International Energy Agency

Technology Collaboration Programme: Energy Conservation through Energy Storage (ECES)

TES for Energy Management and CO_2 Mitigation

Annex 30

Thermal Energy Storage for Cost-Effective Energy Management and CO_2 Mitigation

Work Program

Last Modification Date: 16/11/2016

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1. Introduction

Reduction of CO_2 emissions and increases in energy efficiency are two important aspects of the ongoing energy transition within Europe as well as the rest of the world. In particular, two energy targets set by the European Union are relevant in the discussion of thermal energy storage (TES): 40% reduction in CO_2 emissions compared to 1990 levels by 2030 and a 20% increase in energy efficiency by 2020. In addition, the EU has committed itself to a 27% share of renewable energy consumption in the energy system. Integration of thermal energy storage will play a major role in achieving these goals.

Thermal energy storage is critical to reduce the energy end-use consumption in power plants, industrial sectors and buildings for heating and cooling. As an example, Figure 1 shows the end-use of energy by application in Germany in 2010. Noteworthy is that nearly 57% of the overall end-use energy consumption is from heating or cooling, while 70% of industrial energy use is for process heat. This represents a huge potential for thermal energy storage technology to improve process efficiency and reduce overall energy consumption within industry and in turn reduce fossil fuel consumption.

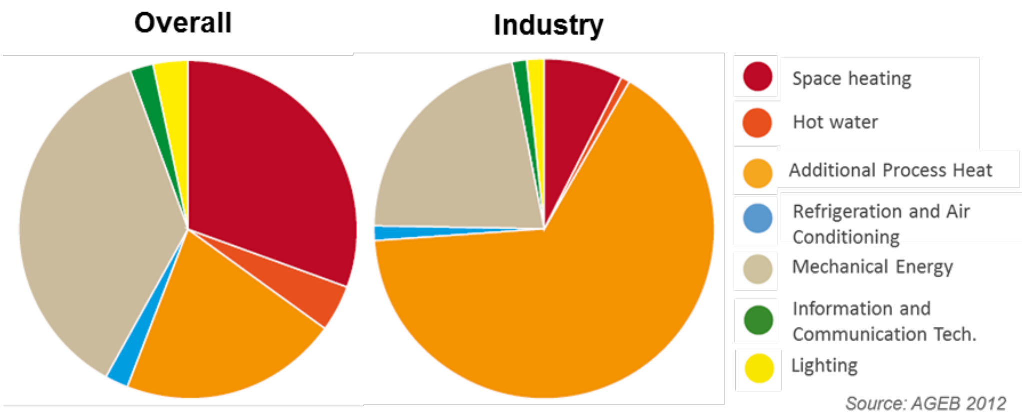

Figure 1 – Energy End-Use by Application in Germany in 2010

The ever-increasing share of renewables in the transition to a clean, secure and efficient energy system also represents a future challenge. Thermal energy storage technologies will play a critical role in this transition by increasing the flexibility of the energy system, particularly in terms of demand response and peak shaving.

Despite this potential, thermal energy storage technologies remain relatively underutilized, especially on an industrial level. This is largely due to TES diversity in both application and technology – there are numerous different applications for each TES technology and often multiple technologies could be chosen for the same process. Improving the ease of integration of TES technologies into processes is a critical step to enabling TES contribution to the energy targets. Annex 30 endeavors to create procedures to support the integration of TES systems in several key sectors and establish methodologies to evaluate how such systems will benefit the processes.

2. Annex Framework

2.1 Objectives of Annex 30

The general objective of Annex 30 is to advance the implementation of thermal energy storage technologies in order to:

- reduce CO_2 emissions and
- improve cost-effective thermal energy management (i.e. increase energy efficiency).

