years ago, and now member states are settling on their 2030 goals[6], which pose a much more ambitious reduction in such emissions (a 40% cut compared to 1990 levels). Energy is central to those plans, and planned changes cut through the entirety of the economic activity, including energy use in the industry.

The 2050 vision however is more ambitious still. The EC calls for a climate neutral Europe by 2050, and the changes will have to be deep and profound. Solar is poised to have a central role, not just in electricity generation, but also towards supplying energy to heat-based applications in the domestic and industrial spheres. While this vision is still in early stages to offer specific targets, it is assumed that the overhaul of all the energy systems across Europe that supply heat and are now based on fossil fuels or electricity conversion, will have to be converted to some kind of renewable source. In fact, IRENA in its 2050 roadmap[7] predicts a massive 49% increase in the final share of renewables in industry, up from 14% in 2015 to 63% in 2050. For SHIP, predicted figures are even more impressive: A rough solar thermal collector area of 1 million m^2 currently is projected to jump to 3,450 million, an almost three and a half thousand times increase in the space of 35 years, despite the fact that most of the growth projected will be in the low-temperature domain.

[6] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy
[7] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf

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3. **Relation to National/Regional Innovation Strategies**

In Work Package 8 of INSHIP, a Deliverable Report D8.1 "Report on analysis of needed national and regional innovation strategies on SHIP"[8] has been developed in parallel to this D7.3 report. This section makes therefore cross-references to the Report D8.1. The main aspects of D8.1 relevant for the present report are summarised in the following.

The analysis in D8.1 is based on the European concept of „National/regional research and innovation strategies for smart specialisation (RIS3[9])", which are integrated, place-based economic transformation agendas fulfilling the following objectives:

- to focus policy support and investments on key national/regional priorities, challenges and needs for knowledge-based development;
- built upon each country's/region's strengths, competitive advantages and potential for excellence;
- to support technological as well as practice-based innovation and aim to stimulate private sector investment;
- to get stakeholders fully involved and encourage innovation and experimentation;
- to include sound monitoring and evaluation systems.

The EC Smart Specialisation Platform[10] provides insight and guidelines to the design and implementation of Smart Specialisation Strategies (S3s). The Platform monitors and tracks Innovation Priorities addressed by the already existing S3s through its tool Eye@RIS3: Innovation Priorities in Europe[11]. In a first step, the total of 1268 currently existing S3 encoded Innovation Priorities (S3 IPs) which are defined in EU countries and regions implementing S3 policy were searched for a reference to SHIP. As it turns out, only 4 RIS3s have a weak, indirect reference to solar energy / renewables, and none of the RIS3s has a direct reference to SHIP (2 in Germany, 2 in Greece).

Therefore, in a second step the main objectives of a national/regional RIS3 were assessed with respect to SHIP for all countries represented in INSHIP in a bottom-up approach, developed mainly from the information provided in the national concept notes[12] and further available information. The RIS3 objectives with regard to SHIP can also be viewed as boundary and framework conditions that may support research and innovation as well as smart national/regional specialisation towards SHIP. Concerning these objectives or framework conditions, a significant variation across the analysed countries (across the EU)

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[8] INSHIP D8.1 "Report on analysis of needed national and regional innovation strategies on SHIP" will be published upon approval here: https://cordis.europa.eu/project/rcn/207022/results/en

[9] European Union, 2012. Guide to Research and Innovation Strategies for Smart Specialisations (RIS 3). ISBN : 978-92-79-25094-1, doi:10.2776/65746.

[10] http://s3platform.jrc.ec.europa.eu/home

[11] http://s3platform.jrc.ec.europa.eu/map

[12] INSHIP D7.2 "Report containing all national concept notes", https://cordis.europa.eu/project/rcn/207022/results/en

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is found. Comparing the analysis results to the actual success (taking the number of SHIP installations per number of country inhabitants as a metric for the success/roll-out) reveals a moderate correlation between success/roll-out and framework conditions, indicating that it actually is beneficial and supportive to SHIP rollout to create supportive framework conditions. However, also other, additional factors strongly influence the success of SHIP rollout (for details on this analysis and discussion, see INSHIP Report D8.1).

In the following, the relation of SHIP related RTD to national/regional innovation strategies is discussed.

3.1. R&D stakeholders

As step 3 (of 6 steps in total) in the definition process of a RIS3, „all stakeholders need to define a shared vision of the regional economy, society and environment"[13], without specifying which stakeholder groups are to be involved.

In the existing RIS3, no direct reference to SHIP can be found, it is safe to assume that no SHIP related RTD stakeholders had been involved in the preparation of the RIS3s (or that they were not successful in placing SHIP as a topic). Therefore, it may be an option to have RTD Stakeholders (more) actively involved in the definition of RIS3s. On the other hand, RTD stakeholders typically have no resources/funding (and maybe not the political skills) to actually do so.

The assumption of a lack of involvement of RTD stakeholders in RIS3s and their definition is further supported by the fact that the term "research" is only found in two RIS3s, of which one is on Automotive/Aeronautics and one on Lasers/Optics, and neither indicates a direct relevance to SHIP. (RIS3 search term "research" using the tool Eye@RIS3: Innovation Priorities in Europe[14], and applying the filters (C-Manufacturing, 05-Energy, E-KETS and J-Sustainable Innovation; compare INSHIP D8.1 report, sections 2 and 3.4).

Therefore, another approach to involve RTD stakeholders in the development of an RTD strategy is proposed:

Within INSHIP, SHIP related national stakeholder groups (NSGs) have been established, which include RTD, Industry (suppliers, potential end users, industry associations, consultants, project developers, etc.), political stakeholders and financing. Within these NSGs it may be discussed who could actually become involved in the definition of RIS3s in order to promote SHIP within RIS3s. Only in a later step can it be seen whether RTD stakeholders may actually become involved in the definition of RIS3s, as follows.

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[13] European Union, 2012. Guide to Research and Innovation Strategies for Smart Specialisations (RIS 3). ISBN : 978-92-79-25094-1, doi:10.2776/65746.
[14] http://s3platform.jrc.ec.europa.eu/map

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Step 4 in the definition of an RIS3 is the "Identification of a limited number of research and innovation priorities, where the region has a realistic chance to progress". Here, it needs to be checked and shown that SHIP can be such a priority and the respective region has a realistic chance to progress. In order to do so, a market analysis may be helpful, showing general potential. Even more helpful and supporting would be a national/regional analysis of potentials and related target industries, as e.g. done in Spain as published in a 2016 study of SolarConcentra/SOLATOM[15], where with the very high spatial resolution of municipality level the potentials of SHIP have been assessed. It may be a topic for further research to provide such detailed information for other countries/regions as well, and by doing so, to support not only the further rollout of SHIP, but also the potential definition of SHIP as priority in a RIS3.

