# Task 58[1] / ECES Annex 33

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# Material and Component Development for Thermal Energy Storage

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**ANNEX 58**

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[1] Task number not definite yet

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# Annex 58

# Material and Component Development for Thermal Energy Storage

## 1. Scope

This joint Annex/Task deals with advanced materials for latent and chemical thermal energy storage, Phase Change (PCM) and Thermo Chemical (TCM) materials. The task deals with these materials on three different scales:

- Material properties, focused on their behaviour from molecular to bulk scale, including material synthesis, micro-scale mass transport and sorption reactions;
- Material performance within the storage system , focused on the materials behaviour and when they are implemented in the storage itself, including heat, mass, and vapour transport, wall-wall and wall-material interactions, and reactor design;
- Storage system implementation, focused on the performance of a storage within a heating or cooling system, including for instance economical feasibility studies, case studies, and system tests.

Because seasonal storage of solar heat for solar assisted heating of buildings is the main focus of the IEA-SHC TCP, this will be one of the primary focus areas of this task. However, because there are many more relevant applications for TES, and because materials research is not and cannot be limited to one application only, this task will include multiple application areas.

## 2. Objectives

The key objectives of the joint Annex/Task are:

- Development and characterisation of storage materials to enhance TES performance
- Development of materials testing and characterisation procedures, including material testing under application conditions
- Development of components for compact thermal energy storage systems
- Mapping and evaluating the TES application opportunities concerning the requirements for the storage material

## 3. Activities

Below an overview of the planned activities focussed on the storage materials is shown. Each point is explained in the following text.

**Subtask 1: "Development and Characterization of Improved Materials"**

**PCM**

- Material Development: Blends / Mixtures
- Material Characterization / Measurements of Material Properties
- Database: Maintaining and expanding

**TCM**

- Material Development: New reactions & composites
- Definition of relevant material properties
- Material Characterization / Measurements of Material Properties
- Database: Maintaining and expanding

**Subtask 2: "Measuring Procedures and Testing under Application Conditions"**

**PCM**

- Methodology of material property measurements (thermal conductivity, viscosity, density)
- Analysis of upscaling effects (supercooling, stability)
- Testing under application conditions

**TCM**

- Methodology of material property measurements (reaction equilibrium,specific heat, kinetics, thermal conductivity)
- Testing under application conditions

Also the subtasks on the component development and the final fields of applications are presented in an overview below. Detailed explanation will follow.

**Subtask 3: "Component Design for innovative TES Materials"**

**PCM**

- Characterization of PCM components (power, HX surface, efficiency)
- List of PCM component concepts

**TCM**

- Characterization of TCM components (power, HX surface, efficiency)
- List of TCM component concepts
- Identification of performance degradation (comparison to lab-scale measurements)

**Subtask 4: "Energy Relevant Applications for an Application-oriented Development of Improved Storage Materials"**

- Listing of relevant thermal energy storage application in future energy systems
- Parameter set collection of operation conditions of relevant applications (temperatures, thermal power, storage period, number of cycles, economic environment)

The actual activities in each subtask may differ for PCM to TCM. This is caused by the different state of development from previous Annexes in the two material classes.

**Subtask 1 “Development and Characterization of Improved Materials”**
The goals in this Subtask are to develop and characterise storage materials in order to improve the TES system performance, and to identify and measure material properties. The material database started in Task42/Annex 24 and Task42/Annex29, shall be maintained and expanded.

The subtask is subdivided into “Phase Change Materials” and “Thermochemical Materials”, since technical details are completely different.

**What has been achieved in Annex 24/Task42 and Annex29/Task42?**
Within the former Annex/Task activities new low-cost PCMs coming from waste, by-products and natural resources have been produced. Most promising ones have latent heat between 200-300 J/g and can cover TES applications at 50°C-70°C. New eutectic mixtures of linear alkanes with saturated fatty acids or monohydrated alcohols were also obtained and proved to be an efficient way for adjusting the melting point while preserving enthalpy values. Also new sugar alcohol based eutectic mixtures lowering the original high temperature of single materials were produced.

