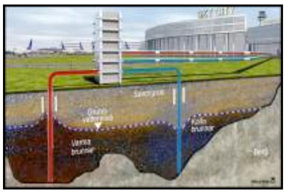
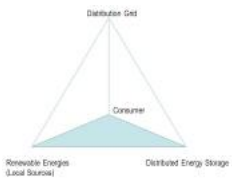
Annual Report 2016
TCP ECES

International Energy Agency

Technology Collaboration Program
on Energy Conservation through Energy Storage


Content

1. Chairman's Report

2016 was an important year in the transition of our global energy system. Following the Paris Climate Agreement, increased momentum to boost the deployment of renewable energy has also led to greater interest in energy storage. The new International Energy Agency (IEA) strategic direction builds on this development and the work of the Technology Collaboration Programmes (TCPs) within the IEA Energy Technology Network has gained further importance. The updated Energy Conservaton through Energy Storage (ECES) Strategic Plan (2016-2021) provides guidance on our TCP priority areas for the coming years. We continue to have good relations with the various IEA bodies and our request for Programme extension was approved by the Committee on Energy Research and Technology (CERT) in February 2016.
We also participated at the annual meeting of Building Coordination Group, held an energy storage workshop in conjunction with the Working Party on Energy End-Use Technologies (EUWP), and provided input to the IEA 2016 World Energy Outlook.

With increasing production of renewable energy (often with variable production e.g. wind and solar), energy storage and flexibility capacities are now considered essential to balance supply and demand. Currently, the research within ECES is focusing on decentralized energy storage solutions that are being developed and researched. **Annex 28** is exploring the potential and contribution of small and medium sized, distributed energy storage (DES) technologies to balance fluctuations caused by renewable energy generation. **Annex 30** is exploring storage options for higher temperatures and industrial applications and CO_2 mitigation. This Annex benefits significantly from strong involvement of industry. Innovative thermal energy technologies like phase-change materials or thermochemical storage can contribute to the integration of renewable energy technologies (e.g. by demand side management / demand response) or to increases in energy efficiency (e.g. by industrial waste heat utilization). For such systems, the question of appropriate novel storage material is crucial. **Annex 29,** a joint Annex/Task with the Solar Heating and Cooling TCP (SHC TCP). This Annex focused on the development and the characterization of new materials and their integration into the storage system. The activities of this Annex concluded in 2016. A continuation of this work (**Annex 33 -** again as a joint Annex/Task with SHC) has been agreed and it will provide more in-depth knowledge on materials to enhance storage volume compactness. The use of underground energy storage (normally in combination with heat pump systems) is reaching a new stage of commercialization. However, quality issues have tended to limit market growth. These issues are being addressed in **Annex 27**. This Annex contributes to pre-normative standards work and also has a very strong industry involvement.

It was identified that there is a need to incorporate storage aspects in current energy computer models to calculate the impact of storage and to make a more complete integral assessment of energy systems. This topic was discussed and recognised also by IEA modellers. A new Annex is in preparation to address this issue and to develop new approaches to incorporate the energy storage impact in existing and new computer models.

Overall, energy storage appears to be gaining increasing international interest. Within this context, the need to reach out to cross-cutting technological solutions has also increased. Exploration of new constructive collaboration projects is a new focus area for the coming period. Collaboration is encouraged by the need to provide integral solutions in our new and increasingly renewables based energy system.

We were happy to welcome Switzerland as the 18th participating country in ECES TCP.
2016 was my first year as Chair of the ECES TCP Executive Committee . I learned a lot and enjoyed working with all the delegates on our Executive Committee, our Operating Agents and the IEA desk officer John Dulac. A special thanks to our previous chair, Halime Paksoy, for all the help and assistance during this first year.

Teun Bokhoven, Chairman TCP ECES

2. About the International Energy Agency (IEA)

Established in 1974, the International Energy Agency (IEA) carries out a comprehensive programme of energy co-operation for its 29 member countries and beyond. The IEA examines the full spectrum of energy issues and advocates policies that will enhance energy security, economic development, environmental awareness and engagement worldwide. The IEA is governed by the IEA Governing Board which is supported through several specialized standing groups and committees. For more information on the IEA, see www.iea.org.

