



TASK 60

PVT SYSTEMS

Application of PVT collectors and new solutions in HVAC systems

ANNEX

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1. Definitions

(a) Description of Technical Sector

Solar markets are subject to a shift from solar thermal solutions to solar photovoltaic (PV) solutions since 3 years mainly due to cost reductions in PV systems, simplicity of installation and versatility of electricity. This must not be forever since solar thermal has huge advantages in terms of efficiency and of storage. Well designed “PVT technologies” have the potential to combine the best of the two systems in an hybrid system.

The combination started in early 2000 but the products were lacking reliability, were much too expensive and the heat pumps were not a big market yet. There has been new industrial development in PVT collectors continuously and systems using PVT and heat pumps are in line to compete with other renewable technologies.

These developments open up new possibilities in the field of PVT collectors and applications. Today, the integration of different renewable energy components into systems is much more in the focus than the further development of the basic components of the different technologies (i.e. solar thermal collectors, PV-panels, heat pumps, bore hole storages etc.). This intensification of renewable energy system aspects provide a broader basis for the PVT technology as it offers - and often even requires - more possibilities to provide heat and electricity at the same time to a system and to store the daily production of solar energy.

PVT systems start to be found in many applications: one family houses, dwellings, industrial processes and even district heating. The collector must combine PV technology with a thermal component, working with air or liquid, with a front cover or not, and even it can be under light concentration. To support this emerging market for solar industries, an IEA Task is welcome by the industry and was asked at several occasions in international conferences (Eurosun, OTTI symposium).

(b) Definitions

A PVT collector is a solar device able to provide both heat and electricity.

A PVT collectors field is a field with arrays of PVT collectors in line that are operated as one central large PVT collector.

A PVT system is an installation able to provide heating, cooling and electricity along the year to any consumer (building, process, network, grid) at a suitable temperature and voltage. The electricity can be internally consumed, or delivered to a grid.

Optimizing a PVT systems means delivering the maximum of solar energy over a year at a minimum cost of kWh or maximizing the solar energy production for a given surface area of collectors on a roof. This comprises both heat and electricity.

(c) Scope

The development of new PVT collectors is a matter of the industrial sector and new collectors are on the market with industries willing to participate in our IEA activity.

The proposed project will therefore concentrate on the application of PVT collectors. The aim is to assess existing solutions and to develop new system solutions principles in which the PVT technology really offers advantages over classical “side by side installations” of solar thermal collectors and PV modules. Energy production, competitive cost, safety and reliability of systems are therefore in the scope of our Task.

Two obvious recent developments of influence towards this direction may be mentioned here:

1. Strong and increasing interest in Building Integrated PV (BIPV) and Façade integrated PV (FIPV) not only in office buildings but also in dwellings where electricity and heat is required.
2. The positive development of heat pumps opens up many more possibilities to make use of the low exergy heat source of uncovered PVT collectors and reduce the energy cost for the user.

The scope is therefore focused on applications with PVT collecting devices in systems of any size and any type of consumers. This will depend on the participants' projects. But the Task will also work on finding the best applications boundaries for PVT collectors.

2. Purpose and Objectives

The objectives of the Task are to:

1. Provide an overview on the present (2018-2020) state-of-the-art of the PVT technology worldwide, in all types of climates.
2. Gather the results and the operating experience made with the systems in which PVT collectors are integrated and in PVT collectors fields.
3. Improve the testing, modeling and adequate technical characterization of PVT collectors in order to enhance (and simplify) the correct inclusion of the PVT technology in simulation programs and planning tools.
4. Address all types of PVT collectors since the current markets have made no clear choices.
5. Find more typical PVT solutions beside the two applications which are well known, i. e. (1) regeneration of bore-hole storages and (2) pre-heating of DHW for multi-family houses. The aim of the Task is to identify other possible solutions which are relevant under other framing conditions (weather conditions, building regulations, electricity regulations and tariffs) or applications in process plants which require heat and electricity (thermally driven desalination systems may be mentioned as an example, or space heating with heat pump and ice storage, high cooling loads in arid climates).
6. Explore potential cost reductions in the balance of systems (BOS), i. e. piping technology and materials, hydraulics, controls etc.

