SOLAR PROCESS HEAT FOR PRODUCTION AND ADVANCED APPLICATIONS

WORK PLAN

Solar Heating & Cooling Programme Task 49

SolarPACES Programme Task IV

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

SolarPACES

OCTOBER, 2011

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Solar process heat for production and advanced applications

1 Task description

Background

Solar Heat for Industrial Processes (SHIP) is currently at the early stages of development. Less than 100 operating solar thermal systems for process heat are reported worldwide (as of 2009), with a total capacity of about 24 MW_{th} (34,000 m^2). Most of these systems are of experimental nature, and are relatively small scale. However, there is great potential for market and technological developments, as 28% of the overall energy demand in the EU27 countries originates in the industrial sector, majority of this is heat of below 250℃.

According to a study (Ecoheatcool 2006), around 30% of the total industrial heat demand is required at temperatures below 100℃ and 57% of the total industrial heat demand is required at temperatures below 400℃. The main part of the heat demand below 100℃ could theoretically be met with solar thermal systems using current technologies, if suitable integration of the solar thermal system can be identified. With technological development, more and more medium temperature applications up to 400℃ will also become market feasible.

In several specific industry sectors, such as food, wine and beverages, transport equipment, machinery, textiles, pulp and paper, the share of heat demand at low and medium temperatures (below 250℃) is around 60% (POSHIP 20 01). Tapping into this potential would provide a significant solar contribution to industrial energy requirements.

The methodology which has been developed in order to realize thermal energy supply in industry with minimal greenhouse gas emissions is based on a three step approach:

- Technological Optimization of the processes (e.g. increased heat and mass transfer, lower the process temperature) and solar thermal system (e.g. operation of solar field, integration schemes, control, safety issues etc.)
- System Optimization (enhancing energy efficiency using e.g. Pinch Analysis for heat exchanger network for a total production site)
- Integration of renewable energy/solar thermal energy (based on exergetic considerations)

In the last two years the awareness for solar process heat in the industry increased and some new solar thermal systems were installed. This positive development should be supported now by further research and development in the key research questions of solar process heat.

After completion of the IEA SHC/Solar Paces Task 33, key areas for further technological development, which should be treaded in the context of a new Task, were identified:

- Process heat collector development with heat loss control and maximization of energy collection
- Material research with improvement of components on a higher temperature level and better materials for concentrated optics

- Process heat collector testing for working temperatures above 100°C

The content of this new proposed project were defined based on this knowledge out of IEA SHC 33/Solar Paces Task IV and other position papers like the strategic research agenda of the European Solar Thermal Technology Platform and the experience of several national projects in the field of solar process heat.

Why an IEA SHC project?

The Solar Heating and Cooling Program of the International Energy Agency offers an ideal platform for international collaborative R&D work. Several added values can be identified in a collaborative, international project compared to a national one.
Participating countries benefit from the specific know-how of each of the other participants. A study of the international state-of-the-art and their potential has only to be done once. Tools, such as design or simulation programs can be exchanged as they can be similarly applied in the participating countries. An international project may be capable of bringing together a supplier of technology in one country and an interesting market in another country.
In this new field of solar thermal application, international co-operation is needed to analyse the potential, to develop new high performance components and adapted system designs as well as for the dissemination of the results of the joint effort. Collaborative work in the framework of the Solar Heating and Cooling Program is a proactive action that can also favour good systems in a reasonable period of time on a more global market than the national one.

Furthermore it was agreed to co-operate with the SolarPaces Program on a “maximum level” according to the SHC Guidelines for Co-ordination with other Programs.
At this level, the Task work is jointly defined, that is, the SolarPACES ExCo provides input to the Task Concept Paper and the Task Definition Phase. Once the Task is defined, the SHC ExCo will manage the Task. The ExCos of SHC and SolarPaces shall agree on any proposed revisions to the Task Work Plan once the Task is underway.
In the course of such collaboration, both ExCos may find that they have differing views on the definition of work. If the two ExCos agree to collaborate at this level, it is assumed that they will make every effort to resolve their differences. Such resolution implies that the SHC ExCo is willing to make changes in the Task Work Plan proposed by the SolarPACES ExCo.
To minimise the additional effort for the Operating Agent, the information exchange with the SolarPACES ExCo will be mainly through a representative participating in the Task and nominated by the SolarPACES ExCo. Experts may be from member countries of both ExCos.
Due to the complementary background and know-how of the participants of the two implementing agreements, significant synergies are expected from this collaboration. Whilst SHC is approaching the process heat sector from a range of lower temperatures and smaller plant sizes, SolarPACES has in the past, mainly focused on large scale, high temperature applications and on the development of new applications like solar chemistry. On the other hand, the implementation of concentrating solar technologies developed in SolarPACES have only just started to be integrated in process applications, whilst flat plate and vacuum tube collectors already can be found in several industrial applications, and standardisation and qualification issues have been comprehensively dealt with.

Joining both Implementing Agreement’s expertise will make it possible to select the most appropriate solar technology for specific applications from a comprehensive range of options (flat plate, vacuum tube, trough,..), and to avoid the re-invention of the wheel by the mutual exchange of know-how (high temperature solutions, standardisation issues,...). The broadened basis of manufacturers, scientists and potential customers will also increase the visibility of technology and applications. Since Task results will be disseminated through complementary contacts and communication channels, improved market opportunities for the technologies and methods developed in this Task 49/IV can be expected.