The IEA Energy Technology Network

The IEA Energy Technology Network (ETN) is comprised of 6.000 experts participating in governing bodies and international groups managing technology programs. The Committee on Energy Research and Technology (CERT), comprised of senior experts from IEA member governments, considers effective energy technology and policies to improve energy security, encourage environmental protection and maintain economic growth. The CERT is supported by four specialized Working Parties:

- Working Party on Energy End-use Technologies (EUWP): technologies and processes to improve efficiency in the buildings, electricity, industry, and transport sectors.
- Working Party on Fossil Fuels (WPFF): cleaner use of coal, improvements in gas/oil exploration, and carbon capture and storage
- Fusion Power Coordinating Committee (FPCC): fusion devices, technologies, materials, and physics phenomena
- Working Party on Renewable Energy Technology (REWP): technologies, socio-economic issues and deployment policies.

Each Working Party coordinates the research activities of relevant IEA Technology Collaboration Programmes (TCPs). The CERT directly oversees TCPs of a cross-cutting nature. The Energy Conservation through Energy Storage Technology Collaboration Programme (ECES TCP) relates to the EUWP. Within that framework, The ECES TCP is also part of the Building Coordination Group (BCG). Within the BCG the various building related TCP's seek opportunities for collaboration (i.e. cross cutting subjects) and exchange results and developments.

The IEA Technology Collaboration Programmes (TCPs)

The IEA Technology Collaboration Programmes (TCPs) are international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues, from building pilot plants to providing policy guidance in support of energy security, economic growth and environmental protection.

The first TCP was created in 1975. To date, TCP participants have examined close to 2.000 topics. Today, TCP participants represent more than 300 public and private-sector organizations from over 50 countries. TCPs are governed by a flexible and effective framework and organized through an Implementing Agreement. TCP activities and programmes are managed and financed by their participants. To learn more about the TCPs, please consult the IEA website (www.iea.org/tcp) which includes short promotional films, Frequently Asked Questions, and further information on TCP activities.

3. Technology Collaboration Programme on Energy Conservation through Energy Storage (ECES TCP)

Created in 1978, the activities of the Technology Cooperation Program on Energy Conservation through Energy Storage (ECES TCP) are coordinated by the Working Party on Energy End-us Technologies (EUWP). The aims of the ECES TCP are:

- To stimulate and facilitate interactive collaboration of (fundamental) research, development, deployment and demonstration of energy storage systems
- To increase the awareness and visibility of energy storage technologies as being an essential component of the overall energy system transformation
- To create an open and accessible platform to exchange the latest development and experience in the field of research and deployment of energy storage systems.

The ECES TCP accomplishes this through:

- Research and dissemination activities relating to both thermal and electrical storage technologies
- Positioning storage technologies as a main driver for the transformation of the energy system toward a renewable based supply
- International collaboration carried out within a framework of typical IEA countries in combination with developing and transition countries.

For further information on the ECES TCP see www.iea-eces.org. Please note that views, findings and publications of the ECES TCP do not necessarily represent the views or policies of the IEA Secretariat or of its individual member countries.

4. Background

The energy sector will soon undergo significant changes. The percentage of renewable energy generation will increase, mainly through the use of wind, solar, and hydro-power. Variable generation sources like solar and wind, shall provide challenges for national grid infrastructures and for matching demand and supply profiles. The amount of fluctuating energy – both on the supply and demand sides – compels us to control these energy flows and capacities. Grid expansion, as well as flexibility mechanisms, will be necessary on the global system level. However, these options are not always the best solutions from an energetic and economic point of view and they may not be possible for all parts of the world.

Many types of electrical storage systems are currently being considered to balance the energy system. Pumped-hydro plants and various electrochemical storage solutions have already been developed. Further R&D activities shall improve the efficiency of technologies (e.g. redox flow cells and NaS-batteries), as well as decrease their costs. Even thermal energy storage solutions may be suitable for balancing the electricity grid (power to heat). Furthermore, decentralized energy storage is expected to make a significant contribution toward matching supply and demand.

Energy storage can also contribute to increasing overall energy efficiency in the industrial sector using waste heat. This can be deduced from the fact that there exists a significant portion of industrial heat demand within the total final energy consumption.