In the field of thermochemical storage materials (TCMs) new sorbent water composites containing CaCl2 within porous silica were prepared. A binder-free zeolite X was launched and zeolite Y was dealuminated for special applications. Salt hydrates were impregnated into porous carbon and vermiculite in order to improve cycling stability. Further improvements of TCM`s properties were achieved by the oxidation treatment of activated carbon.

A material database was implemented in Annex 29 and a number of approved data was uploaded for PCMs and only a few for TCMs.

**Subtask 1P Development and characterization of improved Phase Change Materials**

**Objectives**
Since blends, mixtures, and composite materials are the most promising candidates, different characterization methods (compared to pure materials) have to be adopted. The goal is to finally “design” materials for specific application conditions based on a fundamental understanding on how the thermophysical properties like enthalpy, thermal conductivity, etc. depend on the material parameters like material composition (e.g. mixtures of graphite and PCM to increase thermal conductivity). The main objectives of the Subtask are therefore:
Developing suitable blends and mixtures of PCM
Identifying material parameters influencing the thermophysical properties like melting enthalpy, thermal conductivity etc. of novel materials
Maintenance and expansion of the materials database implemented in Task42/Annex 29

**Main activities**
The already started and ongoing activities on PCM development will be

continuously monitored. The future focus will be on blends and mixtures. The material characterization has to take into account how single material parameters are influencing the properties of the novel material in the storage operation.

In the materials development, blends/mixtures of PCMs are currently under investigation. Phase diagrams of blends are the basis in order to achieve a better prediction of their behavior for given storage applications. The normally used equilibrium phase diagrams have to be extended with kinetic phase diagrams and thermal property measurements should be complemented with physical property characterization (e.g. crystallography, microstructure, characteristics and others).

The materials database that was developed and filled with first materials in the preceding Task/Annexes will be further developed to be able to fill in more thermophysical properties of storage materials (thermal conductivity, viscosity, density).

**Subtask 1T Development and characterization of improved Thermo Chemical Materials**

The Subtask will focus on the development of improved TCM materials as powders, which are based on sorption (micro/mesoporous solids and liquids (hydroxides)), chemical reactions (salt hydrates and metal oxides/hydroxides) and combinations of both (zeolites/graphite+salt hydrates/metal).

The activities of the Subtask ST-1T include the listing of new and improved existing materials, determination of material properties, measurement of thermo-physical properties and expanding the database implemented within the previous task. One of the goals of this activity is to determine the differential heat of sorption / reaction of TCM materials, which can be expressed as a characteristic curve in order to derive possible storage performance.

**Objectives**

- Develop and identify novel chemical reactions and composite materials
- Define relevant material parameters
- Characterize novel reactions and materials by material properties
- Maintenance and expansion of the materials database implemented in Task42/Annex 29

**Main activities**

New developed material based on sorption (porous solids and liquids), chemical reactions (salt hydrates and metal oxides/hydroxides) and combinations of both will be prepared, in the scope of national or international projects, and basic structural properties will be listed.

Materials properties depend on structure and composition of materials, which influence the material performance in storage. The characterization of novel materials deals with a number of material properties, such as chemical composition, bulk density, specific heat, hydrophilicity, porosity, melting point and thermal stability (showing temperature window in which the material can be used), thermal conductivity, kinetics and cycling stability.

The existing database for sorption materials, which was developed in the previous Task, will be expanded in order to include all relevant values for the possible storage performance. Data determined on the base of established measurement procedures of the participants and developed ones will be filled in the database.

**Subtask 2 “Measuring Procedures and testing under Application Conditions”**

In this Subtask measuring procedures for relevant material properties shall be defined. The list of material property measurements, which need these common procedures, differs for PCM and TCM.

For PCM the focus will be on up scaling effects (going from ml range to litre and even larger quantities), which influence melting behaviour, enthalpy and supercooling effects. For thermochemical materials to identify a common procedure to measure the reaction enthalpy will be most important.