Main activities to be undertaken

Process heat collectors:

- Improvement of solar process heat collectors and collector loop components
- Comparison of collectors with respect to technical and economical conditions
- Comprehensive recommendations for standardized testing procedures

Process integration and Process Intensification combined with solar process heat

- Development of advanced pinch and storage management tool(s)
- Survey on integration methodologies for solar process heat
- Develop System concepts and integration guideline
- Survey and dedicated Workshop on new process technologies
- Identification of the increasing potentials and compendium of ongoing activities and existing pilot plants/case studies

Design Guidelines, Case Studies and Dissemination

- Design Guidelines
- Simulation Tools
- Performance assessment methodology
- Monitoring of demonstration projects and “Best practice” projects
- Dissemination of task results
- Market deployment
- Potential study

1.1 Scope of the Task

Applications, systems and technologies which are included in the scope of this task are:

- All industrial processes which are thermal driven and running in a temperature range up to 400℃
- Solar thermal systems using air, water, low pressure steam or oil as a heat carrier, i.e. not limited to a certain heat transfer medium in the solar loop.
- All types of solar thermal collectors for an operating temperature level up to 400℃ are addressed: uncovered collectors, flat-plate collectors, improved flat-plate collectors - for example hermetically sealed collectors with inert gas fillings, evacuated tube collectors with and without reflectors, CPC collectors, MaReCos (Maximum Reflector Collectors), parabolic trough collectors.
- Technologies for industrial application which can be driven by sunlight or specific spectrums (e.g. UV)

Specific process engineering technologies to which solar heat has to be supplied, such as the technologies for desalination of sea water, industrial cooling applications and electricity generation, are not the main focus of the Task. They may be considered to a certain extent if there is strong interest from industry.
For cooling applications, for instance, the work will be restricted to the adaptation of the results of SHC Task 38 to industrial applications.
The foreseen activities in the field of heat storage management will not deal with the development of storage technologies and the application of new storage materials. This work will be addressed in the IEA SHC Task 42 and its follow up activities.
There is a link of this IEA SHC Task to the activities in IEA SHC Task 45 “Large scale systems” due to the size of the solar thermal systems and the challenges faced by both

applications. The main differences of the planned Task 49/IV from the IEA SHC Task 45 can be seen in:

- Close interlink age between solar thermal system and industrial processes
- Combination of process intensification and solar thermal systems
- Dealing with new applications
- Different temperature levels (SHIP up to 400℃) an d more relevance on the development and application of concentrated systems
- Based on the higher temperatures different challenges on material, fluids, collector and components behaviour are considered
- Different stagnation behaviour due to batch processes and different hot storage management
- Detailed focus on industrial processes in combination with solar thermal collectors

1.2 Objectives and subtasks' organisation

The main goals of the activity will be to:
Process heat collectors:

- Improving solar process heat collectors and collector loop components
- Providing a basis for the comparison of collectors with respect to technical and economical conditions
- Giving comprehensive recommendations for standardized testing procedures

Process integration and Process Intensification combined with solar process heat

- Improved solar thermal system integration for production processes by advanced heat integration and storage management, advanced methodology for decision on integration place and integration types
- Increase of the solar process heat potential by combining process intensification and solar thermal systems and fostering new applications for solar (thermal/UV) technologies

Design Guidelines, Case Studies and Dissemination

- to provide a worldwide overview of results and experiences from solar heat for industrial process systems(including completed and ongoing demonstration system installations using monitoring data, as well as carrying out economic analyses) in order to lower the barriers for market deployment and to disseminate the knowledge to the main target groups involved
- to develop a performance assessment methodology for a comparison and analysis of different applications, collector systems, regional and climatic conditions
- to support future project stake holders by providing design guidelines, simplified fast and easy to handle calculation tools for solar yields and performance assessment
- to investigate system solutions for stagnations behaviour, control and hydraulics of large field installations

1.3 Participation from industry

There are several actors in the solar industry: engineering companies, manufacturers of solar components and the installers of systems.

The Task is designed to attract as many as possible from engineering companies, solar manufacturers, solar thermal system sellers, machinery producing companies, energy consultants and producers of heat exchangers. The latter can contribute a lot to the quality of the Task and they can learn a lot from other's experiences and the Task work.

The Task defines two levels of participation for the industry:

- <u>an industrial participant at level 1</u> should expect to participate in an annual workshop organised by Task 49 / IV and to receive at least once during the Task duration a visit from a Task participant, and to answer technical and marketing questions on solar heat for industrial applications (this activity is part of the system survey and the dissemination activity of Subtask A).

- an industrial participant at level 2 should expect level 1 commitment and to participate in all Task meetings, bringing information and feedback from the market. Level 2 participation should be seen in close connection with the main participant of the country of origin of the industry.

Task 49 / IV will invite the solar industry organisations from all participating countries, as well as the international umbrella organisations such as ESTIF to participate.
As the task tackles for the first time the possible increase of solar thermal integration potential in industry through new (intensified) technologies, process engineering platforms dealing with these new technologies will be invited, such as EUROPIC (European Process Intensification Centre) or the EFCE Working Party on Process Intensification.

The financial aspects of industry participation are left to the decision of each country: either the industry will have to make its own contribution or some support can come from public funding.

1.4 Subtask A

Process heat collectors

Lead Country: Switzerland (Dr. Elimar Frank - SPF)

In this Subtask, the further development, improvement and testing of collectors, collector components and collector loop components is investigated. All types of solar thermal collectors for an operating temperature level up to 400℃ are addressed: Uncovered collectors, flat-plate collectors, improved flat-plate collectors (for example hermetically sealed collectors with inert gas fillings or vacuum) with and without reflectors, evacuated tubular collectors with and without reflectors, CPC collectors, parabolic trough collectors, Fresnel collectors, air collectors etc. Furthermore, to identify and select the most suitable collector technology for specific boundary conditions an overview of collector output and key figures will be compiled. It is assumed that for all activities of this subtask the temperature range will have to be separated in several segments. For instance, up to around 200℃ water and steam can be used as heat carriers with acceptable pressure. With higher temperatures and with choosing another heat carrier (e.g. oil) the boundary conditions change substantially. A simple up-scaling of the results from the investigations and recommendations for the temperature range up to 200℃ or 250℃ will not be possible. This is true both for the investigations aiming at improvements of the solar loop as well as for recommendations with regards to test rigs, testing procedures and standardization.