These overarching targets can be supported by the integration of thermal energy storage systems to:

- Improve overall energy efficiency of the processes
- Increase process flexibility
- Increase utilization of renewable energy technologies (including solar thermal technologies as well as fluctuating power generation by PV and wind)
- Boost energy system flexibility through peak shaving and demand response applications

Advancement of the process integration of thermal energy storage systems will make significant contributions to all of these fields. As mentioned in the introduction, crucial to the improved integration of TES systems is a better procedure for discussing the systems. A first objective of Annex 30 is therefore to define a procedure for process analysis and specify technical and economic parameters of thermal energy storage on a system level. Subsequently, determination of 'key performance indicators' (KPI) will be an important step in the performance evaluation of a TES system. Annex 30's ultimate objective is to evaluate thermal energy storage systems for a given application. The methodology will be applied to various case studies originating from demonstration projects where TES systems are applied in a real environment. Thus, in a long-term perspective real-world examples of integration of thermal energy storage systems can be discussed with stakeholders ranging from industry as process owner and turnkey or component supplier to national, European and other funding agencies as well as national governments.

2.2 Scope of Annex 30

In terms of technology, Annex 30 will cover all three main types of thermal energy storage: sensible heat, latent heat and thermochemical energy storage. Annex 30 focuses on system integration, particularly on an application-oriented level. The following sectors will be considered:

- Industry
- Power generation
- Non-residential buildings
- Transportation

In addition, applications, where electrical energy serves as the heat/cold source will be considered, as will both heating and cooling applications and mobile storage applications.

3. Annex Approach

As introduced, Annex 30 deals primarily with the relationship between the thermal energy storage technology and the process. It discusses the mutually-dependent relationship between these two domains which is crucial for characterizing the storage and eventually assessing its performance within an application. This relationship is shown in Figure 2.