In terms of national RTD strategies and research programmes, the status is described in section 2.2 already. Concerning the involvement of RTD stakeholders, Germany may again be mentioned as an outlier. During 2017/2018, the Federal Ministry for Economic Affairs and Energy BMWi has launched a multilateral consultancy approach for the definition of the next 7th Energy Research Programme which was eventually published in 09/2018[16]. One of the chosen approaches was a bottom-up collection of RTD priorities through expert groups where the German SHIP RTD stakeholders were able to place the respective SHIP related RTD topics successfully, as there is an explicit mentioning of SHIP in the new Energy Research Programme.

3.2. Existing Regional Innovation Strategies

As reported above, there are no existing regional innovation strategies listed in the RIS3 database Eye@RIS3 that refer directly to SHIP, and no RIS3 with a direct reference to "research".

To support the promotion of SHIP, it may be advantageous to have SHIP mentioned explicitly as a research and innovation priority for regions with a realistic potential for SHIP implementation (or industrial development based on and including SHIP). Some suggestions to address this have been made in the previous section.

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[15] "Who is who - Estudio geolocalizado del potencial de aplicaciones de calor solar de proceso en media temperatura. http://www.solarconcentra.org/estudio-geolocalizado-del-potencial-de-aplicaciones-de-calor-solar-de-proceso-en-media-temperatura/

[16] 7. Energieforschungsprogramm der Bundesregierung (2018), https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/7-energieforschungsprogramm-der-bundesregierung.html

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3.3. Potential regional couplings

As there are no direct references to SHIP in any of the existing RIS3s, there are no regional couplings to be considered or proposed yet. However, from the country analysis of objectives of RIS3s with respect to SHIP (also to be seen as an analysis of the status of supportive framework conditions for SHIP) as reported in INSHIP D8.1 Report, a significant difference between countries was observed. This suggests that regional couplings to improve the framework conditions, and to eventually define Innovation strategies including SHIP as priority topics and/or to support broader SHIP rollout, may be possible and beneficial in several respects:

- countries/regions with weaker positioning can learn from countries/regions with a stronger supportive positioning, i.e. use "best practice" as model strategy to identify gaps and to resort adapted solutions
- countries/regions with complementary strengths and weaknesses may couple their strategies to jointly create better conditions
- use results of the three-category-classification of D8.1 as to identify best "matchmaking" possibilities between partners with a good / reasonable / poor/bad positioning.

For further details, please refer to section 6 "Assessment and recommendations" of the INSHIP Deliverable Report D8.1 "Report on analysis of needed national and regional innovation strategies on SHIP"[17].

[17] INSHIP D8.1 "Report on analysis of needed national and regional innovation strategies on SHIP" will be published upon approval here: https://cordis.europa.eu/project/rcn/207022/results/en

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4. Identification of gaps/opportunities

The following passages are divided into three temperature range segments, as they present different gaps and opportunities: 80-150°C, 150-400°C and 400-1500°C.

4.1. Identification of R&D gaps

This identification of existing R&D gaps has been carried out from three different points of view: the INSHIP ECRIA partnership, the national R&D programs and the opinion of several experts on the field.

According to the INSHIP partnership members, the pre-definition of specific research topics to be pursued under this project derived from a preliminary discussion of both, the most relevant R&D topics and the Work plan structure, according to a strategic approach to SHIP related questions: industrial sectors; process temperature vs. solar thermal technology; integration in the overall energy system.

This discussion was held amongst the Core partners group, involving representatives of both Central and Southern European countries where SHIP potential is more clearly identified, in face of the geographical distribution of solar resource: Austria, Cyprus, France, Germany, Greece, Italy, Portugal, Spain, Switzerland and Turkey.

It took into consideration the current state-of-the–art of Solar Thermal technologies – low and medium temperature technologies at a higher TRL level yet lacking swift technological solutions for efficient integration of SHIP into existing processes/facilities; high temperature technologies at a lower TRL level, drafting the most pressing questions hindering the application of these technologies in a SHIP context and the identification of research activities fostering the development of technical solutions at TRL levels 2-5:

Table 3: Listing of R&D gaps

Topic	Questions / Research Activities (TRL 2-5)
stationary technologies and low temperature processes (*according to* WP 2)	optimized integration of SHIP at process level; standardized integration components; durability and reliability of solar collectors under industrial environment conditions
line-focus technologies and medium temperature processes (*according to* WP 3)	optimized integration of SHIP at supply level; DSG and integration of SHIP into steam networks; durability and reliability of solar collectors under industrial environment conditions; compact and flexible designs aiming the reduction of spatial requirements and the use of facades; development of lightweight designs enabling the use of light building covers
point-focus technologies and high temperature processes (*according to* WP 4)	design of point-focus optical systems adapted to reactor/kiln shaped receivers; design of specific industrial processes in the Energy Intensive (EI) industrial sectors aiming an integration of SHIP at process level

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integration in the energy system (according to WP 5)	development of hybridization concepts; integration of waste heat recovery and promoting a priority to the exploitation of the energy efficiency potential; use of centralized heat storage systems as regulator element to the electricity grid; development of 100% RES production concepts; integration of heat distribution networks either in industrial parks or in connection to district heating

A survey on recently concluded and/or ongoing related projects in these countries set up the base for the identification of ongoing research topics, enabling the identification of research gaps towards the Research Agenda and hence the definition of concrete research activities to be funded directly through INSHIP. This survey identified the research topics in 52 recently concluded and/or ongoing projects involving the participation of partners in the Core Partner countries and its results are illustrated in the graphic of Figure 1 below.