Operation conditions of relevant applications which are to be identified in Subtask 4 shall be used for realistic performance testing. Storage capacity as well as the stability after a number of storage cycles will be the main parameters to be identified. Also corrosion in conjunction with the storage material will be investigated.

The subtask will be subdivided in a subtask “Procedures for Phase Change Materials Testing” and “Procedures for Thermochemical Materials Testing”, since the technical details are completely different.

**What has been achieved in Task42/Annex24 and Task42/Annex29?**

In the preceding phases, the focus of material characterization was put on the determination of basic thermophysical properties, e.g. measuring the enthalpy change of PCM upon melting and crystallization.

For PCM a common measurement procedure of the melting enthalpy and the melting temperature range (e.g. by DSC) was established in previous activities. Also for the thermal conductivity of PCM first steps were taken. In the field of TCM a first round robin test for the reaction equilibrium of Zeolite/water was performed in Annex 24, but no common procedure was formulated so far.

The behavior of PCM and TCM under application conditions has not been addressed explicitly yet.

**Subtask 2P PCM measuring procedures and testing under application conditions**

**Objectives**

The key to better understand how the material parameters are influencing the material properties and finally the storage performance are suitable procedures and methods to determine the different thermophysical properties. Important are common procedures, upon which all participating institutions shall agree.

The performance of PCM in a storage unit is often different from the material behavior measured at lab scale. In order to be aware of these differences and to be able to select a suitable PCM for a given application, effects that occur when going from lab scale experiments to tests of PCM at application scale (hereinafter referred to as “upscaling effects”) have to be investigated. Thereby, the impacts of a different sample size and a possibly different purity, e.g. analytical or technical grade, have to be investigated separately. Following this, test procedures to assess and, if possible, quantify the upscaling effects shall be identified or elaborated.

The main objectives of Subtask 2P are therefore:

- Establishing common procedures for measuring material properties
- Description and analysis of upscaling effects, i.e. changes in the PCM behavior under application conditions compared to lab scale experiments
- Identification of test procedures for the assessment and quantification of these effects
- Testing of novel PCM under application conditions

**Main activities**

As a start, an inventory will be made of which test procedures are performed to assess the enhancement of materials, for instance by using additives (increasing thermal conductivity by adding graphite etc.). The target is to develop guidelines for test procedures which have to be performed to confirm these enhancements. Work will be done to accomplish the measuring procedures for the determination of thermal conductivity, viscosity, and density of PCM.

The approach of organizing workshops in which a group of experts performs, compares, and discusses the measurement procedures was very effective and will again be used in the present Task/Annex.

The common practice is to study the melting and crystallization behavior of PCM at small scale experiments. However, at application scale, other phenomena can take place compared to those observed at lab scale (e.g. supercooling and chemical stability). Based on the results of participants projects and a literature review, a description and analysis will be made of the upscaling effects that can occur going from investigating small scale standard materials to testing larger storage units.

Furthermore, the PCM behavior under application conditions is influenced by the operation strategy of the storage unit. For instance, partial melting / crystallization of the material as well as extended standstill periods can lead to an accelerated separation of PCM mixtures or a settling of additives.

In order to reach the indicated objectives and deliverables, the relationship between encountered upscaling effects (including possible interdependencies) and relevant operation conditions that are given by the intended application (e.g. grade of materials, operating temperatures, cycling frequency depending on heating/cooling rates and isothermal periods) has to be investigated. The effects will be discussed and methods to assess and quantify these effects under operation conditions, which are to be identified in Subtask 4, will be proposed.

**Subtask 2T TCM measuring procedures and testing under application conditions**

**Objectives**

Since the measurement procedures for TCM were not as extensively discussed in the previous Annex as for PCM, it will be the focus of this Subtask.

This Subtask aims to have reliable thermal analysis methods/protocols and procedures for the characterization of material and reaction properties for sorption and chemical reactions of TES applications. One goal is an inventory of already standardized measurement procedures for TCM as well as needed characterization procedures.

