IEA SHC TASK – SOLAR ENERGY IN INDUSTRIAL WATER AND WASTEWATER MANAGEMENT

Work Plan

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1. Background

Solar Heat for Industrial Processes (SHIP) has a huge potential, however this potential is still largely untapped. Within the past years of activities in IEA SHC Task 49/IV[1] (duration 2012-2015; operating agent Christoph Brunner), several shortcomings that were hindering a successful market deployment could be overcome: This relates to a number of guidelines and papers on how to place solar thermal plants best within the complex industrial environment. It also relates to available simulation tools and design strategies of solar thermal systems. Suitable process heat collectors are also well established, although research on new low-cost and low-weight collectors for the medium temperature range is still required.

Besides the ongoing optimization of the technology of solar process heat collectors, there are some main topics however that still need to be addressed for successful market deployment: To reach high solar ratios, available area and easy installations are one requirement, but also new technologies will be a decisive research topic to really allow for significant solar shares in industry. Future energy systems in industry will rely on hybrid solutions, and the interactions of solar thermal systems with other energy supply technologies, storage management and industrial heat flows will become of high importance in these thermal energy networks. These networks might also cross boundaries of industrial sites and relate to larger city areas or regions. The development of new process technologies will also have an impact on solar process heat or vice versa an economic availability of solar process heat might stimulate the use of low exergy technologies in industry.

An important field of **application of solar energy** could be identified in the field of **water treatment technologies**.

Just recently the IEA underlined the importance of NEXUS Water-Energy by performing a workshop of the Experts' Group on R&D Priority Setting and Evaluation (EGRD) where amongst others the interaction of water and energy in industry has been addressed.

On the one hand about 20 % of water utilization in the world is devoted to industrial use and is therefore an essential economic good. On the other hand, fresh water is a scarce resource in many regions today while the disposal of waste streams comes along with destructive environmental impact. Additional resources as sea- and brackish water are utilized by means of desalination with exponential growth rates since the 1950s. Theoretically 100 % solar ratio could be envisioned in solar heat supply for water treatment technologies, as it is common to work with large volumes and buffer storages in this sector allowing to some extent production capacity variation along with solar availability.

2. Scope

This Task will develop and provide the **most suitable and accurate information on the technical and economical possibilities for effectively applying solar thermal energy and solar radiation to disinfect, decontaminate and separate industrial process water and waste water.** Water shortages in specific regions worldwide as well the need of CO_2 reduction and primary energy savings underline the importance of this research area and specific technological development will be required to develop tecno-economic solutions. This task will **support specifically the solar energy industry, the water technology sector and the producing industry** in

[1] http://task49.iea-shc.org/

identifying new technologies, innovative fields of application and business opportunities.

The scope of work covers all low temperature solar radiation technologies supplying either thermal or photon primary energy for fluid separation and water treatment in regard to industrial applications and sewage plants either in the context of municipal water treatment/purification or development cooperation.

3. Objective and Organization

The main objective of the Task is to **improve the conditions and increase the applications of solar driven separation and water purification technologies in industrial applications** in order to push the solar water treatment market, solve water problems at locations with abundant solar energy resources and reduce the fossil-fuel consumption.

To achieve these objectives, the work is organized into the following three Subtasks:

Subtask A: Thermally driven water separation technologies and recovery of valuable resources

The main objective of subtask A is to foster the *development and promotion of new energy efficient solar driven separation technologies* for industrial waste water and process fluid treatment via:

- Identification of separation technologies that show high potential for solar thermal heat supply (e.g. membrane distillation, pervaporation, vacuum evaporation, rectification, etc.)
- Identification of suitable fields of application (e.g. industrial sectors, production processes, geographical sites; synergistic use of solar and industrial excess heat…)
- Assessment of advantages and disadvantages of these technologies for different industrial applications and the interaction with solar thermal technologies and other renewable energy technologies
- Comparison (technical and economic) of these emerging technologies with state of the art separation technologies (e.g. ultrafiltration, reverse osmosis…)

Subtask B: Solar Water Decontamination and Disinfection Systems

The main objectives of subtask B are the elaboration of **emerging technologies with increased efficiency due to integration of solar radiation which may also affect the quality of the conversion process** and **the definition of new solar collectors' concept** for reducing manufacture costs though maintaining high efficiency in the collection of UV photons for better performance of chemical oxidation reactions.