Based on existing approaches, methods and parameters for the assessment of the collector and collector loop performance as well as of the impact of the properties of materials and components will be developed and identified. Appropriate durability tests will be applied to specific materials / components to allow the deep understanding of the collector and collector loop behaviour for a wide range of operation conditions and the prediction of service life time.

Based on the investigation of the dynamic behaviour of solar process heat collectors and loops (both experimentally and theoretically), recommendations for process heat collector testing procedures will be worked out.

Subtask A has three main objectives:

- Improving solar process heat collectors and collector loop components
- Providing a basis for the comparison of collectors with respect to technical and economical conditions
- Giving comprehensive recommendations for standardized testing procedures

The participants will achieve the objectives by

- updating the IEA SHC Task 33 state of the art survey of process heat collectors
- increasing the knowledge of general requirements and relevant parameters for process heat collectors and their improvement
- determining parameters for
    - modelling collectors in simulation programs to reflect the realistic performance of medium temperature collectors in process heat systems and
    - comparable measurement data evaluation also from dynamic data for different locations, applications etc.
- developing and/or improving collectors, components and solar loops for process heat applications in co-operation with the involved industry. The main aspects are

performance, reliability and cost effectiveness. Both new or improved collector or component/solar loop concepts and design details will be addressed
- investigating the collector behaviour by collector testing at high temperatures and by the evaluation of measurement data from existing plants
- investigating material aspects for collectors with up to 400℃ operating temperature and system components
- investigating the overheating behaviour and constructive prevention measures of medium temperature collectors in large fields
- measurements on the thermal performance of other components and solar loops of solar thermal systems operating at high temperatures
- elaboration of recommendations for collector testing standards for the medium temperature level

Special effort will be made to involve the solar industry in the analysis of all working fields, e.g. through industry-dedicated workshops (compare Subtask C).

Proposed activities in this subtask are the following:

A1. Improvement of solar process heat collectors and collector loop components (SPF, CENER, CIEMAT, ISE, ITW, Uni Stuttgart, University of Balleares, DLR, AIT, Industrial Solar, tcs, ISFH, AEE INTEC…)

In order to support the development and improvement of cost effective and at the same time well-performing and reliable process heat collectors, the appropriate requirements are investigated. It shall be described and evaluated which parameters have to be taken into account for the development and improvement, which ones are more important than others and which kind of measurements can enhance the development/improvement. Also material topics and the accuracy that is necessary will be discussed and described.

Characteristic parameters will be determined for both modeling collectors in simulation programs to reflect the realistic performance of medium temperature collectors in process heat systems and comparable measurement data evaluation for different locations, applications etc.

For the integration of solar heat into industrial processes it is compulsive that the systems operate totally reliable in all the operation modes that may occur. In this respect, special emphasis has to be put on the aim that the solar thermal systems can handle stagnation or overheating situations without any danger of failure and without the need for additional maintenance works. Whereas for collectors with stagnation temperatures lower than e.g. 250℃ stagnation has to be regarded as a normal ope ration mode of solar thermal systems, this has to be investigated and analyzed for collector concepts leading to higher temperatures when there is no sink for the solar heat (e.g. times without industrial production because of weekends or vacation times, but also technical faults like the breakdown of a pump etc.). In this context, also the terminology “stagnation” will have to be discussed and adapted with respect to process heat collectors as for collectors aiming at high usual operation conditions overheating will lead to severe material problems. The influences and consequences of stagnation/overheating on the collector loop fluids and components will also be addressed and solutions (avoidance of overheating/stagnation by conceptual approaches, coolers, …) will be developed. The aim is to develop techniques to handle stagnation situations also in large medium temperature collector fields.

Not only stagnation, but also the (dynamic) behavior of the collectors and the collector loop is of interest. Investigating the collector behavior will be done by collector testing at high temperatures and by the evaluation of measurement data from existing plants. Also, material problems for medium temperature collectors up to 400℃ operating temperature and system components will be investigated, such as heat carriers, insulation etc. If possible, these measurements will be carried out in existing systems and in laboratory measurements in order to be able to realistically model medium temperature systems and to give recommendations for testing procedures.

With all the knowledge gained, even some of the collectors already available on the market for up to around 100℃ could be modified to be used for higher temperatures. Furthermore, there is a considerable potential for the improvement of existing process heat collectors in many aspects. New collector developments and improvements will lead to a better cost/performance ratio as is presently achieved for medium temperature systems. The collectors to be investigated are for example, double glazed flat plate collectors with anti-reflection coated glazing, hermetically sealed collectors with inert gas fillings or vacuum (with and without reflectors), CPC collectors, evacuated tubular collectors with and without reflectors, parabolic trough collectors, Fresnel collectors etc...). In these activities, investigations on materials suitable for medium temperature collectors will play an important role.

Beside developing and/or improving collectors, also other components and whole collector loops for process heat applications will be analysed and further developed in co-operation with the involved industry. The main aspects are performance, reliability and cost effectiveness. Both new or improved collector concepts and design details will be addressed and improved peripheral devices are aimed at (e.g. tracking with high accuracy, collector connections, …).

In order to achieve an improved performance / cost ratio for collectors for industrial processes, the reliability of collectors and their service life time is important. Moreover, in the development of medium temperature collectors, new materials and components will be used. This concerns the full width of collector technologies from flat-plate collectors to vacuum tubular collectors and parabolic trough collectors, e.g. reflectors (including their mechanical support), tracking devices, glazing and absorbers addressed.

Representative and realistic test samples will be identified and prepared. Relevant performance parameters will be defined and characterisation procedures will be established. Existing durability test procedures will be investigated and adapted where required. Adequate accelerated ageing tests will be developed as a basis for longevity assessments.

Summarizing, the overall aim of this activity is to achieve improvements optimizing the combination of thermal performance, collector costs and durability for process heat collectors.