There is a large variety of energy efficiency and storage measures applicable to the building stock. Passive measures can reduce the heating and cooling demand of buildings. Cold storage can decrease the total power demand during summer and help to avoid black-outs. Seasonal storage can complement energy supplies, especially when used in combination with district heating and cooling systems. In buildings, energy storage bridges the gap between efficiency measures on the one hand and increases use of renewables on the other. Solar and heat pump assisted heating and cooling systems in combination with storage provide very promising solutions. Transforming surplus solar or wind energy and storing it in decentralized storage solutions, such as batteries or latent heat, may become very energy-efficient and economical solutions.

Energy storage technologies can overcome the temporal mismatch between electricity and thermal energy supply, and demand. They are one of the key instruments used to reduce peak loads and enable load management. Electricity, heat or cold, centralized or decentralized, autonomous or grid connected storage solutions are becoming crucial components of the energy systems of the future.

There is a tremendous potential for the use of energy storage, across a wide range of applications and for many different types of business cases. Every situation requires a different technical storage based solution. Apart from the technical development on component and sub-system level, more insight knowledge on very efficient storage solutions on the overall energy system will increase the value of storage in energy systems.

All kind of storage solutions should be considered to find the optimum in each supply and demand situation.

5. ECES TCP Contracting Parties and Sponsors

Country	Contracting Party	Delegates
Belgium	Vlaamse Instelling voor Technologisch Onderzoek, VITO	Bert Gysen
Canada	Public Works and Government Services Canada	Paul Sra
China	China Academy of Building Research	Xu Wei, Zhang Shicong
Denmark	Danish Energy Agency	Per Alex Sørenson, Paul Frich
Finland	Pirkanmaa ELY-Centre	Jussi Mäkelä
France	Agence de l'Environnement et de la Maitrise de l'énergie (ADEME)	Louise Oriol, Paul Kaaijk,
Germany	Forschungszentrum Jülich GmbH	Hendrik Wust, Steffen Linsmayer
Ireland	Dublin Institute of Technology (Sponsor)	Mick McKeever, Aidan Duffy
Italy	ENEA – Italian National Agency for New Technologies, Energy and Sustainable Economic Development	Pier Paola Prosini
Japan	Tokyo Denki University	Tadahiko Ibamoto, Kouichi Ishida
Korea	Environment & Energy Systems Division	Hyun-Choon Cho
Netherlands	Netherlands Enterprise Agency (RVO)	Lex Bosselaar, Teun Bokhoven
Norway	Norwegian Geotechnical Institute (NGI)	Rajinder Kumar Bhasin
Slovenia	University of Ljubljana	Urus Stritih, Vincenc Butala
Spain	University of Lleida (Sponsor)	Luisa F. Cabeza, Camila Barreneche
Sweden	Energy Technology Department, Swedish Energy Agency	Sara Malmgren, Emina Pacic
Switserland	Bundesamt fur Energie BFE	Carina Alles, Michael Moser
Turkey	Cukurova University	Halime Paksoy, Hunay Evliya
UK	Department for Business, Energy & Industrial Strategy	Shane Long, Philip Sharman
USA	U.S. Dept. of Energy	Imre Gyuk

6. Conferences, workshops, awards, papers and posters

Conferences

After a successful Stock-conference in Beijing in 2015, preparations started in 2016 for the tri-annual Stock-conference in 2018. The Enerstock Conference will be held in 2018 at the Çukurova University in Adana, Turkey.

Workshops

- In March 2016, a workshop was organized in Munich in conjunction with an EUWP meeting. It provided the opportunity to highlight the work of ECES to EUWP representatives.
- A workshop on a potential new Modelling Annex was organized in Genk in July 2016. A definition stage will be undertaken in the course of 2017 in order to develop a proposal for approval in the autumn meeting 2017. This Annex is well connected to the requirements of IEA modellers.
- A special workshop was held in conjunction with the 82th Executive Committee meeting in Paris (November 2016) to address the implementation of the strategic plan 2016-2021 and the choices the TCP needs to make to evaluate new annex proposals in order to contribute to the goals in the strategic plan.

An overview of papers and posters related to the ECES TCP are included in the the below Annex reports.