- To provide a deep analysis on the energy reduction potential associated to the application of solar based processes to the industrial water management system. (Electrical consumption associated to UV lamps will be also considered)
- To deal with research questions like fluid dynamics, reactor design, etc. to optimize the purification results as well the energy consumption
- To promote collaborative initiatives for assessment of technical and economic feasibility of specific water decontamination and disinfection problems
- Identification of treatment processes of other water-based streams (e.g. in the bio-based and agro-food industries) that could potentially benefit from direct solar/UV radiation
- To initiate the development of new collector technologies

- To promote tools and services in this area to accelerate the market penetration.

Subtask C: System integration and decision support for end user needs

The main objective of the subtask is to develop a **guideline for decision support, designed purposefully for end users/technology adopters (e.g. solar thermal companies, manufacturer, food producer, water utility operating a wastewater treatment plant, etc.) to select the optimized combination of water technology in combination with solar thermal supply technology to achieve a certain practical outcome.**

- Show viable and innovative solutions to particular needs in treating wastewater or capturing valuable products. A key feature of the work will be to connect the process need to a technology solution (e.g. removal of carbon (biological oxygen demand) from a wastewater using solar heat)
- The guideline will refer to water process solutions, with examples, that principally harness solar thermal energy (related to the work of Subtask A and B).
- Integration and design concepts (solar process heat system concepts) for solar thermal energy will be developed with solar supply as key focus, but industrial excess heat will be also considered (based upon methodologies developed in IEA SHC Task 49/IV, Integration Guidline)
- Where possible, the SHIP Database, which was developed within IEA SHC Task 49/IV, will be utilised and extended with present working examples of processes that are utilising a solar thermal process to meet a treatment need or produce a valuable product
- The practical outcomes of interest will be assessed in the project in consultation with industry experts, which could include needing to deal with matters such as removing contaminants from wastewater prior to environmental/sewer disposal or reuse. This may be achieved by the proposed technologies by contaminant destruction (e.g. organic mineralisation), isolation/purification for potential sale as a valuable product or by reducing its volume to enable more convenient disposal.
- In keeping a narrow focus on solar thermal technologies, acknowledgement of other technologies will be included respecting their benefits such as maturity and/or efficiency.

The work of all subtasks will build on the results of IEA SHC Task 49/IV, looking at available potential studies, integration strategies and design concepts (solar process heat system concepts). Collector manufacturers shall be deeply involved in the development of these solar process heat system concepts, and possibly triggered to develop specific solutions for the waste water treatment sector to position themselves in the market.

4. Process

The Task starts on October 2018 and ends on September 2022.

Task meetings will be held twice a year. In addition, Subtask meetings or working group meetings may be held in between Task meetings.

Expert/Industry workshops, during the Task duration, in conjunction with some Task meeting, will be organised in the host country of the meeting. The defined target groups will be invited.

National industry workshops will also be organised by the national Task participants using the information gathered during Task workshops and the material produced by the Task.

The results of this Task will be different publications, e.g. **guidelines**. Also, improved or new methods, integration concepts, processes etc. will be developed. Different types of education material will also be produced.

An **electronic media** targeted at the defined target groups will be produced at the end of Year 1, 2, 3 and 4. The information will be distributed through the IEA SHC Channels. Furthermore, existing social media accounts (e.g. Twitter) will be used to share news about the Task.

In general - the dissemination of results will take place at a national level and international level on conferences, workshops and in magazines and journals.

See further in the Task Information Plan (Chapter 6).

5. Subtasks

Subtask A: Thermally driven water separation technologies and recovery of valuable resources

Lead: Joachim Koschikowski, *Fraunhofer-Institute for Solar Energy Systems ISE, Germany*

Objectives

The overall objective of this subtask is to foster the **development and promotion of new energy efficient solar driven separation technologies** for industrial waste water and process fluid applications, benchmarking them with state of the art technologies and accelerating market uptake. The technological focus will be on advanced thermally driven membrane technologies such as e.g.

- Membrane distillation (MD)
- Diffusion Dialysis (DD) in combination with MD
- Pervaporation

But will also include technologies such as e.g.:

- Advanced Vacuum Evaporation (VE)
- Plastic based units for Humidification-Dehumidification (MEH)
- Selective Crystallisation (SC)

An initial mapping of available separation technologies with the very diverse separation challenges and needs of very different industries will be in the focus as well as a mapping of specific process heat demand with potential for solar or excess heat supply at different sites and in different industries.

The utilization of advanced material as new polymers or advanced membranes will be investigated in order to make future separation processes more efficient, more reliable and resistant but also cheaper due to the avoidance of expensive highly-alloyed steels. This enhanced reliability and improved economics will be an important aspect for market uptake of solar thermal driven waste water technologies and potentially also influences the solar collector per se.