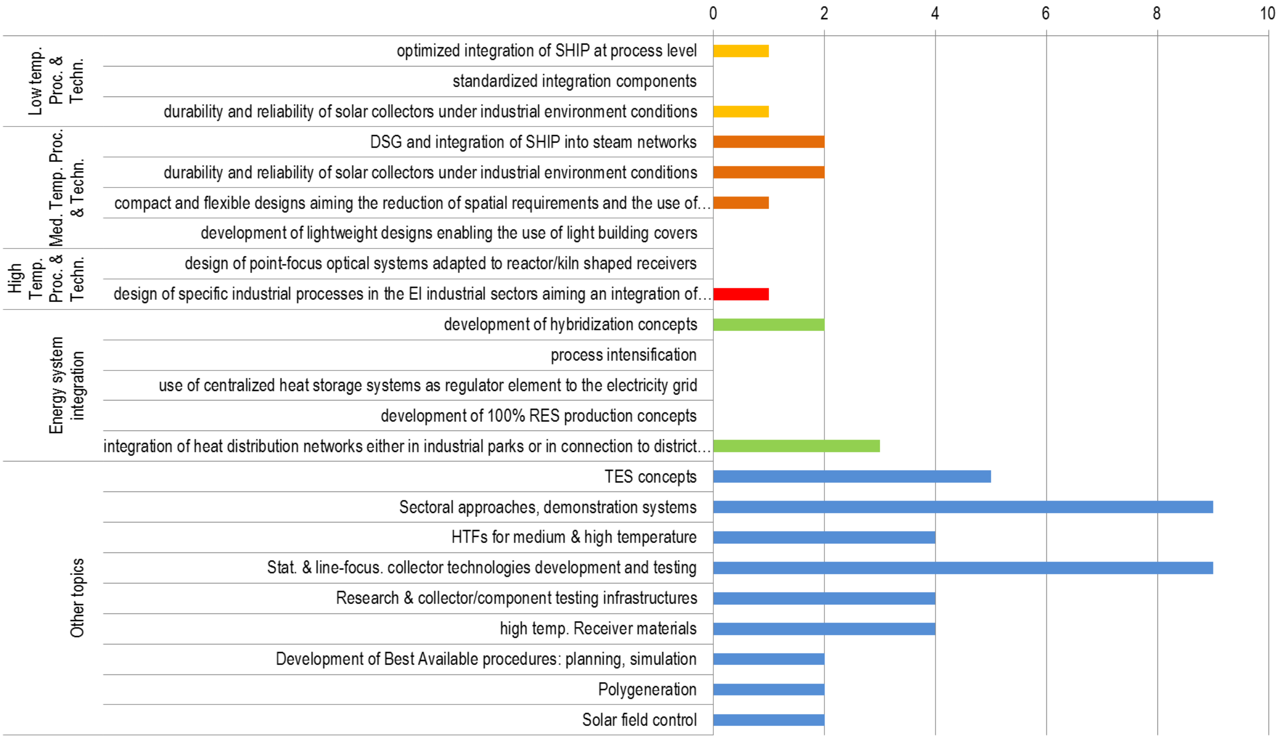

Figure 1: Distribution of research topics in 52 recently concluded and ongoing SHIP projects involving the participation of institutions in the Core partners' countries (Austria, Cyprus, France, Germany, Greece, Italy, Portugal, Spain, Switzerland and Turkey)

On the other hand, and according to a survey carried out to identify **national R&D funding programmes** that could cover SHIP, it becomes apparent that the thematic foci are predominantly on low and medium temperature applications, with also a significant number of topics relating to high temperatures (Figure 2).

Low and medium temperatures are also in the lead when it comes to the priorities of the INSHIP's own organisations (Figure 3), with the difference that hybrid energy sources comes third and emerging process technologies comes fourth, leaving high temperature applications further behind.