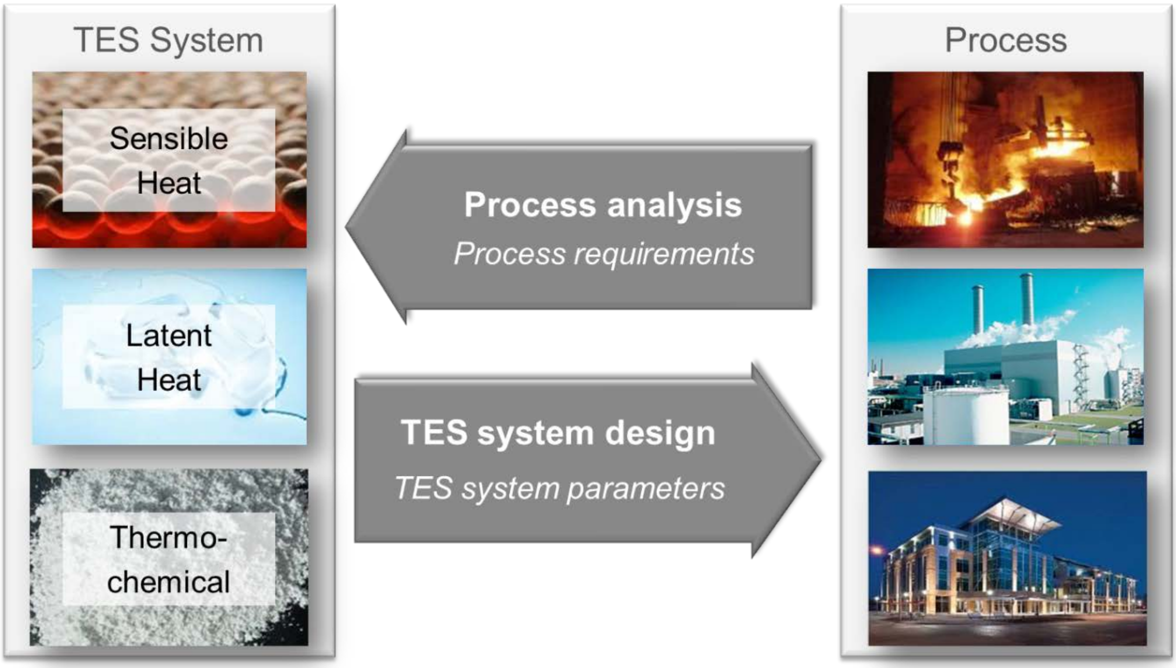

Figure 2 - Dual feedback relationship between storage technology and application

Both the TES system and the process convey key information to one another. On the one hand, the TES technology displays certain system parameters which define the bounds of its operation. These can be either technical or economic parameters ranging from e.g. system storage density to cost per kWh installed. It is necessary for these parameters to be determined independently from the process they will be eventually integrated to in a sort of 'bottom-up' fashion. Lab- and pilot-scale experiments could be very helpful to collect experimental data of thermal energy storage systems under well-defined operational conditions and to investigate what is theoretically possible in the storage rather than what is its real-world performance. Also important is a clear definition and consistency in the calculation of these parameters.

On the other hand, each process has specific requirements to be met. These are operational targets which must be reached in order for thermal energy storage integration to occur in the first place.

Bringing the two domains thermal energy storage system and process together introduces the concept of an application. The evaluation is done by collecting real-world case studies of TES systems integrated into processes. The cases provide valuable information about actual values of technical and economic parameters in applied TES systems as well as aspects of process analysis which have been neglected. In each of these cases the performance of the TES system in that specific application can be defined and the benefit the TES system provides can be determined.

Once the process with an integrated TES system has been examined as an application, a final step is to consider the stakeholders in the application. The concept of performance of a TES system in an application can change depending on the perspective from which it is evaluated. Using previously-defined technical and economic parameters as well as process information, the cases can be evaluated in terms of their key performance indicators.

This procedure is shown in the figure below. The TES system and process are evaluated in isolation, then together in an application context, and finally the benefit is determined from different stakeholder's perspectives.

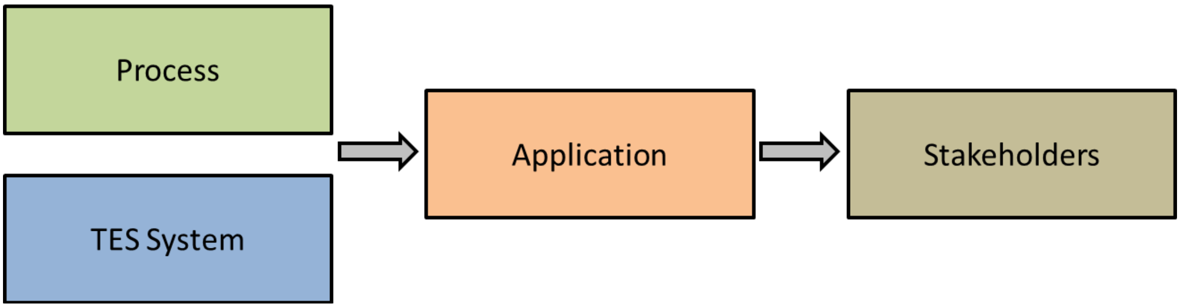

Figure 3 - Flowchart of Annex 30 approach

As mentioned in the previous sections, determination of the key performance indicators of the thermal energy storage system is a critical step in its performance assessment and directly supports its integration into processes. With that in mind, a methodology will be developed for the determination of key performance indicators of a thermal energy storage system in a given application with stakeholders.

The creation of this methodology will be beneficial in improving the evaluation of TES systems that will help improve their integration within processes in several different sectors.

4. Work Plan and Subtask Definition

The work plan is split into five separate subtasks as shown in Figure 4. Following the annex approach, subtasks 1-3, shown inside the dotted line, consider the process and the thermal energy storage system in isolation and focus on determining the process requirements (subtask 1) and the TES system parameters from a technical and economic point of view, respectively (subtasks 2 and 3). With the TES system and process being evaluated in these subtasks, the 4th subtask is responsible for dealing with applications of TES systems, i.e. the process with an integrated TES system in real-world case studies. The 5th subtask concerns itself with the development of the methodology for determining KPI in an application. Consultation with stakeholders, in particular industrial partners, is critical to the success of this subtask. Finally, the case studies will be evaluated with the KPI methodology. The specific objectives of the subtasks are shown in the following section.