Therefore, it is intended to form a subtask group consisting of experts from very different complementary fields of academia and industry.

Activities

The Subtask A will basically contain **three Activities:**

A.1. Analysis

A.1.1. Identification and systematic listing of industrial separation processes with focus on thermally driven technologies.

A.1.2. Identification of future demands for water and process fluid treatments, drivers for market uptake (e.g. disposal costs, legislations, etc.) and specification of related technological requirements.

A.1.3. Identification and mapping of industries with thermal separation possibilities and potential for the utilization of solar heat.

Identification of applications and industries respectively which are most suitable for the implementation of solar thermal or/and waste heat driven separation processes in terms of technical solutions and sound business models

A.1.4. Identification of technological challenges and hurdles and specification of related R&D demand including basic research, component development, system technology and control strategies (e.g. preparation for industry 4.0 requirements…)

A.1.5. Identification of legislative, economic and socio-economic challenges and hurdles and specification of related requirements for adaptation harmonization

A.1.6. Documentation and recommendations for R&D programs

A.2. Assessment of concepts and best practices (flanked by R&D projects)

A.2.1. Elaboration of a matrix comparing state of the art separation technologies in industrial applications with new technologies which are currently under development – identification of benchmarks

A.2.2. Survey on existing simulation models and identification of interfaces and gaps on technologies and energy supply systems (focus on solar thermal)

A.2.3. Comparative assessment of simulation models (similar round robin) for different thermal separation technologies as well as models for the simulation of entire solar and waste heat supply systems

A.2.4. Introduction of different system designs (treatment technology and solar heat supply, incl. back-up/synergy with excess heat) for different applications as basis for comparative simulation studies

A.2.5. Definition of “key performance indicators” (KPI) to compare performances of different systems (separation and energy supply) on a same basis

A.2.6. Comparison of experimental results and simulation results on basis of key performance indicators

A.2.7. Economic assessment of solar thermal driven technologies and their implementation

A.2.8. Technology design, best large-scale design of technologies (incl. collector as membrane reactor)

A.2.9. Presentation and dissemination of results to attract industry for R&D support and project initiation

A.3. Evaluation and dissemination of results

A.3.1. Evaluation of demonstration projects and related R&D results (close link to Subtask C) – identification of further R&D needs

A.3.2. Summary of results and lessons learned in a report

A.3.3. Conduction of workshops with industry (producing industry, separation technology supplier, solar thermal technology)

A.3.4. Networking with e.g. national and European industry associations

Deliverables

No.	Deliverable	Month
D.A1	Matrix of different industrial separation demands to be subjected to cutting edge thermal technologies versus availability of different low exergy heat sources	24
D.A2	Definition of future R&D demand	30
D.A3	Specification of System design and key performance indicators as basis for comparative simulation studies	12
D.A4	Summary of results from comparative simulation calculations	36
D.A5	Report on new solar thermal collectors' concepts/for industrial water treatment. Potential link with photocatalytic solar water treatment	42
D.A6	Summary of technical and economic studies to hand out and present to industry	45
D.A7	Summary report on lessons learned from demonstration projects and recommendations on best practices	46
D.A8	Conduction of, or participation in of 3 workshops initiated by the IEA activities	16 /32 / 48
D.A9	Set up of a reliable and sustainable crosslinked network of industry and academia	48

Milestones

No.	Milestone	Month
M.A1	Target group of industries and potential customers which are most suitable for the implementation of solar thermal separation processes is identified	12
M.A2	Technological, legislative, economic and socio-economic challenges and hurdles for market uptake of new (targeted) separation technologies are identified	18
M.A3	R&D demand for different technologies and applications is specified	24
M.A4	Boundary conditions including technology set up and KPIs for comparative simulation and experimental studies are set	11
M.A5	Simulation studies and experiments are finalized and ready compiled for dissemination	35
M.A6	The task group successfully organised or contributed to 3 workshops	44

Subtask B: Solar Water Decontamination and Disinfection Systems

Lead: Isabel Oller, (Sixto Malato, Manuel Ignacio Maldonado e Inmaculada Polo), *Plataforma Solar de Almería-CIEMAT, Spain*

Participants: Klaus Hennecke, Jürgen Kern, Dirk Krüger, Christian Sattler, *German-Aerospace-Center, Germany*

Objectives

The main objective of this subtask is the **elaboration of emerging process technologies with increased efficiency which can render process technologies much more efficient due to integration of solar radiation, as it also may affect the quality of the conversion process under study.** The most prominent example is waste water treatment. But also, many chemical processes could benefit from the direct use of solar radiation.