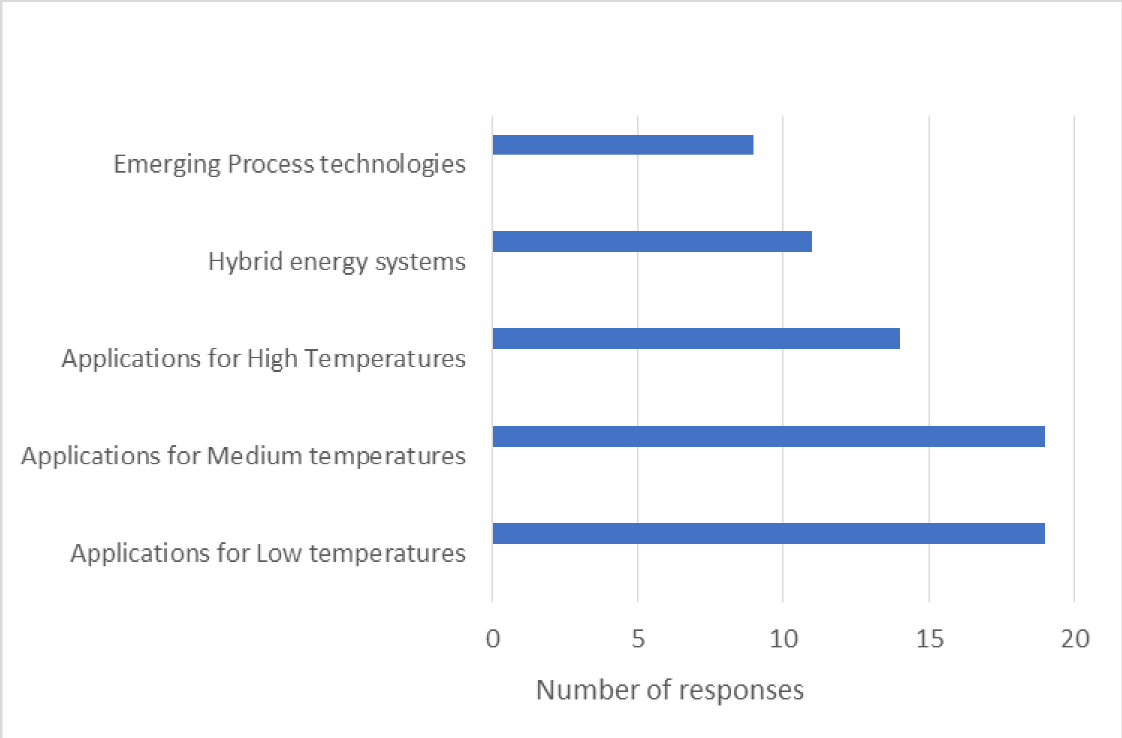

Figure 2: Thematic priorities at National R&D Programmes

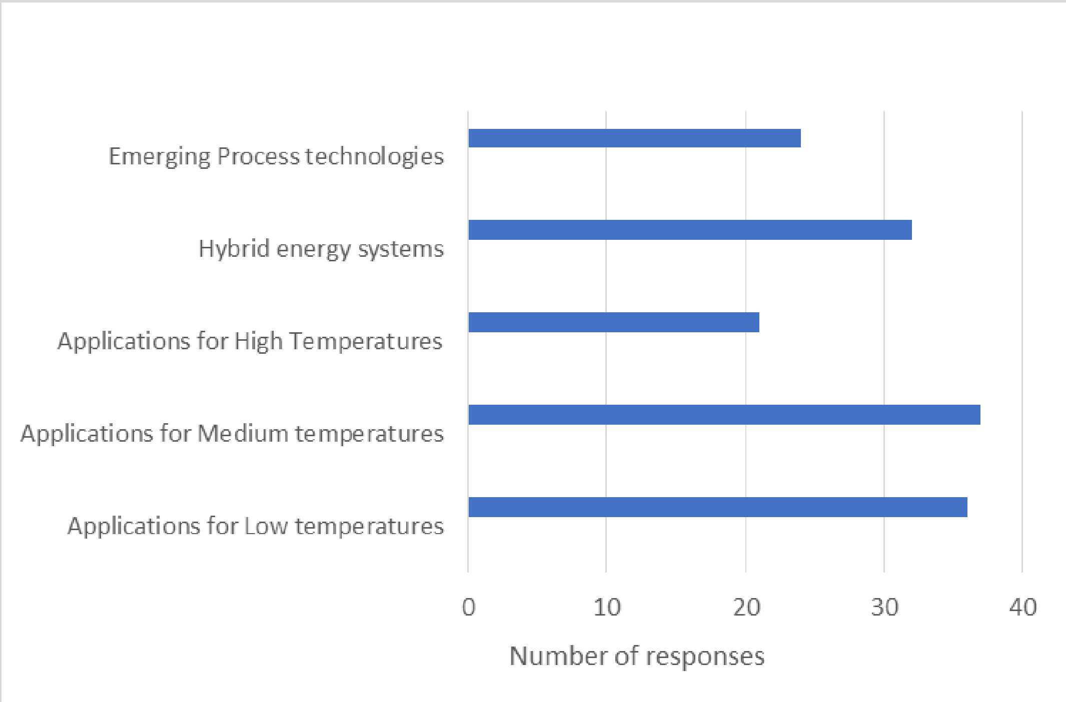

Figure 3: Thematic priorities at INSHIP members' organizations

Last but not least, the opinion of **other recognized experts** in the field has been collected and this is their assessment, split to the three temperature ranges:

4.1.1. Low-temperature SHIP (80°C - 150°C)

The current gaps/challenges faced by low-temperature solar thermal processes, with a particular focus on separation technologies are:

a) Increased capture efficiency, in order to reduce the area of the solar field and reduce the impact of the investment cost. Research into new coatings for the absorber surface, the reduction of thermal losses (increased vacuum levels, new anti-reflective coatings) as well as the testing of new working fluids (e.g. nanoparticles) can help to improve the efficiency of converting solar radiation into useful heat.
b) Thermal separation technologies require perfect control of operating temperatures so that the different heat exchange elements operate as close to the design conditions as possible. Research on auxiliary regulation elements as well as advanced control strategies can help achieve this objective when operating with a variable source such as solar radiation.
c) Thermal separation technologies have a high investment cost. This is why the intermittent operation of these technologies has a negative impact on the final cost of desalinated or treated water. For this reason, it is mandatory to look for

hybridization solutions that allow the continuous operation of these systems with maximum use of the solar resource.

d) Thermal technologies for low-temperature process industrial heat also have an associated auxiliary electricity consumption in the process of capturing and exchanging heat with the industrial process. In the case of thermal separation technologies, where temperature intervals must sometimes be very small in order to avoid problems such as scaling, these parasitic electrical consumptions may become relevant. The optimization of this consumption is a fundamental task in order to compete against other technological options.

e) Both in the case of water desalination and in the treatment of industrial water, aggressive fluids are used that can damage or reduce the performance of the heat exchange surfaces. Research into low-cost heat exchangers that offer acceptable heat transfer values at the same time, as well as avoiding the loss of efficiency due to the detrimental effect of operating with aggressive fluids.

4.1.2. Medium temperature SHIP applications (150°C-400°C)

Most important barriers to the commercial development of SHIP applications are, on the one hand, that 95% of the industrial plants that consume process heat are small or medium, which requires a solar system design that is appropriate to this size. In addition, for small or medium sized industries, it is usually a disadvantage the implementation of systems in which the initial investment is large, although the annual costs of O&M are small. Finally, the existence of a certain lack of knowledge of possible solar thermal solutions and their operation, as well as the shortage of reliable and long-lasting suppliers of components and equipment, represent an important barrier at present for the development of Solar Process Heat applications.

Unlike the development projects of solar thermal power plants for electricity generation that are promoted and carried out by large companies, solar systems for application to process heat can be designed and marketed by small and medium enterprises (SMEs), which are the real drivers of the economy in Europe.

In the medium temperature range in Europe, it has been identified that there is a very scarce number of companies supplying components for solar fields composed by parabolic trough or linear Fresnel collectors[18], which are viable technical solutions for the supply of solar thermal energy in the temperature range 150-400°C. Moreover, the existing solutions are not yet designed or optimized in most cases, for example, for installation on building roofs. In addition to the absence of manufacturers/distributors, there is not a sufficient number of companies with the knowledge to carry out detailed engineering and construction of a system using solar thermal energy with tracking solar collectors, which limits the knowledge that potential end users (industries or end users with high demand of

[18] Fernández-García A, Zarza E, Valenzuela L, Pérez, M. Parabolic-trough solar collectors and their applications. Renewable and Sustainable Energy Reviews 14 (2010), 1695-1721. Doi: 10.1016/j.rser.2010.03.012.

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thermal energy) about the possibilities of incorporating a solar thermal solution in their applications, not only in a solar mode solution alone, but also hybridizing with e.g. gas heater/boiler, which for a first approximation to the technology, would be very attractive to demonstrate how the solar system can become an energy-saving solution.

The supply of direct solar steam, a promising solution that already has some commercial examples in Europe, would also allow attracting the attention of new and potential industrial users. The existence of several pilot demonstration projects integrated in different types of industrial or applications with high thermal energy demand would favour the availability of real data on the technical and economic viability of different technological solutions and modalities of integration. This information would be extremely helpful to different stakeholders to analyse and check the benefits, pros and cons of this technological solution to supply thermal energy in the industry.

4.1.3. High-Temperature SHIP applications (400°C-1500°C)

In this temperature range some developments are needed to further integrate solar heat into these processes from a general point of view, some of them are outlined below:

a) The challenge is to develop efficient solar receiver/reactors to carry out the process in a continuous manner suitable for coupling with a downstream fuel production process.
b) Integration of thermal energy storage and/or hybridization for 24/7 continuous operation is also mandatory.