Available lab scale reactors can be used to show differences between micro and lab scale tests of the investigated materials or reactions.

The dependencies of the final storage performance on the actual material properties have to be investigated. Testing under operation conditions given by the application shall be performed.

The main objectives of Subtask 2P are therefore:

- Establishing common procedures for measuring material properties (starting with reaction equilibrium and including all material properties in the end)
- Testing of novel TCM under application conditions

**Main activities**

Different characterization approaches with different methods are already in use or planned to be used in current TCM TES projects. This subtask should summarize the activities and give the opportunity to harmonize characterization approaches. Following possible characterization procedures for material and reaction properties are discussed:

- Reaction enthalpies and specific heat
- Mass change due to reaction (e.g. water uptake)
- Decomposition temperatures and evolved gases
- Thermal cycling stability
- Thermal conductivity
- Kinetics

First established measurement procedures which are defined in literature or already used by the contributors will be identified and described. This state of the art description should show where a harmonized approach is necessary.

A Round-Robin-Test following a defined measurement procedure with a well-known material should be performed. A proposal for a material candidate is Zeolite 13X, which was already tested in Annex 24 and is in use in a number of applications.

Since the performance of thermochemical storage systems is strongly depending on the operation conditions, this subtask also needs inputs from ST 4 activities. ST 4 delivers parameter sets of possible application conditions for temperature and pressure or concentration of the reaction partners.

**Subtask 3 “Component design for innovative TES materials”**

A new focus of the joint Task/Annex will be on component development for newly developed materials. The improved performance of thermal storage systems – system energy density, output temperature, thermal power, storage efficiency, stability and others - with a new material strongly depends on heat (and mass) transfer of heat exchangers, reactors, evaporators and condensers. The design of the component is also most important for any economic analysis of the storage system.

The subtask will be subdivided in the subtasks “Component Design for Phase Change Materials” and “Component Design for Thermochemical Materials”, since the technical details are completely different.

There are different approaches (concepts) to improve the performance of the storage components, but up to now, there is no common procedure proposed to assess the performance of the components in order to compare them. This new joint Task/Annex aims to contribute to this common assessment procedure.

**What has been achieved in Task42/Annex 24 and 29?**

In the previous Task/Annex the component level was approached to define the theoretical limits of the system (from technical and economical points of view). Most common geometries and design parameters were identified. A set of key elements for thermal energy storage reactor design were collected in a template.

In the new Task/Annex this knowledge will be used to detail the concepts and their main characteristics. From the comparison of the concepts this subtask aims to rank them.

Finished and on-going projects deal with the improvement of this performance for similar applications and literature show previous results for the different components.

## Subtask 3P Component design for Phase Change Materials

### Objectives

The main challenges for PCM components are to provide increased thermal performance in terms of adequate power and stored energy densities satisfying the requirements of the application, with lower temperature difference over the storage volume. Different approaches have been taken, but no compilation or analysis on them has been found.

This Subtask will work on an inventory of the concepts used and on a draft description of the possibilities to define and measure the performance characteristic for these PCM components. Finally an evaluation of the concepts, linked to the targeted performance characteristic shall be performed.

Then, the main objectives in this subtask are:
Inventory of component concepts for PCM
Definition of characteristics of performance for PCM components

### Main activities

Most of the materials currently used as PCM have intrinsically low thermal conductivity. For those application in which high power rates are needed the low conductivity is a drawback. On component level, this can be compensated through an optimised design of the heat exchanger in a PCM storage.

Several finished and ongoing projects worked on improving the design of PCM components (storage containment, heat exchangers) with the aim to increase the thermal performance. In order to compare different solutions in terms of thermal performance and effective thermal energy storage density, adequate performance characteristics have to be defined. This subtask will list a set of characteristics of performance of the storage component (i.e. power, storage density, heat exchanger surface, efficiency…) depending on operation characteristics such as mass flow or temperature.