The definition of new solar collectors' concepts for reducing manufacture costs though maintaining high efficiency in the collection of UV photons for better performance of chemical oxidation reactions according to the specific operation requirements should be tackled in close collaboration with technology providers companies.

Specific objectives:

- To provide a deep analysis on the energy reduction potential associated to the application of solar based processes to the industrial water management system. (Electrical consumption associated to UV lamps will be also considered)
- To deal with research questions like fluid dynamics, reactor design, etc. to optimize the purification results as well the energy consumption
- To promote collaborative initiatives for assessment of technical and economic feasibility of specific water decontamination and disinfection problems
- Identification of treatment processes of other water-based streams (e.g. in the bio-based and agro-food industries) that could potentially benefit from direct solar/UV radiation
- To initiate the development of new collector technologies
- To promote tools and services in this area to accelerate the market penetration.

Activities

The Subtask B will basically contain **four Activities:**

B.1. Solar Photocatalytic systems for industrial process water and wastewater treatment

B.1.1. To provide a comprehensive description of the state-of-the-art and potential applications of solar water decontamination and disinfection systems in industrial water management.

B.1.2. **Development of new photocatalysts for both homogeneous and heterogenous photocatalytic processes** to speed up the degradation and disinfection process under solar radiation, thus reducing the irradiated surface and making process more competitive with conventional processes/technologies.

B.1.3. **Membrane solar photocatalytic systems for industrial wastewater treatment and reuse.** The hybrid systems coupling photocatalysis and membrane processes have attracted great attention. In order to commercially implement TiO_2 photocatalytic membranes, the configuration of the membrane reactor needs to be better designed so the exposure of the membrane surface to the UV lamp should be optimized, besides of the use of solar light instead of UV light.

Great effort has been devoted to develop photocatalytic inorganic membranes consisting of nanophotocatalysts (normally nano-TiO_2 or modified nano-TiO_2). Ceramic membranes offer advantages over organic polymer membranes e.g. they are stable to higher temperatures and in a wide pH range, they do not decompose or swell like plastics and they are much harder and more resistant to abrasion. In addition, ceramic membranes are stable under UV exposure and in an oxidative environment, which is essential since photocatalysis produces reactive oxygen species. Organic polymer membranes are not stable under these conditions.

B.2. Solar photocatalytic production of hydrogen

B.2.1. To provide a comprehensive description of the state-of-the-art and potential applications of solar photocatalytic production of hydrogen coupled to water decontamination.

B.2.2. Solar photocatalytic production of hydrogen with simultaneous removal of organic pollutants. Analysis of new photocatalytic materials prepared and tested for such specific application.

Many efforts have been directed in recent years to generate hydrogen from renewable resources. In particular, in the last decades, different photocatalytic systems for hydrogen generation with simultaneous removal of organic pollutants have been studied at laboratory scale but, so far, little has been published about these systems at a larger scale and based on solar energy technologies.

B.2.3. Design of new solar collectors specifically adapted to hydrogen production combined with wastewater treatment.

B.3. Solar driven new thermochemical technologies

B.3.1. Solar driven new thermochemical technologies (low-medium temperature up to 300 ºC) for specific industrial wastewater treatment.

Wet air oxidation (WAO) is a technology used to treat the waste streams which are too dilute to incinerate and too concentrated for biological treatment. It can be defined as the oxidation of organic and inorganic substances in an aqueous solution or suspension by means of oxygen or air at elevated temperatures and pressures either in the presence or absence of catalysts. According to this method, the dissolved or suspended organic matter is oxidized in the liquid phase by some gaseous source of oxygen, that may be either pure oxygen, or air. The usual temperature range, 150–320 °C, requires high pressure to maintain a liquid phase. Typical conditions for WAO are 150–320 °C for temperature, 2–15 MPa for pressure, and 15–120 min for residence time; the preferred chemical oxidation demand (COD) load ranges from 10 to 80 kg/m^3. For instance, emulsified wastewaters, containing non-biodegradable substances have been reported to be easily converted into biodegradable by WAO.

B.4. Application and awareness

B.4.1. Integration of solar water decontamination and disinfection technologies driven with solar thermal energy with membrane separation technologies for recovery of nutrients and products/wastes with added value.

B.4.2. Design of new solar collectors for industrial wastewater decontamination and disinfection for reusing purposes in the own industrial process.