4.2. Identification of Opportunities

According to the current global scenario claiming of and in support of a deeper penetration of renewable energy sources, it is worth to carry out an exercise of identification of industrial applications where SHIP could be applied at a large scale[19][20]. In parallel, this implies that a stronger R&D funding effort should be accomplished.

The identified new opportunities for SHIP application are split into three temperature ranges in the sections below.

4.2.1. Low-temperature SHIP (80°C - 150°C)

One of the possible applications for low temperature SHIP technologies are thermal water separation processes, which range between 60°C and 130°C and including, as a particular case, the desalination of both brackish and sea water.

In the case of water desalination, the two conventional thermal distillation processes with the greatest commercial implementation operate in a temperature range that falls within

[19] GIZ, 2011. Identification of industrial sectors promising for commercialisation of solar energy. https://www.giz.de/en/worldwide/15776.html

[20] IDAE, 2011. Plan de Energías Renovables 2011-2020. http://www.idae.es

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the range mentioned above: 70°C in the case of the low temperature multi-effect distillation process (LT-MED) and 90-120°C in the case of multi-stage flash evaporation (MSF) processes. In the case of more innovative thermal processes such as membrane distillation (MD) the maximum operating temperature is 80°C and in the case of forward osmosis (FO) the maximum temperature for the recovery process of the extracting solution can be as low as 80-90°C.

In recent years, competition in the market against other solar options such as the combination of photovoltaic energy with reverse osmosis (PV-RO) has made thermal separation technologies look for other market niches. One of these niches are industrial wastewater treatment processes with the dual objective of recovering water (reducing the volume of emissions) as well as recovering high value-added elements contained in these waste waters.

4.2.2. Medium temperature SHIP applications (150°C-400°C)

According to the study published in 2015 by the International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA), looking at the year 2030 there is a technical potential to supply about 4.17 million GWh of energy with solar thermal systems (about 20% of energy demand).

In the world, more than 66% of the total energy consumption in the industrial sector is dedicated to industrial heat processes, and 50% of this thermal energy consumption takes place below 400°C. According to data from the end of 2015, 40% of industrial consumption of primary energy was supplied with natural gas and approximately 41% with oil (IEA-ETSAP, 2015). This means that looking at the year 2030 there is a technical potential to supply around $4.17 \cdot 10^6$ GWh of energy with solar thermal systems (about 10% of industrial energy demand), while the contribution of solar thermal energy in the industrial sector could reach 33%. There are important areas of application in the food, textile, machinery and paper sectors, where around 60% of thermal consumption can be supplied at temperatures below 250°C (GIZ, 2011), see Table 4:

Table 4: Examples of processes in different industries with demand of thermal energy in the medium temperature range. (Source: Modified from Fernández-García et al, 2010).

Industry	Process (es)	Temperature (°C)	Medium
Food processing, beverages production, milk processing	Cooking, pasteurization, sterilization, tempering drying, heat treatment…	40 - 150	Steam, water, air
Textile	Blanching-dying, Drying, Pressing, Fixing, printing	40 - 180	Water, steam

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Industry	Process (es)	Temperature (°C)	Medium
Pulp and paper	Bleaching, de-linking, drying, pulp preparation…	60 - 200	Water, pressurized water, steam, air
Chemical and pharmaceutical	Distillation, evaporation, drying…	100 - 170	Water, steam, air
Leather products, rubber, plastic and glass manufacturing	Pre-tanning, drying and finishing, preheating, preparation, distillation, lamination…	50 - 200	Water, air, steam

4.2.3. High-Temperature SHIP applications (400°C-1500°C)

Lime and cement manufacturing are high-temperature energy intensive processes. Global cement production has increased more than 30-fold since 1950 and almost 4-fold since 1990, with much more rapid growth than global fossil energy production in the last 2 decades. According to the World Business Council for Sustainable Development (WBCSD, 2002), the cement industry produces 5% of global man-made CO2 emissions. By substituting concentrated solar energy for the fossil fuels, one can reduce by 20% the CO_2 emissions in a state-of-the-art lime plant and by 40% in a conventional cement plant.

Next steps will be scaling-up the basis of efficient energy transformation from the laboratory (2 kW) to the industrial scale (some hundreds of kW) for reliable solar processing at the industrial size. To reach this objective, strong efforts for improving reactor modelling, concentrator technology, on-line process control are expected. A good example is given in *SolPart* project (European project funded by the H2020) whose main objective is to develop, at pilot scale, a high temperature (950°C) 24h/day solar process suitable for particle treatment in energy intensive industries (e.g. cement or lime industries).

The extractive metallurgical industry is also a major consumer of high-temperature process heat and consequently, a major contributor of CO_2 emissions derived from the combustion of fossil fuels for heat and electricity generation. In particular, the aluminium industry presents unique opportunities for industrial implementation of solar process heat. Use of high-temperature solar process heat can drastically reduce the emission of climate-altering gases, reduce the reliance on electricity, and make possible a direct thermal route from the ore to metal. Some further research is needed to identify those routes for ore reduction what have the greatest potential; i.e. a direct reduction process to Al or Al–

Si alloy, or a reduction process to an intermediate such as AlN or Al_2S_3 that could be electrolyzed more easily than Al_2O_3 must be evaluated.

Finally, hybrid technologies that involve fossil fuels in some form or other, but use solar thermal energy to provide the heat to drive an endothermic reaction, that generates hydrogen in either an open- or closed- loop cycle i.e. gasification, reforming, etc. remains an alternative for integration of solar heat in a process. This route is especially important, considering that the wide use of hydrogen can become one of the possible avenues for the future energy development, especially by the constraints on the greenhouse gas emissions.

According to the concept of hydrogen economy, hydrogen will gradually replace fossil fuels and become the main energy carrier in the second half of the 21st century. The production and energy-related consumption of hydrogen by 2050 to 2100 may exceed the current level by tens or even hundreds of times.

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5. **Identification of possible funding**

5.1. Existing funding resources

The data taken out from the National concept notes provide information on the existing funding resources in each of the targeted countries. Here are the main findings:

5.1.1. Germany

The German Federal Ministry for Economic Affairs and Energy has announced the 7th Energy Research Programme of the Federal Government. Funding is generally available for stakeholders and consortia and rates may reach up to 100% to R&D institutions and up to 50% to industrial partners (up to 60% for SMEs), consortia involving industrial partners are strongly encouraged. There is a two-stage process for proposals with presentation and pre-approval of sketches before submission of full proposals.

The Federal Ministry of Education and Research, BMBF, funds research topics on rather basic research level (e.g. materials research or other topics) which might also encompass SHIP related research, but typically tackling lower TRLs. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) runs the Klimaschutzinitiative (BMU NKI/IKI Program). There are possible funding rates of 100% and projects must trigger some CO_2 reduction level and mostly aim at higher TRLs (Technology Readiness Levels).