## Subtask 3T Component design for Thermo Chemical Materials

### Objectives

In addition to heat transfer, components for thermo chemical storage systems have to provide an optimized heat <u>and</u> mass transfer. The actual heat/mass exchanger design is crucial for the achievable storage capacity and power output. The possibilities in designing such a reactor are multiple.

A list of TCM component concepts shall be compiled.

Since there is usually remarkable decline in storage capacity between the values measured in the lab with a small amount of material and the applied set-up including the reactor, the sub task aims at identifying the reason for this degradation.

The objectives in this subtask are:

- Inventory of thermochemical storage concepts
- Definition of characteristics of performance for TCM components
- Identify and locate significant performance losses compared to the maximum values (delivered by Subtask 1T)

**Main activities**

There are many different demonstrator and lab scale systems under design, construction and testing. These vary highly in process, power, capacity and application. Objective of this task is to develop and compiles a fact sheet to obtain a systematic description of present processes as basis for a system comparison. Fact sheets, in the form of a two page description, of all involved demonstrator systems will give a good overview of the systems worked on.

The storage system includes not only components like heat and mass exchanger, but also storage tanks, pumps, valves, sensors, etc. A comparison of component and system performance to the theoretical maximum performance concluded in Subtask 1T will assist in the identification of performance gaps. This shall support design and operation improvement leading to better performance. And it will give insight to the impact of components design on performance.

**Subtask 4 "Energy Relevant Applications for an application-oriented Development of improved Storage Materials"**

The overall goal of this new annex/Task is the development of improved thermal energy storage materials (and reactions) for a better performance. Since energy storage systems in general are strongly linked to the operation conditions of their actual application, it is important to define these conditions carefully. The potential improvement of any new material development should be evaluated as soon as possible under such conditions in order to give a first hint of the improved performance within its application configuration.

This subtask shall collect parameter sets for operation conditions of relevant fields of application. The data shall be found within the activities of other Annexes and TCPs.

The work is not divided into PCM and TCM related applications.

**What has been achieved in Task42/Annex 24 and 29?**

Within the previous activities the influence of the operation conditions given by the application was discussed, but so far no methodological approach was started. A list relevant application fields described by their heat source, the general requirements for the storage itself and the final demand at the consumer side was compiled (see p. 3).

The approach to define Key-Performance-Indicators (KPI) was set up for seasonal solar thermal storage applications.

**Objectives**

Since the main goal of the Task/Annex is the application-oriented development of new and improved storage materials, the goal of this Subtask is to reach an agreement on the operation conditions for a number of relevant applications.

Therefore an intensive exchange between the material scientists and the engineers designing the actual application is very important.

**Main activities**
The approach, which this subtask will follow, shall provide a list of thermal energy storage applications relevant for our future energy system. The storage application sets the technical and economic environment of the storage system and defines the operation conditions. These conditions include available charging and required discharging temperatures, available and required thermal power in- and output, as well as the available reactant concentrations for the process in the case of thermochemical energy storage.

The list shall also include parameters like the expected number of storage cycles, the predicted lifetime and the required system size. The relevant Key Performance Indicators have to be defined. All these parameters can be utilized for integrated system simulations, which finally can give first estimations of performance improvement of the new storage materials.

This cross-cutting subtask shall be an ongoing discussion forum, where the material designer will meet the application engineers and thus the gap between these two groups will be bridged. The subtask shall take up results from other ongoing or completed Annexes within the ECES TCP, e.g. Annex 30 for details from industrial applications and Annex 31 for input from the building sector, and look into the work of SHC Task49 on Solar Heat Integration in Industrial Processes and the work of SHC Task44 on system classification performance assessment methods, as well as into the work of other TCPs.