The installation of PV for renewable electric supply of such new integrated technologies should be considered.

B.4.3. Awareness and dissemination for solar industry

Awareness raising for emerged process technologies. Describing how solar technologies are being applied in this context and showing advantages and market potential for companies of solar industry

Deliverables

No.	Deliverable	Month
D.B1	Report on existing solar based technologies applied to industrial water decontamination and disinfection (real and research cases). Potential applications on industrial new sectors	18
D.B2	Report on new solar collectors' concepts/design for hydrogen production and industrial water decontamination and disinfection. Potential link with thermal technologies	36
D.B3	Roadmap for technology implementation for defined applications and industries	36
D.B4	Technological, economic and political barriers for up-scaling new decontamination and disinfection systems for industrial water and wastewater management and reuse	22
D.B5	Report on legal thresholds for accomplishing water quality required depending on the final application	30
D.B6	Marketplace/Fair (tbd if virtual)	24

Milestones

No.	Milestone	Month
M.B1	Roadmap on successful practical cases: Solar energy-based technologies applied to industrial water decontamination and disinfection for reusing purposes	18
M.B2	Report on integrated activities between subtasks	24
M.B3	Summary of legal and economic barriers for the implementation of new technologies/procedures for industrial water and wastewater management and inclusion in the market.	30
M.B4	Electronic platform (or database) for connecting potential end-users with technology providers	48

Subtask C: System integrations and decision support for end user needs

Lead: Prof Mikel Duke, *Victoria University, Australia*

Objectives

The main objective of subtask C is to develop a **guideline for decision support, designed purposefully for end users/technology adopters, who wish to achieve a certain practical outcome**. The work within this Subtask and the development of the guideline will build on the results of IEA SHC Task 49/IV where among others an integration guideline for solar heat into industrial processes was developed[2]. The guideline of this Task will refer to water process solutions, with examples, that principally harness solar thermal energy. The end user may be an industry such as a manufacturer or foods producer or water utility operating a wastewater treatment plant. Solar thermal energy will be a key focus, but will also consider excess industrial heat where possible, due to its abundance and ability to minimise use of more expensive solar collectors to improve technology cost viability. The practical outcomes of interest will be assessed in the project in consultation with industry experts, which could include needing to deal with matters such as removing contaminants from wastewater prior to environmental/sewer disposal or reuse. This may be achieved by the proposed technologies by contaminant destruction (e.g. organic mineralisation), isolation/purification for potential sale as a valuable product or by reducing its volume to enable more convenient disposal. In keeping a narrow focus on solar driven technologies, acknowledgement of other technologies will be included respecting their benefits such as maturity and/or efficiency. Technologies investigated in more detail will be an important feature in the proposed guidelines produced in this subtask.

Where possible, the SHIP Database[3], which was also developed within Task 49/IV, will be utilised or potentially built on present working examples of processes that are utilising a solar driven process to meet a treatment need or produce a valuable product. A key feature of the work will be to connect the process need to a technology solution; for example, removal of carbon (biological oxygen demand) from a wastewater using solar thermal reactor. Selection criteria can include options better suited to where the industry is located, such as in an urban region serviced by a sewer system that is charged for use by a utility which will have different treatment process requirements compared to one in a remote/isolated region where environmental discharge occurs.

Aspects to be weighed up include technology maturity/readiness, range (e.g. types of solar thermal collectors), reliability or operation continuity (e.g. 24/7 for municipal water treatment or 5-day operation with peaking/variable flows/compositions). Companies providing technology solutions will be contacted to provide information on their products and working examples.

[2] Muster B., Hassine I. B., Helmke A., Heß S., Kummenacher P., Schmitt B., Schnitzer H. (2015), Integration Guideline, Deliverable B 2, IEA SHC Task 49, Solar Process Heat for Production and Advanced Applications, <task49.iea-shc.org/data/sites/1/publications/150218_IEA%20Task%2049_D_B2_Integration_Guideline-final1.pdf> accessed 23/05/2018.
[3] http://ship-plants.info/

The output will be a publication (print and/or online database) containing a decision-making framework for selecting solar thermal technologies to achieve a desired outcome. The target audience includes industry (plant operators), consultants, governments/councils, and potentially farm operators or house owners. The aim is to show viable and innovative solutions to particular needs in treating wastewater or capturing valuable products.

Activities

The Subtask C will basically contain **four Activities:**

C.1. Literature and market review report on established and emerging technologies

C.1.1. Investigate information provided from other subtask leaders

C.1.2. Contact external partners including companies to gather information on current examples, established technologies and emerging technologies.