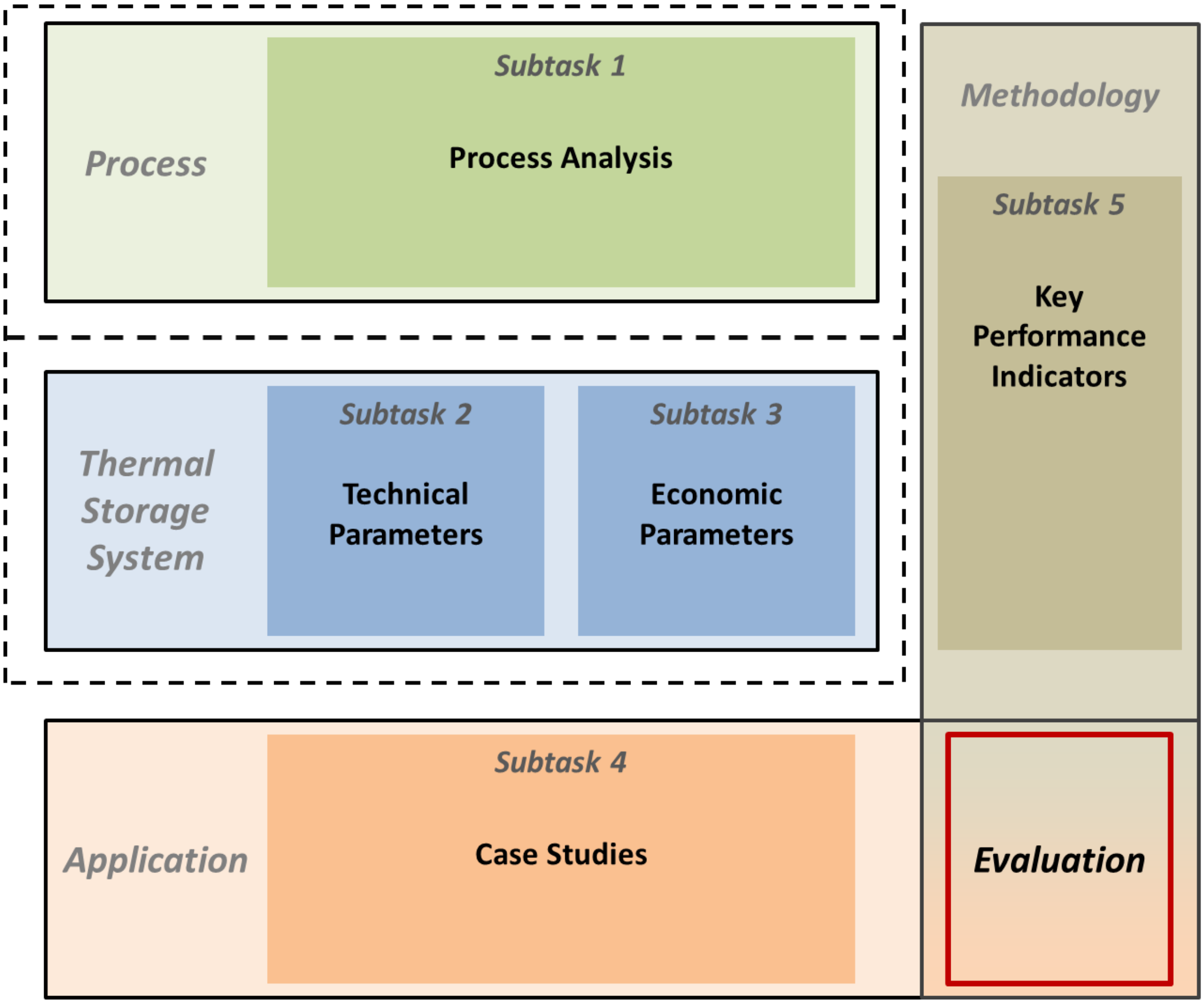

Figure 4 Annex 30 work plan

4.1 Subtask 1 – Process Analysis *(Maike Johnson, DLR)*

Subtask 1 will investigate the determination of process requirements. The main focus is on the development of a process analysis methodology for integration of thermal energy storage. This will be a guide to the most important considerations when evaluating a process and assessing its suitability for TES integration. Additionally, an investigation into the creation of "generic processes" will be performed.