7. Communications

In line with IEA /EUWP recommendations, a communication plan for 2017 was approved. The plan, which shall be implemented in 2017, includes a decision to start a newsletter and create a new website for ECES.

With the change of secretariat in 2016 a new website was needed. The new site will allow the Annexes to have their own (protected) web-environment. The website shall be managed by the ECES TCP secretariat.

The new site will provide general information and also highlight:

- Completed annex reports
- Agendas for upcoming events
- General ECES TCP publications and Strategic Plans.

Currently there are also individual web addresses for the following Annexes, which are maintained by operating agents:

- Annex 28: www.eces-desire.org
- Annex 29 (joint Annex with SHC) : task42.iea-shc.org
- Annex 30: www.eces-a30.org

The Chair, vice chairs and individual delegates have contributed to a number of scientific events (workshops, forums, meetings, etc). ECES TCP was one of the supporting organizations of Energy Storage Europe 2016 - this is a major annual international trade fair and conference that takes place in Germany. Participation at these conferences provides opportunities to attract interest from new countries to ECES TCP. In addition to these conferences, ECES TCP is organizing workshops in parallel with ExCo and annex meetings with different focused themes. Industry engagement also features prominently in workshops organized by the annexes. See the Annex reports below for further information.

In terms of further international collaboration, ECES TCP has links with a variety of organizations through its delegates and operating agents. ECES TCP maintains contact with the activities of the European Energy Research Alliance (EERA), which is an integral part of EU Horizon 2020, through the Operating Agent of Annex 30. ECES TCP also has maintains contact, via the Spanish sponsor member delegate, with the European Technology Platform on Renewable Heating and Cooling. The team responsible for leading Mission Innovation Challenge #7 on affordable heating and cooling (where storage is identified as a high priority theme) is also a recently established ECES TCP contact.

8. Financing

All contracting parties and sponsors make an annual financial contribution to the common fund used for ECES TCP administration and communication matters. The following table outlines the budget distribution among participants. The completed and ongoing Annexes of this term were all task-shared. The additional effort for the co-operation within the IEA is usually 3 man months /year. The work of the Operating Agent requires funding of about 6 MM/year.
The overall ECES TCP 2016 budget from the common fund was $ 57.000. Per ultimo $ 38.972 was received.

Table: ECES TCP common fund distribution in 2016

Contracting Party	No. of Countries X Common Fund/ Country (USD)	Total Common Fund (USD)
Germany, Canada, Japan, USA, France, Italy	6 X 4.800	28.800
China, Korea, Sweden, Finland, Norway, Denmark, Switzerland	7 X 3.000	21.000
Belgium, Slovenia, Turkey, The Netherlands	4 X 1.200	4.800
University of Lleida (Spain)	1.200	1.200
Dublin Institute of Technology (Ireland)	1.200	1.200
TOTAL (USD)		57.000

9. Annex Reports

9.1. Annex 27: Quality Management in Design, Construction and Operation of Borehole Systems

Operating agent

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Annex duration

start 2016 – end 2019

Contracting partners/sponsors

Institution	Country
ZAE Bayern, EIFER – European Institute for Energy Research, KIT – Karlsruhe Institute of Technology, University of Applied Sciences Biberach, Solites, IGO – International Geothermal Office	Germany
IGSHPA – Canada, International Ground Source Heat Pump Association	Canada
China Academy of Building Research	China
VIA University College	Denmark
Hokkaido University, Geo-Heat Promotion Association of Japan	Japan
KEA - Korea Energy Agency	Korea
GTK – Geological Survey of Finland	Finland
Groenholland Geo-energiesystemen BV	The Netherlands
Svenskt Geoenergicentrum, Geostrata HB, KTH - The Royal Institute of Technology,	Sweden
Iller Bank, Ankara University, Istanbul Technical University	Turkey

Scope overview

The thermal use of the underground is an important method to increase energy efficiency for heating and cooling in domestic and commercial applications. The market for underground thermal energy storage (UTES) for heating and cooling, especially for ground source heat pumps (GSHP), has been growing rapidly in recent last years. Depending on the local geological situation, different technologies are typically applied. Besides aquifer based systems (ATES) and groundwater heat pumps systems with borehole heat exchangers (BTES), heat pumps with BHE's are the most popular solution covering a wide range of applications from family homes to large commercial buildings for heating and/or cooling and very large BTES for seasonal storage of heat (e.g. in solar district heating systems, cogeneration, …). In consequence, such growing markets require special effort in quality management to achieve well running systems without harmful effect to the underground environment.