## 4. Expected Results/Deliverables

The deliverables, allocated to the seven Subtasks, will be:

- D1P1: List of novel developed PCMs as well as blends and mixtures
- D1P2: Extended list of material properties for the characterization of novel PCM
- D1P3: Measured material data for the maintenance and expansion of the PCM Database

- D1T1: List of novel developed chemical reactions and composite materials
- D1T2: Extended list of material properties, including their definition and description, for the characterization of novel TCM
- D1T3: Measured material data for the maintenance and expansion of the TCM Database

- D2P1: Agreement on measuring procedures for thermal conductivity, viscosity and density

- D2P2: Guidelines for test procedures to evaluate thermophysical properties of novel storage materials
- D2P3: Survey of upscaling effects and development of guidelines for test procedures to determine these effects

- D2T1: List and description of available and needed TCM characterization procedures for the identified material and reaction properties
- D2T2: Result of a round robin test of a TCM candidate (e.g. Zeolite 13X)
- D2T3: Description of a harmonized measurement procedure for the TCM performance under realistic application conditions

- D3P1: Inventory of concepts to improve component performance
- D3P2: Definition of the targeted performance characteristic for PCM components
- D3P3: Evaluation of the existing PCM components based on the defined characteristic and classification of concepts according the defined performance characteristic

- D3T1: Basic Description of investigated thermochemical storage processes and their impact on the component design
- D3T2: Inventory of actual component designs currently under investigation (template / questionnaire)
- D3T3: Identification of performance degradation from Lab-scale measurements to pilot installations

- D41: List of energy relevant application currently under investigation.
- D21: List of relevant operation conditions in order to describe the application sufficiently
- D43: List of parameter sets of operation conditions derived from the list of applications

## 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 participate in the editing and reviewing of draft reports of the Task and Subtasks

(c) Each country will bear the costs of its own participation in the Task, including necessary travel costs.

(d) 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, i.e. a total minimum of **9 person months**.
2) Participation in the Task requires participation in at least one of the Subtasks.
3) The Operating Agent will contribute with a minimum of **2-person months per year** to the Task.
4) The Subtask leader shall commit a minimum of **2-person months per year** to the Task.
5) The level of effort to be contributed by each country will be specified in a "Letter of National Participation" which is signed by the Operating Agent and the Executive Committee representative within 3 months from the start date of the Task.

## 6. Management

### 6.1 Operating Agent

Austria, acting through Wim van Helden (AEE – Institute for sustainable technologies, Gleisdorf), is designated as Operating Agent.

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 Articles 5 of this Agreement, the Operating Agent shall:

1) Prepare and distribute the results mentioned in Article 4;
2) 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;
3) Provide reports semi-annually to the Executive Committees on the progress and the results of the work performed under the Programme of Work;
4) 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;
5) 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;
6) Provide the Participants with the necessary guidelines for the work they carry out with minimum duplication;
7) Gather documents from Subtask Leaders, edit and distribute the output of the Task either as a printed handbook, electronically or on a website.

## 6.2 Subtask Leaders

A Subtask Leader for each of the foregoing Subtasks shall:

1) Co-ordinate the work performed under that Subtask;
2) Assist the Operating Agent in preparing the detailed Programme of Work;
3) Direct technical workshops and provide the Operating Agent with written summaries of workshops results and
4) Edit technical reports resulting from the Subtask and organise their publication.
5) Subtask leaders may arrange meetings in between or in association with Experts meetings of the Task.

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.

## 6.3 Experts 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. It is intended to organize a number of expert / industry workshops, directly linked to Task meetings.

## 6.4 Dissemination

The overall scope and objectives of the Task and the different Subtasks will be described on a public website, possibly the IEA-Task website.

## 7. Admission, Participation and Withdrawal of Participants

Admission, Participation and Withdrawal of Participants is subject to the rules of the Implementing Agreement. Share of results produced will be subject to the active contribution of each Participant to the above mentioned activities.

## 8. Information and Intellectual Property

For purposes of this Annex, in case of conflict with the provisions of the 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:
   i. On the most favourable terms and conditions for use by the participants in their own country; and
   ii. 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 Extensions

This Annex shall enter into force on January 1$^{st}$ 2017 and shall remain in force for a period of 3 years until 31$^{st}$ December 2019. 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.