The main goals of the activity will be to:

PVT Collectors:

- Improve knowledge of current collectors and evaluate their risks
- Improve collector designs and cost
- Improve collectors and collector fields design for hot and humid climate with mostly a cooling demand (The PV production is highly impacted by high collector temperature)
- Improve PVT collectors modelling
- Provide a basis for the comparison of collectors with respect to technical and economical conditions.
- Give useful recommendations for standardized testing procedures and pave ways to new standards if needed

PVT applications:

- Identify current PVT examples
- Identify most interesting PVT applications in all type of climates
- Develop system models
- Validate models against monitored systems
- Improve the PVT collection efficiencies and/or economics

Design Guidelines, Case Studies and Dissemination:

- Provide a large overview of results and experiences from PVT solutions in order to lower the barriers for market deployment and to disseminate the knowledge to all target groups.
- Support current industry and future project stakeholders by providing design guidelines and definition of performance assessment of the hybrid PVT technology (using also methods developed in other Tasks like Task 54)
- Investigate risks in stagnation behaviour, control and hydraulics of PVT systems.

Connections to other SHC Tasks

The PVT activities are connected to several SHC Tasks such as:

- Task 58 about thermal storage: the storage solutions are part of a PVT system to optimize.
- Task 57 about standardisation: the PVT industry need common standards and in all types of climates.
- Task 56 about Building solar envelope systems: the PVT collectors can be part of a productive skin of a modern building.
- Task 54 about Price reduction in solar systems: the combination of PV and T can be a way to reduce the cost of a kWh delivered to a building.
- Task 53 about solar cooling with new generation of systems: the PVT collectors and systems can be well suited for cooling purposes in hot and humid climates delivering a source of power together with an heat exchanger for heat rejection but with a penalty on the PV generation.
- The outcome of Task 52 about solar energy in urban networks will be worked on to catch the main recommendations if applicable for PVT solutions.

- And past Tasks such as Task 35 (PV/Thermal systems) from which we will re-read and use the outcome of the published documents still available on the IEA SHC web site.

Collaboration with other TCPs

A “minimum level of collaboration” with PVPS programme will be organized since PVT collectors are also of interest for a PV strategy worldwide. A common workshop could be organized at some international conference.

Contacts with the heat pump programme (HPP) will be organized since the OA has already worked with this TCP with Task 44 (Solar and Heat pump systems).

3. Activities

(a) Main activities

- PVT collectors assessment
- PVT collectors testing
- PVT collector fields testing
- PVT collectors modeling
- PVT systems evaluation for all kinds of final energy use
- PVT simulation tools
- PVT Design Guidelines, Case Studies and Dissemination

(b) Sub-activities

The activities will be performed in 4 subtasks:

Subtask A: PVT systems in operation

- A1. Inventory and information data sheet on existing PVT systems and solutions on the market
 - Identify market segments and examples of PVT systems in those segments (Housing, BIPV, Industrial, District heating, ...)
 - Define reporting formats and Key Performance Indicators for PVT systems and applications in all market segments
 - Gather systems description and specifications
 - Gather and prepare monitoring data at least for 1 year on all examples
 - Classify the examples in term of quality of data (best, average, bad)
 - Build a data base of data for subtask D validation mission
- A2. Comparison of systems with respect to technical and economical considerations (with Subtask D)
 - Project achievement
 - System Design principles both for PV and T
 - Industrial approach
 - Economical performance
 - Energy performances
 - Operating conditions
 - Stagnation risks
 - Maintenance Issues
 - Reports failures and barriers in the development of projects
 - Life cycle considerations

- Recycling possibilities

- A3. Comprehensive recommendations for improvements of future PVT systems
- Provide recommendations for designing, operating and maintaining, monitoring of PVT systems
 - Provide a basis for the standardized comparison of systems
 - Provide recommendations for testing procedures

Subtask B: PVT Performance characterization

B1: Describe or develop standardized method for testing all kinds of PVT collectors and for reporting the characteristic curves, based on existing or new standards or data

- Current standards for PV collectors
- Current standards for T collectors
- Current standards or practice for PVT collectors and gap analysis
- Alternative ways and methods to test PVT collectors and report performances (literature, ideas,...)
- Proposed standards for PVT testing and reporting for all types of collectors: water, air, concentrated.