The overall objectives of the proposed annex are to avoid mistakes and failures related to the design, construction and operation of the borehole system. Information and knowledge collected should serve as a basis for national and international standards. Additionally, the compiled experiences of the international experts group will be a valuable contribution for education of consultants, drillers, installers and operational staff.
This will make BTES technically safer, more cost effective and will strengthen the future usage of this technology. Consequently, the knowledge and confidence of the regulation bodies in this technology should be suffiicient to avoid ineffective restrictions resulting in increasing costs.

The specific objectives are:

- Collect and compile national standards and guidelines for BTES/BHE for heating and cooling
- Analyze national design procedures and construction methods
- Identify and investigate problems of the design and construction phases
- Develop design and construction handbooks and guidelines to avoid future mistakes
- Investigate operational failures
- Develop preventative guidelines for monitoring, maintenance and rehabilitation measures
- Identify related problems to establish further R&D activities.

The scope of this Annex includes quality management issues of borehole heat exchangers for ground source heat pumps and BTES in all project phases ranging from design via construction to operation.

The subtask structure follows the headlines of the Annex topics (Figure 1).

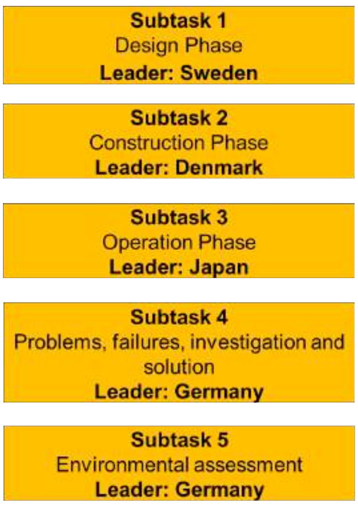

Figure 1: Annex 27 organization matrix

All of the Annex work is captured within the motto:
"Learn from experiences, don't make a mistake twice!"

The Annex will cover the following topics:

Design phase
Energy concept
Pre-feasibility
Feasibility

Construction phase
Site preparation
Drilling methods
Grouting
Borehole heat exchangers
Final test-methods
Start-up

Detailed planning
Approval procedure
Call for tenders
Operation
Supervision of operation
Maintenance

Problems, failures, investigation and solutions
Common problems with BHEs and BTES
Problems from poor grouting
Problems deriving from modification of design parameters
Description of methods to avoid and solve problems – remediation

Environmental assessment

Activities/achievements

In 2016, two workshops and experts meetings were held in Horsens, Denmark (hosted by VIA University College) and in Lund, Sweden (hosted by Svenskt Geoenergicentrum). At these meetings 48 scientists and engineers from research institutions, as well as from industry and governmental institutions, participated in giving 33 Annex related presentations.
Each participating country commenced by presenting the state of the art of BTES and BHE technologies as related to their local geology and hydrogeology. For example, the BHE market in Sweden is dominated by water filled boreholes in bedrock which is coming up to surface in most regions. In central European countries, the market features unconsolidated rock boreholes that are typically grouted. These differences have to be taken into account in the work of Annex 27. An overview of existing national guidelines and standards given by the country representatives demonstrated different level of detail and legal importance in each country.

In subtask 1, the typical design process from the energy concept, via detailed planning, to the call for tenders was discussed. A first draft of the chapter on the design phase will be prepared for the next meeting. Subtask 2 covers the construction phase from site preparation via drilling, injection of heat exchanger pipes and borehole grouting, to the system start-up. The different construction methods used in each country were not only related to the geology, but also to the common local drilling technology. Further collection of information and discussion is required before summarizing this subtask. The status of the operation phase (subtask 3) was evaluated by a questionnaire send out to the participants. The feedback shows a quite heterogeneous picture regarding the situation of monitoring guidelines. All three subtasks require further input from the participating countries. Subtask 4 on "problems, failures and solutions" and subtask 5 "environmental assessment" are still under intensive discussion. Especially for subtask 5, as a first approach to this subject from Annex 27 will be analyzed and further developed.