C.1.3. Compile information into summary report that isolates the technologies by parameters including current suppliers, maturity, solar thermal, photocatalytic or other, relative cost information and variants.

C.1.4. Demonstration of interlink between energy and water in industry (applied technologies and synergetic use)

C.2. Draft solar thermal energy guidelines/decision making tool

C.2.1. Interview industry experts to develop list of questions from end user needs, establishing the inputs to the decision-making tool

C.2.2. Map of technologies as proposed solutions to end user questions, including weighting/metrics around maturity, cost, efficiency, reliance on other technologies, etc. Define boundaries of the decision-making tool. Utilise findings from other tasks, especially Subtask A matrix, to prepare map to end user.

C.2.3. Development of integration and complete solar process heat system concepts considering the separation and purification technologies in combination with solar thermal technologies, other renewable energies and excess heat from industrial processes

C.2.4. Propose draft decision-making framework/guidelines

C.3. Final solar thermal energy guidelines/decision making tool

C.3.1. Distribute draft to experts for feedback on relevance and ease of use

C.3.2. Consolidate feedback and revise guidelines

C.3.3. Finalise into publishable report/book

C.4. Dissemination

- C.4.1. Prepare material for dissemination including flyers, media releases (including social media) and conference presentations.
- C.4.2. Guidelines external consultation and revision
- C.4.3. Present at workshop organised for the task
- C.4.4. Organizing industry days and expert events
- C.4.5. Advertisement and involvement of industry to participate in TASK via conferences and trade fairs

<u>Deliverables</u>

No.	Deliverable	Month
D.C1	Report on technologies to be considered for guidelines	12
D.C2	Report on how water-energy nexus concept is actually being applied in the industry	20
D.C3	Report on draft version of guidelines/decision making tool	30
D.C4	Report on final guidelines/decision making tool	42
D.C5	Summary of media releases and workshop presentations	60

<u>Milestones</u>

No.	Milestone	Month
M.C1	Literature research and market review of established and emerging technologies completed	10
M.C2	Draft version solar thermal energy guidelines/decision making tool available	28
M.C3	Solar thermal energy guidelines/decision making tool completed	40
M.C4	Dissemination activities completed	59

6. Task Information Plan

The following documents and activities are planned during the Task work:

1. *Expert/Industry workshops*, during the Task duration, in conjunction with selected Task meetings, will be organised in the host country of the meeting. The defined target groups will be invited.

2. *National industry workshops* will also be organised by the national Task participants using the information gathered and the material produced during the Task.

3. Electronic e-mail n*ewsletters* targeted at the defined target groups will be produced and distributed through the IEA SHC Channels.

4. Part of the information and results produced by the Task can be made available through the Internet on the *IEA SHC Website*. Furthermore, relevant information, news and updates about the Task will be disseminated via *social media platforms* (Twitter, LinkedIn, etc.)

5. In general - the dissemination of results will take place at a national level and international level on conferences, work shops and in magazines and journals.

6. Electronic platform (or database) for connecting end-users with technology providers, maybe on http://wiki.zero-emissions.at Web-site, or as separate Website

7. Application examples gathered within the Task will be included in the SHIP Database (http://ship-plants.info/), which was developed within IEA SHC Task 49/IV.

7. Activity and Time Table Summary

The time schedule for the activities foreseen during the Task is given in Table 1.

Table 1: Time schedule

IEA SHC Task - Solar Energy in Industrial Water and Wastewater Management	Year 1												Year 2												Year 3												Year 4											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Project Management																																																
Subtask A: Thermally driven water separation technologies and recovery of valuable resources																																																
A.1. Analysis												M.A1						M.A2						D.A1 M.A3						D.A2																		
A.2. Assessment of concepts and best practices (flanked by R&D projects)											M.A4	D.A3																							M.A5	D.A4						D.A5						
A.3. Evaluation and dissemination of results																D.A8																D.A8												M.A6	D.A6	D.A7		D.A8/9
Subtask B: Solar Water Decontamination and Disinfection Systems																																																
B.1. Solar Photocatalytic systems for industrial process water and wastewater treatment																		D.B1 M.B1																														
B.2. Solar photocatalytic production of hydrogen																																				D.B2												
B.3. Solar driven new thermochemical technologies																																				D.B3												
B.4. Connections with other subtasks																						D.B4		D.B6 M.B2						D.B5 M.B3																		M.B4
Subtask C: System integration and decision support																																																
C.1. Literature and market review report on established and emerging technologies										M.C1		D.C1								D.C2																												
C.2. Draft solar thermal energy guidelines/decision making tool																												M.C2		D.C3																		
C.3. Final solar thermal energy guidelines/decision making tool																																								M.C3		D.C4						
C.4. Dissemination																																															M.C4	D.C5

Milestone Deliverable

Table 2 shows the level of efforts for the task participants. Totals are based on a number of 8 countries participating in the Task and a minimum of 3-4 participants in each Subtask.