A2. Comparison of collectors with respect to technical and economical conditions (ISE, SPF, University of Balleares, CENER, Industrial Solar, DLR, tcs)

In this activity, the results of A1 are used and extended to develop a user guide with criteria for collector selection. Areas and suitable boundary conditions and parameters will be discussed to find out if and how a comparison of different collector types is possible. This part is strongly connected with Subtask C (Design guidelines). In Subtask A, collector models are used to derive collector parameters which describe the performance of individual collectors. Based on that an overview of collector output and key figures for defined conditions will be produced depending e.g. on climate, temperature range. Information on other properties of the collector related to generic system conditions will be added to prepare the basis for a first choice of collector as some restrictions may be unfeasible for some collector concepts (required temperature level, heat carrier, pressure etc.).

A3. Comprehensive recommendations for standardized testing procedures (SPF, CIEMAT, ITW Uni Stuttgart,)

There is a broad range of experience in collector testing for operating temperatures below 100℃. Most of the testing laboratories carry out t he tests with water as the fluid and up to a maximum temperature of less than 100℃. Therefore, only very few test results are available for higher operating temperatures. In simulation programs, an extrapolation of the collector performance determined at moderate temperature levels (up to 100℃) is made to describe the collector performance at higher temperatures. These extrapolations often have a high uncertainty resulting in system design calculations with uncertain component dimensioning results. The present situation is undoubtedly a major obstacle in designing medium temperature process heat systems with the needed accuracy for successful pilot systems.

Therefore the testing of suitable collectors at medium temperatures and the exchange of experiences amongst different testing laboratories is very important. The possibilities for round-robin tests on a medium temperature collector with efficiency measurements at 160℃ or higher will be evaluated. Depending on the findings and the respective financing, such tests will be carried out. The results will be discussed with respect to improving the testing procedures in the ISO 9806 and EN12975 standards. A comparison of outdoor and indoor measurements (using solar simulators) will be carried out.

An important task for the wide spread commercial application of solar collectors in industrial processes will be the development of test and qualification standards allowing to assess such different technologies as flat plate collectors (stationary, using global radiation) and parabolic troughs (tracking, using direct radiation) with a view to their respective suitability for a particular application (in terms of the degree of compliance with specific requirements). During the last years, the methods used for non- or low-concentrating collectors have been partially extended to concentrating systems. Different progress can be seen in different countries and for different aspects, but a comprehensive test standard is not yet in sight that includes also quality testing, tracking accuracy etc. Therefore, based on the measurements described above and the further work described in this Subtask, significant steps towards such a "unified" standard shall be achieved. This would be a major added value for the co-operation between IEA, SHC, and SolarPACES, helping potential customers and manufacturers to plan and operate solar process heat plants with high performance, reliability and safety. However, it has to be mentioned that this will be a challenging task due to the inherent differences of the technologies to be characterised. Also, specifications for suitable test rigs are needed and decisions which tests can be carried out in labs (indoor/outdoor) and/or field tests (e.g. mobile test rigs to be used for instance at demonstration sites). The aim is that two of those test environments shall be in operation during the time of this Task and different collector types shall be tested. The development of (recommendations for) testing procedures will be done in cooperation with other IEA SHC Tasks that also have the aim to develop testing standards (e.g. the follow-up Task of IEA SHC Task 48 “Quality Assurance and Support Measures for Solar Cooling” and IEA SHC Task 43 “Solar Rating and Certification Procedure”).

For the collector tests, not only the thermal performance but also aspects such as safety (high temperatures and high pressure) and environmental safety will be important (e.g. in case of using oils as heat carriers).

Besides collector testing, also the testing of collector components and solar loop components will be addressed. This comprises sub components like mirrors, receivers etc. and also ageing behavior tests and tests for the optical accuracy. For these tests, not only test procedures but also specifications for suitable test rigs will be worked out.

The overall aim of this activity is to elaborate recommendations for collector testing standards for the medium temperature level and to contribute to an unified standard for medium temperature collectors.

Deliverables

A1 Improvement of solar process heat collectors and collector loop components:

- A1-1 Definition of general requirements and relevant parameters for process heat collectors (and specific collector loop components) and their improvement [SPF, University of Balleares, CENER, DLR, ISE, AIT, Industrial Solar, AEE INTEC]
- A1-2 Report on overheating/stagnation issues including the high temperature behavior of the investigated components [SPF, AIT, AEE INTEC, ISFH]
- A1-3 Brochure on State of the Art of process heat collectors [SPF, all]

A2 Comparison of collectors with respect to technical and economical conditions:

- A2-1 An overview of collector output and key figures for defined conditions [ISE, SPF, University of Balleares, CENER, Industrial Solar, DLR, tcs]

A3 Comprehensive recommendations for standardized testing procedures:

- A3-1 Recommendations for different kind of test procedures, reports and test rig configurations [CENER, SPF, CIEMAT, ITW, ISE, AIT, DLR], e.g.:
    a. Sub components (tracking, receiver, mirrors, glasses, …)
    b. Collector laboratory tests
    c. Collector field tests
    d. Service life time test procedures for collector components of medium temperature collectors.

A4 Subtask report.

1.5 Subtask B

Process integration and Process Intensification combined with solar process heat

Lead country: Austria (DI Bettina Muster - AEE INTEC)

The general methodology for the integration of solar thermal energy into industrial processes was developed during the IEA SHC TASK 33/IV. It was shown that the pinch analysis for the total production site and - building upon it - the design of an optimized heat exchanger network for the production system is one of the best approaches for an intelligent integration. Due to the fact that in the identified industry sectors with high potential for solar integration very often production processes are running in batches, the developed pinch methodology can only be a rough estimation of the real profile of heat sources/sinks. Additionally it has been proven that the adaptation of existing heat management strategies (operation of storages) can help to integrate solar thermal plants more efficiently. In order to fulfil these needs of further improvements to model the real heat management of a production system it is necessary to further develop the existing methodology and software tools. This advanced process integration will additional consider time dependency of the production profile, the integration of heat storages and the optimized design and management of all heat flows within the production system. The aim is to reach further reduction of the companies' energy demand and an ideal condition for solar integration.