9.2 Annex 28: Distributed Energy Storage for the Integration of Renewable Energies - DESIRE

Operating agent

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Annex duration

Start: January 2014 - End: December 2017

Contracting parties/sponsors

Institution	Country
ZAE Bayern	Germany
Fraunhofer UMSICHT	Germany
KTH	Sweden

Institution	Country
TNO	The Netherlands
Cukurova University	Turkey
University of Lleida	Spain

Scope overview

A rapidly growing contribution by renewable energy to the overall energy production can be expected worldwide. Most renewables, like wind, PV or solar-thermal, are fluctuating resources. With increasing integration of renewable energy technologies, energy storage/energy balancing capacities are needed. So far the focus in the public discussion is on large-scale, central and the most cost effective energy storage technologies - mainly pumped hydro. The potential and contribution of small and medium sized, distributed energy storage technologies to balance fluctuation caused by local renewable energy is mostly unexplored. This Annex aims to answer the question of what can be the contribution of distributed energy storage on the integration of renewable energy technologies in future energy systems.

Distributed energy storage (DES) can be classified by their purpose of operation and their degree of grid connection:

Storage solutions with no connection to distribution grids are referred to as "'island solutions". For example, this may be a PV system with battery in self-contained remote buildings. The category "electricity grid connected, but locally optimized" represents storage solutions that are connected to distribution grids, but instead of providing grid services they are optimized for the local application *e.g. a PV/battery-system with grid connection optimized for the buildings self-consumption. The third category "electricity grid operated" refers to system configurations delivering grid services like grid balancing etc. An example of this category could include refrigerators with icold storage that can be used for demand side integration purposes.*

The Annex work is structured in Subtasks. The structure is shown in the figure on the right. In Subtask 1 storage solutions in ongoing R&D projects (TRL 3-6), as well as actual examples of DES demonstration or pilot installations (TRL 6-9) shall be presented and classified, while Subtask 2 shall focus on techno-economic analysis of these systems. Based on this inventory from both subtasks, Subtask 3 shall identify the general potential of DES solutions (TRL 3-9) in different countries. In this Subtask, actual business cases shall also be reported. Subtask 4 is focused on the necessary control requirements for the operation of DES solutions, especially when operated in order to provide flexibility measures for the grid.

Sub-Task 1
Distributed Energy Storage Solutions
Leader: The Netherlands

Sub-Task 2
Economic Analysis & Business Cases
Leader: Sweden

Sub-Task 3
Potential of Distributed Storage Solutions for the Integration of Renewable Energies
Leader: Denmark

Sub-Task 4
Control Requirements for Distributed Energy Storages

The overall goal of Annex 28 is to foster the role of DES and to better evaluate the potential storage capacities for the integration of renewables at an economical competitive level. To reach this goal, distributed energy storage technologies and their properties will be examined, storage requirements depending on the different renewable energy sources will be reviewed and possible control and operation strategies for DES and technologies for use in smart grids will be studied. Finally, the potential of DES systems to promote the integration of renewable energy technologies, related to final energy demand, shall be quantified and guidelines for choosing the most suitable DES technology for individual applications will be developed. Best practice and success stories examples will also be given.

The scope of this Annex includes all energy storage technologies suitable on the consumer side.

Activities/Achievements

In 2016 two workshops and expert meetings were held in Stockholm, Sweden, and Paris, France. At these meetings over 40 scientists participated and gave over 20 presentations on their ongoing R&D activities.

Distributed energy storage described by the energy source, the storage technology and the final consumer are referred to as DES "configurations". These configurations are listed and classified within the activities of Subtask 1, while in Subtask 2 economic performance and possible business cases are analyzed. Below you find sample results from subtask 1 and 2.