B2: Consider equations and methods for testing day time and night time operations of PVT collectors and systems if necessary

- Current used equations and gap analysis
- Current methods to test PVT collectors
- Proposed new equations to take care of all parameters and observations for all types of PVT collectors, for combined heat and electricity production.
- Differences between day and night operations, with and without heat pumps
- Equations at system level if different than at component level. Influence on simulation models.

B3: Develop definitions of PVT systems efficiency

- Current definitions in standards and practice (at system level)
- Gap analysis between current and need
- Proposition of a set of equations defining the PVT system efficiency to be implemented in Subtask C models.

B4: Design Guidelines

- Analysis of current literature and gaps
- Make comprehensive recommendations to designers of PVT collectors based on observations during testing
- Publish them on internet with Subtask D

Subtask C: PVT Systems Modeling

C1: Numerical Simulation Tools for the simulation of PVT collectors based on Subtask B results

- Current tools to simulate PVT collectors: list and features
- Gap analysis compared to Subtask B recommendations
- Tool development for a PVT collector model in simulation models like Trnsys or equivalent

- C2: Numerical Simulation Tools for the simulation of PVT systems based on Subtask B recommendations for definitions of efficiency
- Current simulation tools for systems with PVT production (Trnsys, Polysun, etc...): features
 - Gap analysis with Subtask A and B recommendations
 - Tool development or modification or adaptation to be able to simulate Subtask A projects under Subtask B definitions requirements.
- C3: Simulate existing PVT systems monitored in Subtask A and validate the tools
- Simulation Subtask A projects with local weather data
 - Compare to monitored results
 - Gap analysis
 - Validation of simulation tools with parameter and/or model adjustment – Feedback to Subtask B
 - Publication of results with Subtask D
- C4: Conduct sensitivity analyses on simulated systems to find and report optimal solutions, including control strategies
- Sensitivity analysis after validation: parameters variations
 - What could have been done better in the project ?
 - Looking for a more optimal performance solutions in the boundary conditions of the real project.
 - Recommendations for future projects and applications in PVT
- C5: Find most efficient systems in different market segments through simulations and conduct economical analysis if possible
- Define relevant market segments with Subtask D
 - Design best in class solutions for each segment and plant sizes (2 or 3 classes)
 - Simulate the solutions with a validated tool from C4
 - Find optimal solution and energy and economical performances of the best solution for each segment / size

Subtask D: PVT Systems design examples and dissemination and market support

- D1: Define performance assessment methodology for PVT systems and all KPIs necessary and useful.
This activity is important for evaluating PVT systems solutions and comparing them. A set of KPIs or criteria is needed for an assessment and can be derived also from other SHC Tasks that have tackled a similar problem (Task 44, Task 53).
- D2: Use the methodology to assess PVT systems of Subtask A, with a relevant reference as benchmark.
All systems described and followed in Subtask A that have sufficient relevant data and information to be assessed comparatively should be studied here. For comparison purposes, a reference case should be defined. This is a difficult mission since a reference solution can mean different visions for different countries (is it a gas boiler, a heat pump, a PV + T solution or else ?). The reference case is a system that delivers the same quality of energies to a demand but is more current practice than the newer PVT solutions.

D3: Analyze best control strategies for PVT systems with economical boundaries (with Subtask C and B) and provide recommendations to the industry.

For best solutions identified in E2, it can be possible to refine or simplify the control strategy to get to better results in terms of some of the performance KPIs. This activity will pick up a few systems to look for more advanced control concepts if this is possible and relevant, using new IT technologies for instance and big data algorithms.

D4: Prepare and manage industry workshops

When our meetings are in conjunction with solar conferences in a particular country, industry workshops on PVT solutions will be organized. At the SPF dedicated PVT workshops can also be set up during one of our working years, probably the last one to present more results. This will also be done during SHC conferences as stated under (c).

D5: Prepare documentation for industry and market and disseminate documentation and task results along the course of the Task.

This activity is important to make understandable and useful for a broad audience the outcome of all the other Subtasks. Format should be similar and ease of reading is also required.

(c) *Workshops*

Industry workshops will be held in conjunction with some of the Task meetings if the meeting is linked to a national or international conference. The workshops will be organised in the host country of the meeting and all relevant target groups will be invited. It can also be sessions dedicated to PVT in international conferences.

(d) *Publications/Newsletters*

The overall scope and objectives of the Task and the different Subtasks will be described on the Task Website. In addition to the publication of scientific results in conferences, journals and magazines, printed leaflets will be distributed to describe the scope of the Task.