Within the solar community there is still an open discussion whether the ideal integration for solar heat under certain circumstances is the integration on process temperature level over low temperature collectors or whether the integration of high temperature collectors into the distribution system is economically favourable. The technical and economical feasibility of both integration types for certain applications needs to be compared to serve as reference case studies. Based on decision criteria and in close cooperation with solar yield studies (subtask C), the decision on different integration strategies shall be analysed.

Beside the system optimization by the pinch analysis a technology optimization of the applied process technologies will also reduce the energy demand and increase the potential for solar thermal integration. Process intensification (PI) can be seen as a key word for emerging technologies which achieve the framework conditions for effective, solar (thermal and/or UV) driven production processes. Process intensification can be described as any engineering development that leads to a substantially smaller, cleaner, and more energy efficient technology. PI may lead to higher process flexibility, smaller equipment size, improved inherent safety and energy- & process efficiency, decentralized production sites requiring independent energy supply and lowered process temperatures. In general Subtask B aims to bring together know-how and studies to answer the following research question on a sufficiently profound basis: Can developments of new technology concepts (PI in combination with solar thermal systems) lead to enhanced potential for solar integration in industry?

On the one hand existing processes can be replaced by new technologies and thus the potential of the integration of solar thermal energy will increase. The second approach is to identify new applications where up to now solar thermal energy was not used as energy source. This includes detoxification and disinfection of industrial waste water or the upgrading of boiler feed water by solar driven membrane distillation processes.

Based on the foreseen topics Subtask B will be done on following structure:

Advanced integration (pinch analysis and storage management, decision where to integrate solar heat on industrial site)

1. Integration on temperature levels up to 400℃, m ethodology for decision on integration types incl. thermodynamic and cost factors
   i. Integration at process level, at distribution level, combined integration for several processes, combined integration with other heat sources
   ii. Integration methodology: focus on (mis-)match between supply and demand
   iii. Consideration of material aspects, specific heat transfer requirements concerning process fluids
2. Definition of requirements of necessary “components” for system integration (e.g. advanced heat exchangers, advanced system control strategies, collectors (stagnation issues, load profiles, temperature) [link to subtask A])

New process technology concepts and component development (Combining Process Intensification technologies and Solar process heat):

1. For existing processes
2. In new applications (not limited to thermal processes)

In general Subtask B will focus on following main objectives:

- Improved solar thermal system integration for production processes by advanced heat integration and storage management, advanced methodology for decision on integration place and integration types
- Increase of the solar process heat potential by combining process intensification and solar thermal systems and fostering new applications for solar (thermal/UV) technologies

The activities proposed for this subtask are the following:

Advanced integration

B1. **Development of advanced pinch and storage management tool(s)**
Partners with projects in this field: AEE INTEC, DLR
Partners (projects have to be confirmed): Uni Kassel, HFT Stuttgart, ZAFH (Zentrum für Angewandte Forschung in Stuttgart), University of Pannonia, University of Manchester

Bringing together the know-how and expertise of several experts dealing with heat integration and heat management tools, one ore more tools shall be developed to identify ideal integration place of solar heat in industrial processes. The tool shall be able to model current heat flows incl. their real-time profiles (batch or continuous processes with varying loads) and optimize the system via heat integration and ideal heat management. This detailed knowledge of the improved heat management of the whole production system shall allow planners to choose the ideal place to integrate solar thermal heat.
In a second step solar heat flows can be integrated into the tool to assess the heat flow management strategies incl. solar thermal integration.
The tool(s) will be applied in several industrial case studies to prove their performance.

B2. **Survey on integration methodologies for solar process heat**
Partners with projects in this field:
Partners (projects have to be confirmed): DLR, PSE, SPF, AEE INTEC

The activity will deal with specific case studies that are carried out for specific applications where the integration of low temperature collectors on the process level is compared with the integration of high temperature collectors within the distribution system. Studies will be done for applications in different regions. A close co-operation with Subtask A is foreseen, as the results from the generic study (which collector is feasible for which temperature range in which region) will be integrated into the work. The outcome of the case studies will be part of the performance assessment methodology work done in Subtask C.

B3. **Develop System concepts and integration guideline**

Partners with projects in this field: AEE INTEC (food industry)
Partners (projects have to be confirmed): Kassel, Fraunhofer ISE, DLR, SPF, SOLID, PSE, TCS, Industrial Solar GmbH, Greenonetec, TU Graz

As a part of the planning guideline done together with subtask C, the results from the activities B1 and B2, as well as the results of existing studies and demonstration projects and several discussion meetings will be integrated into a solar integration guideline. This document shall guide the future planner or installer of solar process heat from process optimization up to decision where to integrate solar heat and with which collector type. Results from the work done in B4-B5 shall as well be included. The guideline will include the following aspects:

- Integration into the overall heat management system (incl. storages)
- Low temperature applications and related system concepts
- high temperature applications / steam generation and related system concepts
- Consideration of aspects such as circulation, electricity demand, available space
- Checklists for ideal integration, “Asking the right questions”, list of do’s and don’ts
- Definition of requirements of necessary “components” for system integration (e.g. advanced heat exchangers, advanced system control strategies, collectors (stagnation issues, load profiles, temperature)

In the framework of this work the “matrix of indicators” established within IEA SHC Task 33 will be extended. (http://wiki.zero-emissions.at)

<u>**New process technology concepts and component development**</u>

B4. **Survey and dedicated Workshop on new process technologies**

Partners with projects in this field:
Partners (projects have to be confirmed): AEE INTEC; DLR; TU DELFT, AIT, TU Graz

To provide a sound basis to the work foreseen and stimulate the know-how exchange between experts from conventional process technologies with solar process technologies, a dedicated workshop will be done for new process technologies that can potentially be driven by solar. Close cooperation with Solar Paces Task 6 and Task 2, as well as dedicated platforms (EFCE Working Party on PI, EUROPIC) is foreseen.
A survey will be done based on the input of all experts and based on scientific literature to provide a list of possible new process technologies that might stimulate the potential of solar process heat or solar UV in processes.