Subtask 1

Configuration: Frequency containment reserve by virtual storage combined with PV-self-consumption

Utilization of a privately used swarm of energy storage systems for frequency containment reserve by the company Caterva. This system realizes for first time a contribution to the stabilization of the European power transmission grid system in Germany by distributed energy storage. The special feature of the large-scale virtual storage system is the networking of a swarm of household size storage units (lithium-ion storage batteries). Each DES is equipped with its own control unit, so that it can react on a stand-alone basis to grid frequency fluctuations. The storage units, installed in private households, are connected via various networks, to the control center, which coordinates the swarm of DES units. The control center acquires the latest individual data on storage-charging levels of the DES and regulates the swarm so that the balancing power on offer is actually available. Such systems are able to react extremely fast and precise to any changes in frequency.

From an economical point of view, the double benefit for grid services as well as possible increases in self-consumption makes this system very attractive. Thanks to the DES, the users can cover 60 to 80% of their power requirements from their own roof-top PV systems and can at the same time contribute to the German energy transition (Energiewende) by providing balancing power!

Subtask 3

In order to quantify the potential of DES applications a national scenario for Germany was developed as an example. It includes all sectors (heat, electricity, gas, and transport - including. interactions). The question to be answered was: how can DES technologies reduce the critical excess electricity production from PV and wind? The scenario aimed to model the technical potential ("What can we achieve within the system?") as well as the economic potential ("How can we minimize the cost?").

Based on the model of the German energy system, scenarios with increasing renewable capacities shall be investigated. The effects of different energy storage technologies concerning a substantial reduction of the critical excess electricity production is visualized. Additionally, for the scenarios with an increasing share of renewables, sensitivity analyses on the influence of electricity prices, fuel prices and carbon emission prices will be investigated.

9.3 Annex 30 – Thermal Energy Storage for Cost-Effective Energy Management and CO_2 Mitigation

Operating agent

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Annex duration

July 2015 – June 2018

Scope overview

The general objective of Annex 30 is to advance the implementation of thermal energy storage technologies 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 these fields. 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, from a long-term perspective, real-world examples of integration of thermal energy storage systems can be potentially 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.

Annex 30 participants

Full Participants	
Belgium	Energyville (KU Leuven & VITO)
China	Shanghai Jiao Tong University
Denmark	Danish Technological Institute (DTI) Technical University of Denmark (DTU)
Germany	German Aerospace Center (DLR) Technical University of Chemnitz ZAE Bayern
Italy	Italian National Research Council (CNR-ITAE)
France	Atomic Energy and Alternative Energies Commission (CEA) University of Pau
Japan	Tokyo Institute of Technology
Spain	University of the Basque Country (UPV-EHU) University of Lleida
Sweden	Chalmers University of Technology KTH Royal Institute of Technology Swedish Centre for Shallow Geothermal Energy
Switzerland	HEIG-VD
Turkey	Çukurova University
Observers	
Austria	Austrian Institute of Technology

Activities/achievements

The work program of Annex 30 has been updated and is split into five subtasks as shown below. 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 subtask 4 is responsible for dealing with applications of TES systems, i.e. the process with an integrated TES system in real-world case studies. Subtask 5 concerns itself with the development of the methodology for determining an application KPI. Consultation with stakeholders, particularly industrial partners, is critical to the success of this subtask. Finally, the case studies will be evaluated with the KPI methodology.