Table 2: Level of efforts for the participants

Level of efforts for participants		2018 PM	2019 PM	2020 PM	2021 PM	2022 PM	∑ PM	# of Part.	Total PM	Total PY
Subtask A participant	Min. Rec.	1 2	5 10	5 10	5 10	4 8	20 40	4 10	80 400	6.7 33.3
Subtask B participant	Min. Rec.	1 3	6 12	6 12	6 12	1 2	20 41	4 10	80 390	6.7 32.5
Subtask C participant	Min. Rec.	0.2 0.5	4 8	6 10	6 10	1 2	17.2 30.5	3 7	51 210	4.25 17.5
Total	Min. Rec.	2.2 5.5	15 30	17 32	17 32	6 12	57.2 111.5		211 1000	17.6 83.3
Average participation per country	Min. Rec.	0.5 1	0.5 1	0.5 1	0.5 1		0.5 1			

Min. = Minimum effort required PM = Person Month
Rec. = Recommended effort PY = Person Year

Table 3 shows the level of efforts for the Subtask Leaders and the Operating Agent.

Table 3: Level of efforts for the Subtask Leaders and the Operating Agent

Level of efforts for subtask leaders and operating agent	2018 PM	2019 PM	2020 PM	2021 PM	2022 PM	Total PM	Total PY
Subtask A Leader (Joachim Koschikowski)	1	3	3	3	3	13	1.1
Subtask B Leader (Isabel Oller)	1	3	3	3	3	13	1.1
Subtask C Leader (Mikel Duke)	1	3	3	3	3	13	1.1
Operating Agent (Christoph Brunner) Task administration	1.5	5	5	5	5	21.5	1.8

7. Appendix

This appendix is not part of the formal Work Plan. It consists of material from the Task definition phase.

Contributors

Following Institutions and companies were contacted and mainly a positive feedback for contribution was received.

Australia

- Activated Logic
- Australian PV Institute Limited
- Commonwealth Scientific and Industrial Research Organization (CSIRO)
- Future Industries Institute
- James Cook University
- Macquarie University
- Monash University
- NEP Solar Pty Ltd
- Pinches Consolidated Industries
- Queensland University of Technology
- SunSpin Pty Ltd
- Sustainable Energy Transformation Pty Ltd
- University of New South Wales
- University of South Australia
- University of Technology Sydney

Austria

- Johannes Kepler University Linz
- S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbH

Brazil

- Universidad Federal de Uberlândia
- Universidade Federal do Oeste da Bahia

China

- Jiangsu Product Quality Testing & Inspection Institute
- YUBO Shandong Yuanbeo Environmental Protection Equipments Co., Ltd.

Cyprus

- GAIA-Laboratory of Environmental Engineering, University of Cyprus

Denmark

- Acron-Sunmark GmbH

Germany

- BFI
- EvCon, Germany
- Industrial Solar GmbH
- SolarSpring
- Technical University of Berlin
- Technical University of Bremen
- University of Hannover
- University of Kassel

Greece

- Centre for Research and Technology Hellas-CERTH
- Centre for Renewable Energy Sources and Saving; Solar Thermal Department
- Middle East Technical University

Italy

- CNR-ITM
- CNR-INO
- ENEA
- University of Salerno
- University of Palermo
- Università degli Studi di Firenze; Dipartimento di Ingegneria Industriale

Netherlands

- Aquastil
- SolarDew International

South Africa

- North-West University, Potchefstroom, South Africa (Dave Rodgers, Jan van Ravensvaai)

Spain

- ACCIONA (Water/Energy)
- APRIA SYSTEMS (Consistent, comprehensive and operational solutions for the Chemical Industry)
- CIESOL-Universidad de Almería
- ECOSYSTEM Environmental Servicies S.A.
- GAIKER-IK4
- IMDEA Water
- Universidad Autónoma Barcelona
- University of Barcelona
- Universidad Politécnica de Valencia. Campus Alcoy
- Universidad Rey Juan Carlos, Madrid

Sweden

- Absolicon Solar Collector AB

Switzerland

- École Polytechnique Fédérale de Lausanne
- SPF Institut für Solartechnik

United Arab Emirates

- Masdar Institute

Task Definition Meetings and Webinar

The first task definition meeting was held on 18 September 2017 in Gleisdorf, Austria. Table 4 shows the participants of the meeting.