B5. **Identification of the increasing potentials and Compendium of ongoing activities and existing pilot plants/case studies**

Partners with projects in this field: AEE INTEC (food industry), DLR (solar water treatment)
Partners (projects have to be confirmed): AEE INTEC, TU DELFT, TU Graz

Based on the compiled list of potential new process technologies for solar (result from B4) the potential to foster the use of solar thermal process heat via these new technologies will be identified. This identification will be done based on calculations, simulations and existing case studies and pilot plants (integrating the results from B5). New calculations/simulations for new process configurations will be done for selected processes. Selection criteria will elaborated to enable the focus on potential processes.
The results for B5 will be integrated into the integration guideline and the "matrix of indicators" (B3).
A compendium will be done compiling current trends in process technology change and new technology developments. Results from existing pilot plants and case studies will be collected and integrated into the compendium.
Next to new trends in thermal processes that can enhance solar process heat trends in solar water de-toxification, solar water disinfection and solar driven reactions will be integrated, as well as results from case studies and pilot plants.

Following deliverables are defined for Subtask B:

Deliverables:

- B1. Advanced pinch and storage management tool
- B2. Integration guideline (methodology for advanced integration, system concepts, guidelines on integration types, checklists etc.)
- B3. Extended matrix of indicators (http://wiki.zero-emissions.at)
- B4. Catalogue of additional required components for advanced integration
- B5. Report on potential for enhancement of solar integration with new process technologies (based on (existing) case studies)
- B6. General booklet of Subtask B
- B7. Subtask B final report

1.6 Subtask C

Design Guidelines, Case Studies and Dissemination

Lead country: Germany (Dr. Werner Platzer - Fraunhofer ISE)

The main objective of this Subtask is to provide information and planning methodologies to solar manufacturers, process engineers, installers and potential buyers (industry). This shall support the marketing, planning and installation phase of future SHIP plants.
Experience and results from pilot projects covering a broad variety of technologies in suitable applications representing a significant part of industrial process heat consumers (in terms of size, temperature levels, heat transfer media, load patterns, etc.) shall be evaluated. The operation of projects will be monitored for a representative period to provide feedback on the design and operation concept as a basis for future development and improvements. "Best practice" reference cases shall encourage other potential users to employ these technologies. Tools for a simplified performance assessment and conceptual planning shall be developed. Regional market surveys, case studies and financing schemes will be investigated which should facilitate the market introduction of solar process heat.

The objectives of this Subtask are:

- to provide a worldwide overview of results and experiences from solar heat for industrial process systems. This includes the evaluation of completed and ongoing demonstration system installations using monitoring data, as well as carrying out economic analyses.

- to develop a performance assessment methodology for a comparison and analysis of different applications, collector systems, regional and climatic conditions

- to support future project stake holders by providing design guidelines, simplified fast and easy to handle calculation tools for solar yields and performance assessment

- to investigate system solutions for stagnations behaviour, control and hydraulics of large field installations

- to identify, address and lower the barriers for market deployment by giving examples of successful implementation, by describing suitable financing and incentive schemes, and develop relevant project constellations (e.g.)

- to disseminate the knowledge to the main target groups involved: solar manufacturers, energy consultants, process engineers, installers and potential buyers (industry), and policy makers and platforms.

For the work packages described below one partner from each participating country will be responsible for the sub-coordination, documentation of the state-of-the-art and dissemination of results.

Proposed activities in this subtask are the following:

C1. Design Guidelines (ISE, all partners contribute to specific chapters)
Development of a design approach described in structured guidelines and using checklists, giving guidance with respect to the criteria and sequence of decisions during the system

design process. In a first step a publication plan (structure, contents, authors, time schedule; interactions with other Subtasks) will be developed. After that information from projects (within the participant group but also worldwide) has to be collected. The experiences of companies about problems and customer needs have to be included. Technically several issues have to be dealt with, such as solar thermal design, stagnation behaviour, hydraulics, control strategies and integration possibilities. By condensing and structuring the information an approach leading from the analysis of the intended application (with methods developed in Subtask B) through evaluation of different technological solutions to the definition of basic system design parameters (e.g.: size and temperature level of the solar contribution) and to the selection of appropriate components will be developed and published as a comprehensive guideline.

C2. Simulation Tools (DLR, ISE, SPF, UniK, ZaFH, evtl. Vela Solaris, Aiguasol, Valentin)
Based on the testing results for collectors and subcomponents, model libraries of frequently used programs (TRNSYS, Greenius, INSEL, evtl. other commercial tools) will be extended to include appropriate collector and component models as well as standard industrial consumer models (if not yet available).
In order to be able to perform complete and detailed system simulations "standard" project configurations based on results of Subtask B process integration will be created, including information on weather and load profiles and a data base of default values and component parameters (as far as available).
A documentation of the models, input parameters, default values, standard configurations is essential in order to allow potential software developers worldwide to include these into their programs. Commercial software is the key to user-friendly tools which are used in practice. Therefore commercial developers will be contacted and supported (e.g for tools Polysun, Tsol,…) to develop their products further on.

C3. Performance assessment methodology (ISE, DLR, AEE INTEC, UniK, SPF, manufacture, Polimi, Tecsol, AIT**)**
In order to be able to compare different system approaches and projects a performance assessment methodology has to be developed reaching from the documentation of input assumptions, definition of necessary evaluation criteria to the presentation of results in a defined output sheet. It is intend to link this activity to the IEA Solar Paces Task1 where such work is done for Concentrated Solar Thermal Power.
Especially the comparison of high-temperature concentrating collector systems and non-concentrating integration schemes possibly using generic collector types, regions, temperature levels and costs (input to Subtask B) will be addressed. The different fluid and steam networks have to be specified for those cases. In combination with Subtasks B case studies for promising applications identified will be carried out in close co-operation with interested industries. An economical analysis has to be included.