4. Expected Results/Deliverables

On top of individual publications and reports from the participants, the common deliverables, allocated by subtasks, will be the following:

Subtask A: PVT systems in operation

R1. Report A1: Collection of data sheet on existing PVT systems and solutions

R2. Report A2A3: Comparison of systems with Subtask D with recommendations for improvements of future PVT systems

R3. Subtask report with management issues

Subtask B: PVT Performance characterization

R1: Report B1B2B3: methods for testing PVT collectors (water, air, concentrator,...) with measured results and day time and night time operations, and definitions of PVT systems efficiency

R2: Design Guidelines for PVT collectors and systems

R3: Subtask report with management issues

Subtask C: PVT Systems Modeling

R1: Report C1C2: Numerical Simulation Tools for the simulation of PVT collectors and systems

R2: Report C3: PVT systems simulation and validation

R3: Report C4C5: Optimised PVT systems

R4: Subtask report with management issues

Subtask D: PVT Systems design examples and dissemination and market support

R1: Report D1D2: performance assessment of PVT systems

R2: Report D3: Control strategies for PVT systems

R3: Report D4D5: Collection of documents prepared along the Task for industry and market

R4: Subtask report with management issues

5. Rights and Obligations of Participants

In addition to the obligations enumerated in Article 4 of the Implementing Agreement:

(a) Each participating institution/company shall provide the Operating Agent with detailed reports on the results of the work carried out for each Subtask;

(b) Each participating institution/company shall collect, assess and report to the Operating Agent data on solar heating systems for industrial applications in his country; and

(c) Each participating institution/company shall participate in the editing and reviewing of draft reports of the Task and Subtasks.

(d) *Operating Agent Meetings*

Each country will bear the costs of its own participation in the Task, including necessary travel costs. The cost of organising meetings will be borne by the host country.

(e) *Individual Financial Obligations*

Aside from providing the resources required for performing the work of the Subtasks in which they are participating, all Participants are required to commit the resources necessary for activities which are specifically collaborative in nature and which would not be part of activities funded by national or international sources. Examples include the preparation for and participation in Task meetings, co-ordination with Subtask Participants, contribution to the documentation and dissemination work and Task related R&D work which exceeds the R&D work carried out in the framework of the national (or international) activity.

(f) *Task-Sharing Requirements*

The Participants agree on the following funding commitment:

- 1) Each Participant (country) will contribute to this Task a minimum of 3 person-months per year of the Task.
- 2) Participation in the Task requires participation in at least one of the Subtasks.
- 3) The Operating Agent will contribute with a minimum of 4 person-months per year to the Task (i.e., a total of 1.2 person-years for his/her work as Operating Agent).
- 4) The Subtask leaders shall commit a minimum of 3 person-month per year for the work of leading a subtask.
- 5) Participation may partly involve funding already allocated to a national (or international) activity that is substantially in agreement with the scope of work outlined in this Annex. Aside from providing the resources required for performing the work of the Subtasks in which they are participating, all Participants are required to commit the resources necessary for activities that are specifically collaborative in nature and that would not be part of activities funded by national or international sources. Examples include the preparation for and participation in Task meetings, co-ordination with Subtask Participants, contribution to the documentation and dissemination work and Task related R&D work which exceeds the R&D work carried out in the framework of the national (or international) activity.

6. Management

(a) Switzerland, acting through the JC Hadorn, is designated as Operating Agent.

(b) The Operating Agent's rights, obligations and responsibilities in addition to those indicated in the main body of the Implementing Agreement and the organisation of the work under this Annex enumerated in Section 5 of this Agreement, the Operating Agent shall:

- 1) Prepare and distribute the results mentioned in paragraph 4 above;
- 2) Prepare joint assessments of research, development and demonstration priorities for solar heating systems for industrial processes;
- 3) At the request of the Executive Committee, organise workshops, seminars, conferences and other meetings;
- 4) Prepare the detailed Program of Work for the Task in consultation with the Subtask Leaders and the Participants and submit the Program of Work for approval to the Executive Committees of the Solar Heating and Cooling Programme;
- 5) Propose and maintain a methodology and a format for the submission of information on solar heating systems for industrial processes which is collected by the Participants as described in paragraphs 3 and 4 above;
- 6) Provide reports semi-annually to the Executive Committees on the progress and the results of the work performed under the Programme of Work;
- 7) Provide to the Executive Committees, within six months after completion of all work under the Task, a final report for its approval and transmittal to the Agency;
- 8) In co-ordination with the Participants, use its best efforts to avoid duplication with activities of other related programmes and projects implemented by or under the auspices of the Agency or by other competent bodies;