Table 4: Participants of 1st Task Definition Meeting

Name	Surname	Company / Institute	e-mail	Attending
Christian	Sattler	DLR	Christian.sattler@dlr.de	present
Mikel	Duke	Victoria University	Mikel.Duke@vu.edu.au	via Skype
Andreas	Häberle	SPF	andreas.haeberle@spf.ch	present
Joachim	Koschikowski	F-ISE	Joachim.Koschikowski@ise.fraunhofer.de	present
Isabel	Alberola	CIEMAT PSA	Isabel.oller@psa.es	present
Anna	Grubbauer	AEE INTEC	a.grubbauer@aee.at	present
Judith	Buchmaier	AEE INTEC	j.buchmaier@aee.at	present
Jürgen	Fluch	AEE INTEC	j.fluch@aee.at	present
Christoph	Brunner	AEE INTEC	c.brunner@aee.at	present
Bettina	Muster-Slawitsch	AEE INTEC	b.muster-slawitsch@aee.at	via Skype
Hendrik	Müller-Holst	Evonik	h.müller-holst@evonik.at	yes
Xiwang	Zhang	Monash University	x.zhang@monash.at	via Skype
Yunchul	Woo	Unviersity of Technology Sidney	y.woo@unviersity.at	via Skype
Xabier	Olano	CENER	x.olano@cener.at	via Skype
Daniela	Fontani	CMR	d.fontani@cmr.at	via Skype

The second task definition meeting was held on 7 February 2018 in Frankfurt, Germany. Table 5 shows the participants of the meeting.

Table 5: Participants of 2ndTask Definition Meeting

Name	Surname	Company / Institute	e-mail	Attending
Isabel	Oller	CIEMAT	Isabel.oller@psa.es	person
Joachim	Koschikowski	FISE	Isabel.oller@psa.es	person
Christoph	Brunner	AEE INTEC	c.brunnere@aee.at	person
Bettina	Muster-Slawitsch	AEE INTEC	b.muster-slawitsch@aee.at	person
Bastian	Schmitt	Universität Kassel	b.schmitt@universität.at	person
Dirk	Krüger	DLR	d.krüger@dlr.at	person
Junkal	Landaburu	IMDEA Water	j.landaburu@imdea.at	person
Javier	Marugán Aguado	Universidad Rey Juan Carlos	j.marugán aguado@universidad.at	person
Joakim	Byström	Absolicon	j.byström@absolicon.at	person
Ralf	Wolters	BFI	r.wolters@bfi.at	person
Antonio	Arqués	Universidad Politécnica de Valencia, Campus Alcoy	aarques@txp.upv.es	person
Rosie	Christodoulaki	Centre for Renewable Energy Sources and Saving; Solar Thermal Dep.	christodoulaki@cres.gr	Webex
Daniela	Fontani	Instituto Nazionale di Ottica	daniela.fontani@ino.cnr.it	Webex
Fabrizio	Vicari	University of Palermo	fabrizio.vicari01@unipa.it	Webex

On 9 May 2018 a Webinar was hold to introduce the task and its objectives. Table 6 shows the participants of the Webex Webinar.

Table 6: Participants of Webinar

First Name	Last Name	Organization	Email Address
Jose Ignacio	Ajona Maeztu	Seenso	jose.ignacio.ajona@seenso.es
Diego	Alarcón-Padilla	CIEMAT-Plataforma Solar de Almería	diego.alarcon@psa.es
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Sara	Dominguez	APRIA Systems	comercial@apriasystems.es
Daniela	Fontani	CNR-INO	daniela.fontani@ino.cnr.it
Fernando	Fresno	IMDEA Energy Institute	fernando.fresno@imdea.org
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Raldo	Kruger	GreenCape	raldo@greencape.co.za
Javier	Marugán	Universidad Rey Juan Carlos	javier.marugan@urjc.es
Giacomo	Pierucci	Dipartimento di Ingegneria Industriale di Firenze	giacomo.pierucci@unifi.it
Javier	Pinedo	APRIA Systems	javier.pinedo@apriasystems.es
Luigi	Rizzo	University of Salerno	l.rizzo@unisa.it
Guillermo	Zaragoza	Plataforma Solar de Almería - CIEMAT	guillermo.zaragoza@psa.es