C4. Monitoring of demonstration projects and "Best practice" projects (UniKassel ISE, DLR, AEE INTEC, SPF, SOLID, Tecsol, AIT, international participants**)**
We will start with an overview list of existing plants, quoting the basic specifications published. Out of these non-confidential projects possibly with participation of task participants will be selected. For these cases, either under construction or already operating, the evaluation and analysis of monitoring data will be tackled based on a homogeneous approach guided by the performance assessment methodology within the Task.
A comparison to design objectives, design assumptions and component performance will be possible by using these data. Special emphasis will be given the hydraulic management of large process heat collector fields and the problems and solutions connected to stagnation behaviour.

After identification of successful projects with positive results in different application fields a documentation of these “Best Practice” projects will be published. Part of the information will also be included in the wiki-web database (http://wiki.zero-emissions.at)

C5. Dissemination of task results (PSE, all**)**

In this work item the general dissemination of Task results will be tackled. The scope is on the one hand side the dissemination of task information in close cooperation with the OA and all Subtask leaders. On the other all individual dissemination activities by individual subtasks and participants shall be coordinated. See the information plan below.

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 a public website, the IEA SHC-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 would like to distribute printed leaflets to describe the scope of the Task. Similarly there is a recognized need to process information from worldwide stakeholders also outside the IEA SHC Task, and to start educational missions to relevant countries in the developing and developed world.

C6. Market deployment (SOLID, UIB/TSC, ZaFH, Ind. Solar, Tecsol, Soltigua, other industries **)**

In a basic step barriers for market deployment will be identified and describe and discuss them. As possible support to overcome the barriers contracting models (ESCO schemes) and project finance schemes will be investigated for different industries and countries. A resulting report will be summarized in a chapter of the design guidelines.

Feasibility studies of existing projects will be used to find levels for the development of national and international supporting schemes. The topic of risk management for innovative technologies will be discussed and solutions proposed. The participants will connect to policy makers and stakeholder platforms in order to spread results, ideas and models developed within this activity.

C7. Potential study (AEE INTEC, CIEMAT, Uni Kassel, DLR, all participants, in combination with Subtask B)

In a potential study we will investigate different markets, industries and different countries The potential study has to reflect the various boundary conditions and technological approaches, where the current low temperature studies will be extended to higher temperatures. This means also the discussion of different process integration routes.

Deliverables

C1: Publication of Design guidelines for solar industrial process heat systems
C2: Overview and description of simulation tools for solar industrial process heat components
C3: Report on Performance assessment methodology and simulation case studies
C4: “Best practice” series of case study reports from demonstration projects
C5: Potential study solar process heat worldwide
C6: A subtask report.

2 Information plan

The following documents are planned during the Task work:

1. "*Solar thermal systems for industrial applications – realised projects and case studies* ", a colour brochure (information dossier) to be published.

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

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

4. An electronic e-mail n*ewsletter* targeted at the defined target groups will be produced at the end of Year 1, 2, 3 and 4. The Newsletter will be distributed through national channels (for instance, included in a solar industry or solar association or HVAC journal)

5. Start mission work shops will be organized in order to disseminate solar process heat in this countries where a low awareness exist

6. A *design guideline on solar thermal systems for process heat* will be a major effort of Task 49/ IV and published electronically, maybe on http://wiki.zero-emissions.at Web-site, or as a printed version.

6. Part of the information produced by Task 49/ IV can be made available through the Internet on the IEA SHC website (www.iea-shc.org/task49)

7. 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.

3 Time table

The time schedule for the Task definition phase is given in table 1.
The time schedule for the activities foreseen during the Task is given in table 2

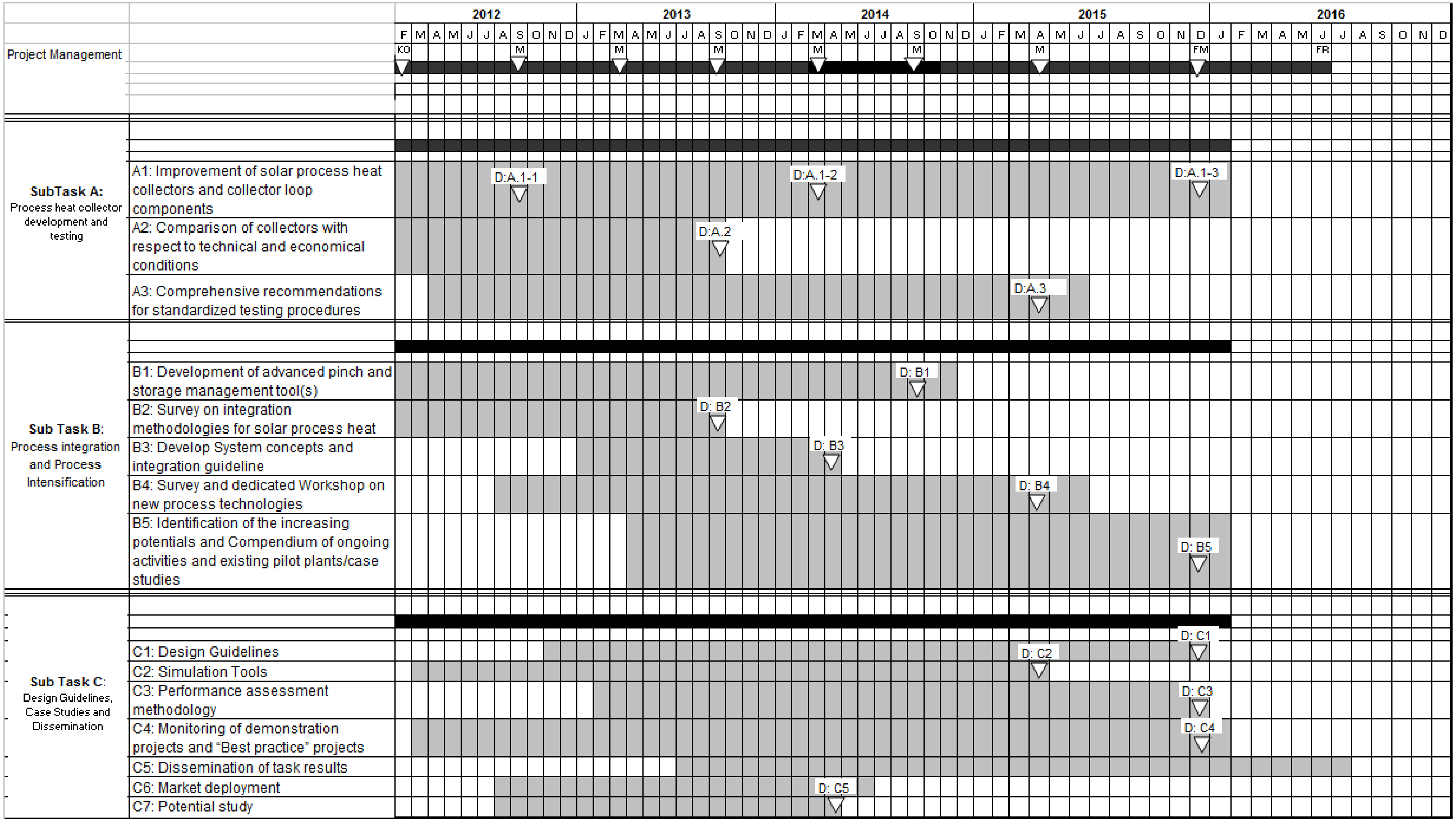
Table 1: Time schedule for task definition phase