SHIP in the funding context of BMWi Energieforschung has been placed under the "umbrella" of solar thermal applications and thus handled by respective ministry departments and the project management organisation PTJ. At European level, and besides the possibility of accessing H2020 calls on the topic, Germany places national funding into Solar ERA-NET calls, yet another possibility for SHIP related research funding.

5.1.2. Spain

There are two main public entities financing R&D projects, both managed by the Spanish Ministry of Economy, Industry and Competitiveness: the CDTI (Centre for Industrial Technological Development) and the State Research Agency. CDTI funding is mainly made of grants and soft loans in an open, not competitive call. There is not a dedicated budget per energy sector but almost no budget limitation either. Spanish entities, other than industry, must participate in the projects as subcontracted entities. The State Research Agency has competitive calls for consortia including Spanish companies and research organisations. There is no dedicated budget per sector and, regarding central government funding, there are no specific red lines. CDTI and the State Research Agency are participating in ERANETs programs as one instrument for cross-national funding. ERANET and EUREKA not attractive to Spanish R&D entities because only their marginal cost can be funded, thus reducing their usefulness to promote SHIP–related research.

5.1.3. Austria

There are programmes without thematic restrictions and there are thematic programmes on federal level and on national level. The Energieforschungsprogramm (energy research programme), the European Research Area and the New Energy for Industry (NEFI) are good places to start. The Climate and Energy Funds is participating in the multilateral FTI programmes ERA-NET Bioenergy, ERA-NetSmart Grids Plus, Industrial Energy Efficiency ERA-NET and SOLAR-ERA.NET Cofund.

5.1.4. Italy

There are some under some RIS schemes in Italy. Within the national call under the national OP 2014-2020 on Research and Innovation (priority "energy" is one of the 12).

5.1.5. Portugal

The FCT (National Foundation for Science and Technology), funded by national state budget and Portugal 2020 programme provide funding. There are open general calls with budgets going up to approximately 200,000 euros. Portugal 2020 funds research activities through competitive calls for individual and collaborative RTD projects.

5.1.6. Cyprus

RPF's RESTART 2016-2020 programme provided the latest funding initiative with a total budget of €100 million. However, Cyprus does not allocate a specific amount to SHIP. The main 'pillars' of research for Cyprus are chosen by local stakeholders and the government are documented in the 'Smart Specialisation Strategy' for Cyprus. Energy is a 'dominant priority sector' – it will attract a large percentage of funds, therefore SHIP related research is eligible for such funding.

5.1.7. Greece

There are direct and indirect national funding mechanisms. Regarding the direct ones, there are 3 funding programmes in 2018, included in the National Strategic Reference Framework (NSRF) 2014-2020. The Greek Ministry of Environment, Energy and Climate Change is expected to publish within this year two funding programmes, for SMEs (incl. Processing enterprises). One is the Improving the Energy Efficiency of Small and Medium Sized Enterprises, which concerns interventions in the building shell (thermal insulation, window frames/ glazing, shading systems, etc), upgrading of the electromechanical equipment for production processes as well as for the space cooling / heating (e.g. hot water production, waste heat recovery, power distribution systems, lighting, etc.). The second is the Promotion of heating and cooling systems from RES and cogeneration of high-efficiency heat (CHP) using RES for self-consumption, which concerns RES installations (i.e. biomass, biogas, geothermal, solar thermal and other RES systems) and CHP systems using RES that will operate exclusively as self-production units.

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The Greek Ministry of Economy and Development along with Ministry of Energy have announced a Modern Processing programme (4th National Action Plan on Energy Efficiency for Greece) – total budget: 100 million euros, with 40% being public expenditure. The eligible budget of investment projects is in the range of 250,000-3,000,000 €. SHIP systems may currently receive funding through the Greek Development Law 4399/2016, "Institutional framework for establishing Private Investment Aid schemes for the country's regional and economic development - Establishing the Development Council and other provisions". The indirect funding mechanisms are the "Energy efficiency obligation schemes". The current main European funding framework for SHIP technologies in Greece is the Horizon 2020, which is the biggest EU Research and Innovation programme with nearly €80 billion.

5.1.8. Switzerland

The Swiss State Secretariat for Education, Research and Innovation (SERI) is the main point of contact for SHIP-related funding. The Horizon2020 and its previous incarnations (FP6, FP7, etc.) from the EU form the main pillars for cross-national funding.

5.1.9. Turkey

There are no national research funding mechanisms specific to SHIP and the main body dealing with funding issues for science and research is TÜBİTAK - Scientific and Technological Research Council of Turkey. The programmes can be summarised as below:

- TÜBİTAK 1001 Scientific and Technological Research Projects Funding Program
    - for research at lower TRLs
    - no inherent budget limit for this mechanism but a budget limit is set for each call
    - Currently this budget limit is 360 000 TRY (~ 73 000 Euro) for equipment, consumables, travel, and student scholarships
    - Open to SHIP-related proposals
- TÜBİTAK 1003 Primary Subjects R&D Funding Program
    - higher TRLs, calls are only opened in specific areas
    - representative budgets are 2.5 Million TRY (~500 000 Euro) for a large-scale project
    - 1 Million TRY (~ 200 000 Euro) for a medium-scale project
    - 500 000 TRY (~100 000 Euro) for a small-scale project
- 1509 - TÜBİTAK International Industrial R&D Projects Grant Programme
    - Objective: create market focused R&D Projects between European countries
    - Open to SHIP
    - Budget limit per call, no budget limit per project
- 1511 - Research & Technology Development and Innovation Program

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- o 1511 is similar to the 1003 Programme except that an industrial organization/SME must be included
- o SHIP technologies have been supported under this Programme. The budget limit is specified according individual calls

Horizon 2020 contains following the call LC-SC3-RES-7-2019: Solar Energy in Industrial Processes, which has a strong alignment with SHIP and LC-SC3-RES-8-2019: Combining Renewable Technologies for a Renewable District Heating and/or Cooling System

5.2. Required funding resources

This chapter lists the funding resources which were, over the past years, required to fund SHIP research, both on EU and on national level.