***Outcome*:** Development of process analysis methodology for thermal energy storage integration.

4.2 Subtask 2 – Technical Parameters *(Yukitaka Kato, Tokyo Institute of Technology & Luisa F. Cabeza, University of Lleida)*

Subtask 2 will investigate theoretical technical parameters and create definitions for certain technical parameters for thermal energy storage systems. These definitions will focus on the system level only. Parameters to be defined will be chosen by the annex members and definitions will be evaluated using lab- and pilot-scale testing facilities.

***Outcome*:** Definition and determination of 5-10 technical parameters of selected TES systems.

4.3 Subtask 3 – Economic Parameters *(Justin Chiu, KTH)*

Subtask 3 will expand the bottom-up costing methodology developed in Annex 29

Outcome: Further development of bottom-up costing methodology with respect to systems and extension of database.

4.4 Subtask 4 – Case Studies *(Richard Gurtner, ZAE Bayern)*

Subtask 4 will collect information on real-world case studies. These cases will range from lab-scale to industrial-scale and comprise projects under development, planned and in operation. Especially of interest are cases with measurement data available.

Outcome: Collection of real-world case studies of TES systems within applications.

4.5 Subtask 5 – Key Performance Indicators *(Luisa F. Cabeza, University of Lleida & Antje Seitz, DLR)*

The focus of subtask 5 is the development of a methodology for determining KPI for a TES system. Specifically, this revolves around the theory that the KPI depend on an application and stakeholders. This theory will be further developed and finally used to evaluate KPI for case studies collected in subtask 4.

***Outcome*:** Development of KPI methodology and application to real-world cases.

Finally, the ***evaluation*** of the various case studies according to the KPI methodology will be done by all participants.

4.6 Timeline

Phase 0: July 2014 – June 2015

- Finalize annex objectives and Work Plan with Executive Committee
- Pre-Definition Meeting, August 2014 in Stuttgart, Germany

Phase 1: July - December 2015

- Publishing of team-site and annex website
- First Workshop and Expert's Meeting, October 2015 in Stockholm, Sweden

Phase 2: January - June 2016

- First draft of process analysis methodology, first definitions of technical parameters for TES systems, first collection of case studies
- Second Workshop and Joint Conference, May 2016 in Frankfurt, Germany

Phase 3: July - December 2016

- Further development of process analysis methodology and technical parameter definitions
- Collection of more detailed information for case studies
- First draft of KPI development methodology
- Third Workshop and Expert's Meeting, October 2016 in Tokyo, Japan

Phase 4: January - June 2017

- Further development of all work in progress
- Fourth Workshop and Expert's Meeting, April 2017 in Lleida, Spain

Phase 5: July – December 2017

- Final version of process analysis methodology
- Final version of system parameter definitions
- Final version of KPI methodology
- Commence evaluation of case studies
- Fifth Workshop and Expert's Meeting, October 2017 in Pau, France

Phase 6: January - June 2018

- Final report due in July
- Discussion and dissemination in common workshop with industry
- Final Meeting, June 2018 in Cologne

5. Major Outcomes of Annex

The major outcomes of Annex 30 will be:

- Process analysis methodology for integration of thermal energy storage systems.
- Detailed definitions for thermal energy storage system parameters.
- Expansion of bottom-up cost methodology from Annex 29 to include systems.
- Methodology for determining KPI in an application.
- Evaluation of real-world cases in terms of KPI based on application and stakeholders.