	2011											
	J	F	M	A	M	J	J	A	S	O	N	D
WP1: coordination and planning of task conctent									D1.1			
WP2: organization and practicipation of TDM and ExCO meetings				D2.1		M2.1			D2.1		M2.2	D2.2

appriciation	Deliverable Name	date
D1.1	Work Plan and Annex	9
D2.1	Minutes of 1st and 2nd TDM	5 and 10
D2.2	List of task participants	12
M 2.1	feedback fromIEA ExCO Meeting	6
M 2.2	feedback from IEA ExCO Meeting	11

TDM: Task definition meeting

Table 2: time Schedule



Abbreviation	
KO	Kick-off Meeting
R	Progress Report (technical and financial report)
FR	Final Report
D:A.1-1	Definition of general requirements and relevant parameters for process heat collectors (and specific collector loop components) and their improvement
D:A.1-2	Report on overheating/stagnation issues including the high temperature behavior of the investigated components
D:A.1-3	Brochure on State of the Art of process heat collectors
D:A.2-1	An overview of collector output and key figures for defined conditions
D:A.3-1	Recommendations for different kind of test procedures, reports and test rig configurations
D:A.4	Subtask report
D:B1	Advanced pinch and storage management tool
D:B2	Integration guideline (methodology for advanced integration, system concepts, guidelines on integration types, checklists etc.)
D:B3	Extended matrix of indicators (http://wiki.zero-emissions.at)
D:B4	Catalogue of additional required components for advanced integration
D:B5	Report on potential for enhancement of solar integration with new process technologies (based on (existing) case studies)
D:B6	General booklet of Subtask B
D:B7	Subtask B final report
D:C1	Publication of Design guidelines for solar industrial process heat systems
D:C2	Overview and description of simulation tools for solar industrial process heat components
D:C3	Report on Performance assessment methodology and simulation case studies
D:C4	"Best practice" series of case study reports from demonstration projects
D:C5	Potential study solar process heat worldwide
D:C6	A subtask report.

Table 3: Level of efforts for the participants.

Totals are based on a number of 8 countries participating in the Task and a minimum of 4-5 participants in each Subtask.

Level of efforts for participants		2012 PM	2013 PM	2014 PM	2015 PM	2016 PM	Σ PM	# of Part.	Total PM	Total PY
Subtask A participant	Min.	5	5	5	5		20	4	80	6.7
	Rec.	10	10	10	10		40	10	400	33.3
Subtask B participant	Min.	5,5	6	5,5	5		22	4	88	7.3
	Rec.	9	10	10	10		39	8	312	26
Subtask C participant	Min.	5	5	5	5		20	5	100	8.3
	Rec.	9	9	9	9		36	10	360	30
Total	Min.	15.5	16	15.5	15		62		268	22.3
	Rec.	28	29	29	29		115		1072	89.3
Average participation per country	Min.	0.5	0.5	0.5	0.5		0.5			
	Rec.	1	1	1	1		1			

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

Table 4: Level of efforts for the Subtask Leaders and the Operating Agent.

Level of efforts for subtask leaders and operating agent	2012 PM	2013 PM	2014 PM	2015 PM	2016 PM	Total PM	Total PY
Subtask A Leader	3	3	3	3	3	15	1.26
Subtask B Leader	3	3	3	3	3	15	1.26
Subtask C Leader	3	3	3	3	3	15	1.26
Operating Agent							
Task administration	4	4	4	4	4	20	1.7
Edition: design handbook					2	2	0.2

4 General information

4.1 Agenda

November 2010: Presentation of a Task concept paper at the IEA SHC ExCo in Cape Town, South Africa

27/28 April 2011: First Task Definition Workshop in Graz, Austria

June 2011: Presentation of the 1st draft of Work Plan and Annex at the IEA SHC Executive Committee meeting in Denmark

September 2011: Second Task Definition Workshop in Kassel, Germany

September 2011 Presentation of the Draft Workplan and Annex at the IEA SolarPaces Executive Committee meeting

November 2011: Presentation of the Final Draft Workplan and Annex at the IEA SHC Executive Committee meeting in Munich

February 2012 First Task meeting

June 2016 End of Activity

5 Contributors

The following people have contributed to the proposal:

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6 Contributors

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

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27/28 April 2011

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1^{st}- 2^{nd} September 2011

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