- 9) Provide the Participants with the necessary guidelines for the work they carry out with minimum duplication;
- 10) Perform such additional services and actions as may be decided by the Executive Committees, acting by unanimity; and
- 11) Gather documents from Subtask Leaders, edit and distribute the output of the Task either as a printed handbook, electronically or on a Web site.
- 12) A Subtask Leader for each of the foregoing Subtasks will:
 - a. Co-ordinate the work performed under that Subtask;
 - b. Assist the Operating Agent in preparing the detailed Programme of Work;
 - c. Direct technical workshops and provide the Operating Agent with written summaries of workshops results and
 - d. Edit technical reports resulting from the Subtask and organise their publication.
 - e. Subtask leaders may arrange meetings in between or in association with Experts meetings of the Task.
- 13) The Subtask Leader shall be a Participant that provides to the Subtask a high level of expertise and undertakes substantial research and development in the field of the Subtask. The Subtask Leaders shall be proposed by the Operating Agent and designated by the Executive Committee, acting by unanimity of the Participants. Changes in the Subtask Leaders may be agreed to by the Executive Committee, acting by unanimity of the Participants.

(c) *Operating Agent's Meetings:* There will be Experts meetings of the Task at intervals of approximately 6 months. Subtask Leaders may arrange meetings in between or in association with Experts meetings of the Task. Attendance at the Experts Meetings of the Task will be mandatory.

(d) It is intended to organize expert / industry workshops every year, directly linked to Task meetings. The overall scope and objectives of the Task and the different Subtasks will be described on the Task Website. The server should be able to process an automatically distributed electronic newsletter.

Apart from publications of scientific results in conferences, journals and magazines we plan to distribute printed leaflets to describe the scope of the Task. Similarly, there is a recognized need to process information from worldwide stakeholders outside the Task, and to start educational missions to relevant countries in the developing and developed world.

7. Admission, Participation and Withdrawal of Participants

In addition to the specific obligations, the Operating Agent will produce, promote and distribute the results of the Task. The Participants will support these activities by contributing respective papers and by dissemination activities financed by the individual Participants.

8. Information and Intellectual Property

For purposes of this Annex, in case of conflict with the provisions of the Implementing Agreement, the following provisions shall prevail:

- a) For arising information regarding inventions the following rules shall apply:
 - 1) Arising information regarding inventions shall be owned in all countries by the inventing Participant. The inventing Participant shall promptly identify and report to the Executive Committee any such information

- along with an indication whether and in which countries the inventing Participant intends to file patent applications, and
- 2) Information regarding inventions on which the inventing Participant intends to obtain a patent protection shall not be published or publicly disclosed by the Operating Agent or the other Participants until a patent has been filed, provided, however, that this restriction on publication or disclosure shall not extend beyond twelve months from the date of reporting of the invention. It shall be the responsibility of the inventing Participants to appropriately mark Task reports that disclose inventions that have not been appropriately protected by filing a patent application.
- (b) The inventing Participant shall license proprietary information arising from the Task for non-exclusive use as follows:
- 1) To Participants in the Task:
 - a. On the most favourable terms and conditions for use by the participants in their own country; and
 - b. On favourable terms and conditions for the purpose of sub-licensing others for use in their own country.
 - 2) Subject to sub-paragraph above, to each participant in the Task for use in all countries, on reasonable terms and conditions; and
 - 3) To the government of any Agency Member country and nationals designated by it, for use in such country in order to meet its energy needs.

Royalties, if any, under licenses pursuant to this paragraph shall be the property of the inventing Participant.

9. Entry into Force, Term and Extension

This Annex shall enter into force on 1st January 2018 and shall remain in force for a period of 3 years/until 31st of December 2020. At the conclusion of that period, this Annex can be extended by at least two Participants, acting in the Executive Committee, for a period to be determined at that time, provided that in no event shall the Annex continue beyond the current term, or actual termination, of the Implementing Agreement.