As outlined previously, the general objective of Annex 30 is the development of thermal energy storage systems to improve energy management (i.e. energy efficiency) and CO_2 mitigation. The attainment of the five major outcomes of the annex will make significant contributions to increasing the integration of thermal energy storage systems in processes for several major sectors. Improved integration of TES will serve to increase process flexibility, increase utilization of renewable energy technologies (including electrical), boost energy system flexibility and improve overall energy efficiency. All of these actions will make significant contributions to the general objectives of the annex and ultimately improved process integration of thermal energy storage systems will lead to more effective thermal energy management and CO_2 mitigation.

6. Information and Intellectual Property

a) *Executive Committee's powers*

The publication, distribution, handling, protection and ownership of information and intellectual property arising from this Annex shall be determined by the Executive Committee, acting by unanimity, in conformity with the Annex.

b) *Right to publish*

Subject only to copyright restriction described in Article 8(ix) below, the Participants shall have the right to publish all information arising from this task, excluding proprietary information, as defined in Article 8(iii) below.

c) *Proprietary information*

The Participants and Operating Agent shall take all necessary measures in accordance with this article, the laws of their respective countries and international law to protect the proprietary information provided to, or arising from, this task. For the purpose of this annex, proprietary information will be defined as information of a confidential nature such as trade secrets and know-how which is appropriately marked provided that such information:

1. is not generally known or public available
2. has not previously been made available by its owner(s) to others without obligation concerning its confidentiality
3. is not already in the possession of the recipient participant(s) without obligation concerning its confidentiality

It shall be the responsibility of each Participant supplying such proprietary information and of the Operating Agent for developing proprietary information to identify each piece of information and ensure it is appropriately marked.

d) *Production of relevant information by governments*

The Operating Agent should encourage governments of all Agency Participating Countries to make available or identify to the Operating Agent all published or otherwise freely available information known to them that is relevant to the Task.

e) *Production of relevant information by Participants*

Each Participant agrees to provide to the Operating Agent all previously available information and information developed independently of the Task which can assist or is needed by the Operating Agent to carry out its function in this Task, which is freely at the disposal of the Participant and the transmission of which is not subject to any contractual and/or legal limitations under the following conditions:

f) *no substantial cost is incurred by the Participant in making such information available at no cost to the task.*

1. If substantial costs must be incurred by the Participant to make such information available at such charges to the Task as shall be agreed upon between the Operating Agent and the Participants with approval of the EC

g) Use of confidential information

If a Participant has access to confidential information which would be useful to the Operating Agent in carrying out the studies, assessments, analyses or evaluations called for in this Task, such information may be communicated to the Operating Agent but shall not become part of any report or form of other documentation issues as part of this Task, not shall it ben communicated to the Participants except as may be agreed between the Operating Agent and the Participant who supplies such information.

h) Acquisition of Information for the Task

Each Participant shall inform the Operating Agent of the existence of information that can be of value to the Task but which is not freely available and each Participant shall endeavour to make such information available to the Task under reasonable conditions in which event the EC may, acting by unanimity, decide to acquire each piece of information.

i) Reports on work performed under the Task

The Operating Agent shall provide reports on all work performed under the Task and the result thereof including studies, assessments, analyses, evaluations and other documentation but excluding proprietary information in accordance with Article 12(iii) above.

j) Copyright

The Operating Agent, or each Participant for its own result, may take necessary measures to protect any copyrightable material generated under this Task. Copyrights obtained shall be the property of the Operating Agent, for the benefit of the Participants, however Participants may reproduce and distribute material, but shall not publish it with a financial intent except as otherwise allowed by the Executive Committee.

k) Authors

Each Participant shall, without prejudice to any rights of authors under its national laws, take necessary steps to provide the co-operation from its authors required to carry out the provisions of this Article. Each Participant shall assume the responsibility to pay awards or compensation required to be paid to its employees according to the laws of the respective countries.