5.2.1. EU R&D funding

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

Table 5: EU funding per framework programme (1998 to mid-March 2018, 2016 million euros)

	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)

Table 6: Top 10 recipients of EU funding by country (2008 – mid-March 2018, in 2016 euros)

Rank	Country	Funding / 2016 Euros
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)

5.2.2. Member State R&D funding

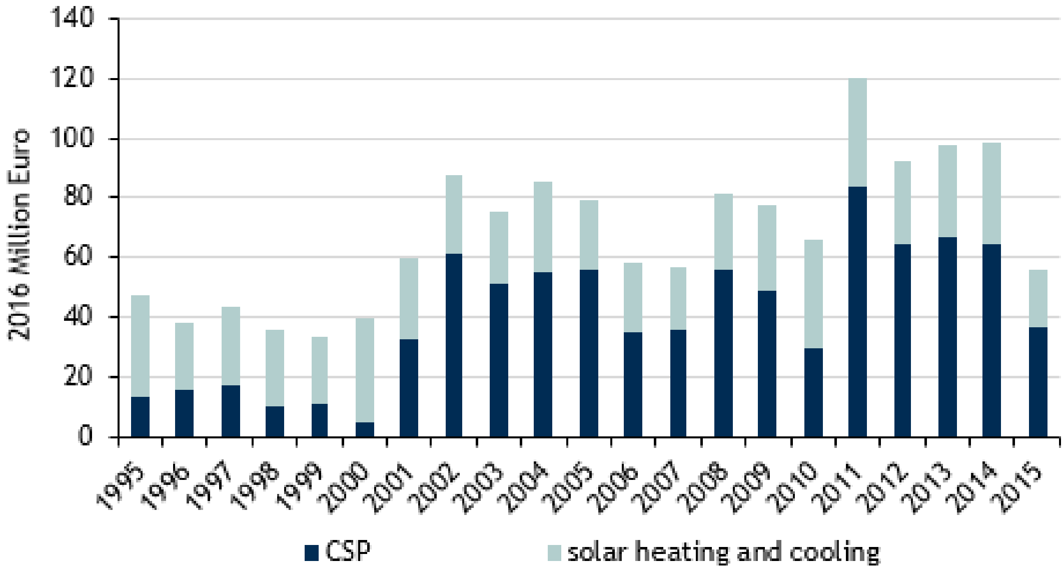

Figure 4: Annual MS R&D funding in the EU for solar thermal. *Source: Based on data from OECD/IEA (2018).*

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.

The largest funders are Italy, Germany, Spain, France and the United Kingdom. Together, they accounted for 90 % of all MS R&D funding. See graph below:

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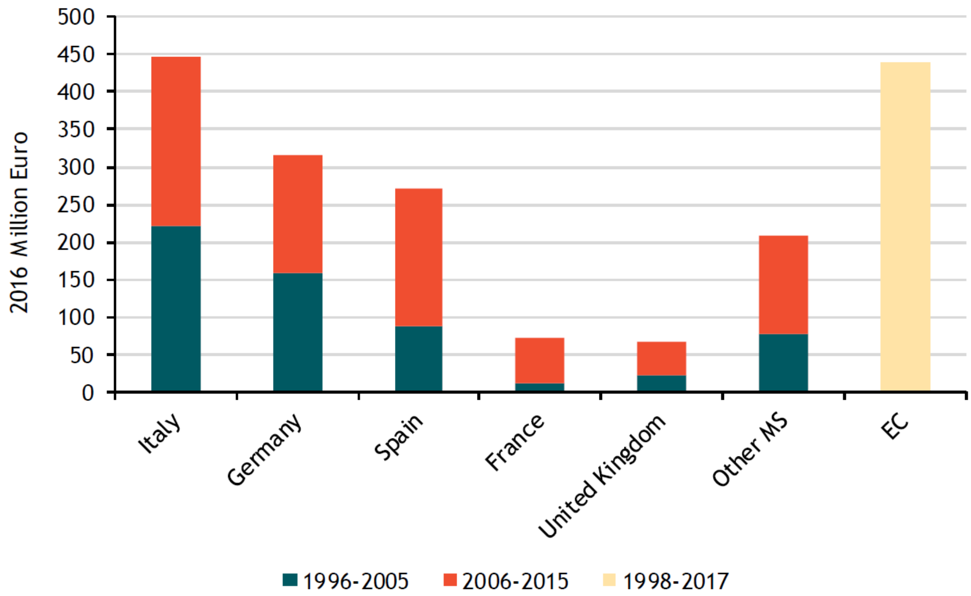

Figure 5: Solar thermal R&D budgets of the Member States with the largest R&D budgets for solar thermal (1996-2015) and the EC (1998-2017)

5.3. Possible funding sources

In the following, existing possible funding sources are listed which served SHIP funding in the past and may serve to fund future SHIP research:

- **Horizon 2020** Framework Programme
  - Grant: **Solar Energy in Industrial Processes** (LC-SC3-RES-7-2019) link
    - Support will be given to solutions that cover by means of solar thermal energy the highest possible share of the heating and/or cooling demand of one or more industrial processes. In the case of heating, the process temperature shall be higher than 150°C. Individual industrial sites and/or industrial parks (coupled to a district heating and/or cooling network) are in the scope.
    - The Commission considers that proposals requesting a contribution from the EU of between EUR 3 to 5 million would allow this challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.
- **Eurogia2020** – a cluster of the **EUREKA** network
  - Two-step process: 1. submit a project online; 2. full project proposal
  - EUROGIA2020, the Eureka Cluster for low carbon technologies, **does not fund projects**. Funding is granted via Eureka Countries' national programmes, based on their national policies, priorities and constraints.
  - EUROGIA Board '**labels'** projects: The label guarantees that projects are technically sound, innovative, well planned and organized and positively impact the world energy system.

        - With this label, project participants can apply for funding in their respective countries
    - Next deadline: 1 March 2019
- **Interreg Sudoe Programme** (link) – supports regional development in SW Europe by financing transnational project through the **ERDF**.
    - total budget of 141 million euros
    - 5 priorities:
        1. Research and innovation
        2. Competitiveness of SMEs
        3. Low-carbon economy
        4. Combating climate change
        5. Environment and resource efficiency
    - 4th call is expected in the **1st semester of 2019** (link to calendar of calls)
        - Priorities: 1 and 5
- **European Institute of Innovation and Technology (EIT) InnoEnergy** (Knowledge Innovation Community) link
    - Investment Round is open for applications year-round.
    - Renewable energy is one of InnoEnergy's thematic fields, therefore solar thermal energy for industries is eligible
    - At least partners from two (2) different European countries must have a substantial role in the project.
    - Documentation and timeline
- **EEEF - European Energy Efficiency Fund**
    - EU member states only
    - Funds go to
        - municipal, local and regional authorities
        - public and private entities acting on behalf of those authorities such as utilities, public transportation providers, social housing associations, energy service companies etc.
    - 2 types of investments:
        - Direct investments
            - Investments in energy efficiency and renewable energy projects in the range of €5m to €25m
        - Investments into financial institutions
            - Selected partner financial institutions will receive debt instruments (senior debt, subordinated debt, guarantees) with a maturity of up to 15 years
- **Marguerite Fund** (2020 European Fund for Energy, Climate Change and Infrastructure) – link
    - Budget: 710 million euros
    - Duration of Marguerite I: 2010-2020
    - Marguerite II: 2020 onwards, with up to 2 one-year extensions

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    - The European Investment Bank has committed EUR 200 million, of which EUR 100 million are guaranteed by the European Fund for Strategic Investments (EFSI), alongside EUR 100 million each from five National Promotional Banks
  - Greenfield: new projects and facilities, with typical development risks largely mitigated (**minimum** of 65% of the Fund)
  - Brownfield: replacement, modernisation and capacity enhancement of existing assets (**maximum** of 35% of the Fund)

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6. **RTD strategy proposition**

6.1. Research topics

6.1.1. Existing topics

The topics below have been carried over from the first such exercise, taking place within the INSHIP project proposal phase. The results of those discussions have been featuring in the project's Grant Agreement, and formed an integral part of the early development of the project. These topics are:

Technology integration aspects, aimed to support the integration of higher Technology Readiness Levels (TRL), and low and medium temperature solar thermal technologies in industrial applications, with the focus on reliability and durability of components, integration into existing heat distribution networks, and integration into industrial processes.

Solar technology development aspects, through the development of low TRL, high temperature solar thermal technologies or low TRL designs for low and medium temperature technologies aiming an efficient use of available area for the installation of solar fields in industrial sites.

Energy system integration aspects, through the development of hybridization concepts, centralized heat distribution networks, thermal storage management or process intensification related activities.

6.1.2. Additional topics

The projects' progression, the analysis of gaps and opportunities as given in section 4 of this report as well as the outcomes of the EU workshop held in Brussels in February 2019, have resulted in additional topics that merit further research. The main highlights are:

Technology cost reduction: Further research is required to achieve cost reductions in the fields of materials, assembly procedures, installation, and site works. Such reductions can also be achieved by widening the manufacturing base and throughput of SHIP components, thus tapping into the benefits of economies of scale. In addition, several O&M procedures need to be revamped and reduced in overall cost.

Financing: A topic often overlooked, research is needed to identify suitable business models, and develop due-diligence, risk analysis and risk sharing tools, guarantees & insurance. At a later stage, research and standardisation is needed for contracting, as well as exploring the possibility of engaging venture capital, equity or commercial banking.

Standardized information: There are strong signals from researchers and industry alike that there is a need for standardisation of the technology cost range and validity conditions, for easier communication of SHIP advantages. These have to extend to O&M costs, system

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size scalability, benchmarking with competing technologies and/or energy sources, and technology learning curves. This will have to be followed by standardization of equipment and procedures, a task that has to be led mostly by the industry.

Impact: An emphasis should be given to the value creation potential of SHIP, away from purely cost-based analyses. This should involve an analysis of job creation and maintenance potential, possible additional tax revenues, energy cost reduction, emissions reduction, and energy security considerations.

Behavioural aspects: Further research is merited for models of consumer driven and sectoral driven motivation, which can have an effect on the choices for electing SHIP technologies.

Research at various TRL levels: Starting with the existing topics research needs mapping, it became apparent that further refinement is needed in research of various TRL bands, as the specialisation and services they provide are – in many cases - increasingly distinct.

- **Low TRL (0-5)** - likely by R&D institutions, generating a continuous flow of innovation able to be introduced to supply and end-user industries at a later (higher TRL) stage
- **Higher TRL (6-7)** - likely to be driven jointly by R&D, supply and end-user industries
- **Market ready (8-9)** - end-user driven and covering "real scale" questions

This specialisation has been supported by many stakeholders in the EU SHIP sphere, and is already apparent in the research curriculum of many organisations in the field.

On the flipside, the possibility of "open TRL" calls could be foreseen by assessing potential impacts (e.g. on competitiveness, costs, efficiency…) through the use of a well-established (and suitable) learning curve, thus levelling the ground for the competition of low and high TRL solutions addressing one specific necessity.

6.2. Recipients strategy

Besides the topics of RTD, the type of projects to be funded and the group of stakeholders to receive RTD funding need to be addressed. As discussed above, depending on TRL level, academic research (RTD only), applied research projects (RTD+Industry) or industrial research will need to receive funding. As in current funding, the subject of research will range from materials, components and products to systems and demonstration. In addition to these existing recipients, the following further recipients were identified.

There are strong signals from industry and research that there is a need for *demonstration projects*, especially flagship demos: Those will have to be "real scale" systems, generating a record of accomplishment on MW-rated scale heat supply, high solar fraction systems. Sufficient funding for such projects and the related installations and infrastructures is necessary.

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Moreover, it has been identified that there is a lack of *project developers* fostering the use of solar thermal in industrial applications. This could be remedied by information dissemination, demo projects, or faster technological adoption.

Finally, a mixture of *technical and financial due diligence tools* enabling the reduction of transaction costs and easier access to financing (through venture capital, equity or commercial banking etc.) is required, rendering SHIP projects more attractive (and simple) to potential EPCs and/or ESCOs.

6.3. Research funding strategy

As laid out in chapter 5 of this report, RTD on SHIP has received noticeable funding over the last years both from the EU level and from national funding sources. In many aspects, with the support from these funding sources SHIP technology reached maturity and high TRL levels and is ready to be implemented. However, competitiveness, perception of SHIP being a reliable heat source, financing and other topics (see above) are still critical issues strongly motivating further RTD efforts under the respective funding support.

At the same time, if compared to the funds which concentrated solar power CSP has received over the last years (Figure 4), it can be observed that until the year 2000, solar heating and cooling has received more national funding than CSP, whereas since then CSP has received significantly more funding as compared to solar heating and cooling, which includes SHIP. Considering the need for funded RTD on the topics listed above, an increase of funding for RTD on SHIP related topics seems desirable.

Given the recent increased public and political awareness for the need for decarbonisation in all sectors to limit climate change, there may be chances to actually allocate such funding sources both on the national and the EU level. Provided the respective funding over the coming years, RTD on SHIP will contribute to a faster dissemination and market penetration of SHIP, thus addressing the joint goal of RTD stakeholders and funding bodies to contribute to the decarbonisation of the European industry through a broader rollout of SHIP.

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