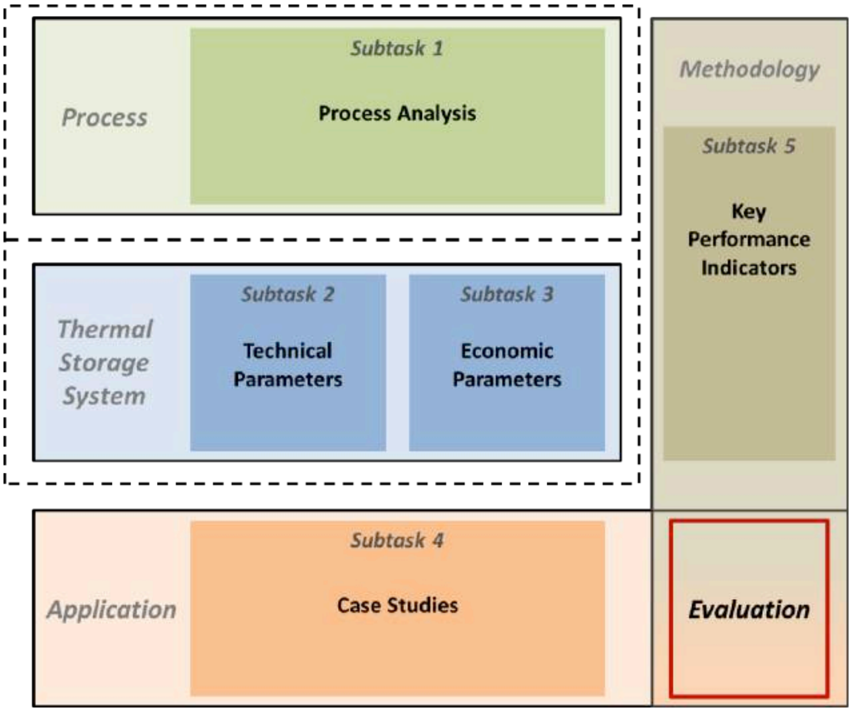

Figure: Annex 30 Work Plan

Several notable results can be reported from 2016. In subtask 1, the first draft of the process analysis methodology has been prepared and presented to the group. This preliminary document serves as a procedure for collecting information critical to assessing the suitability of a process for integration of a TES system. To provide futher context, information on processes from 16 different partners has been collected and through discussions in Annex 30 workshops, a comprehensive list of storage, sinks and heat transfer fluids of processes has been compiled. Finally, a preliminary investigation has been conducted into how to categorize process data. Discussions in workshops have led to the suggestion of several different possibilities: by temperature, by production/process type, by cycle frequency, by process lifetime or by benefit of the storage.

In subtasks 2 and 3, five definitions for technical parameters have already been proposed and discussed within the annex group. These definitions include: cycling stability, energy density, module energy storage capacity, module packing factor and module energy density. Furthermore, a definition for different "analysis levels" of a thermal energy storage system has also been proposed and discussed. This work clearly determines the levels of material, component, module, and system.

Additionally, 17 case studies of TES applications have been collected in subtask 4. These include 13 pilot/industrial-scale installations and 4 lab-scale set-ups. These case studies cover a range of temperatures from 20 – 550°C, sizes from 1 m3 to 200.000 m3, each respectively corresponding to short-term and seasonal storage periods, and different technology types. Subtask 5 has also seen a development of the key performance indicator methodology in which it was applied to two cases (concentrating solar power & cogeneration), with the benefit of storage integration being subsequently determined.

Several notable activities can be reported from 2016. The second Annex 30 workshop took place from May 2nd-4th at DECHEMA-Haus in Frankfurt, Germany. This workshop was held in conjunction with a joint conference entitled, "Thermal Energy Storage: Perspectives and Applications from an Industrial Environment". The conference was hosted by the Annex 30 group in partnership with the German association on process engineering and chemical engineering, ProcessNET. The conference joined the research and industrial worlds to discuss the most important themes of Annex 30: processes, system parameters and key performance indicators.

Over the course of the day, seven lectures were held in the plenum session, the majority of which were given by industrial participants. Two lectures covered the different perspectives on thermal energy storage from both research and industry. In the morning, the participants were divided into groups based on temperature ranges and the first subtask of the Annex "Process Requirements for TES Systems" was discussed, whereby process parameters critical to storage design were identified. The afternoon saw the discussion of the second, third and fourth subtasks, where the 49 participants were split into application-based groups: mobile applications, industrial processes, district heating, and power plants. In this session, the decisive issues of the Annex where discussed from both an industrial and research perspective. The conference then closed with a presentation and further discussion of these sessions in the plenum, as well as a panel discussion on market models for thermal energy storages.

Figure: Participants of the joint conference in Frankfurt in May 2016

Furthermore, the third Annex 30 workshop was held from October 17th-19th at the Tokyo Institute of Technology in Tokyo, Japan. Twenty-five members of Annex 30 took part in the closed sessions on the 17th and 19th, while 14 additional Japanese colleagues participated in the open session on October 18th. This open session brought together Japanese colleagues from research and industry to discuss thermal energy storage. The day began with seven presentations on current research from Annex 30 members. In the afternoon, two colleagues from Nagoya University and Hokkaido University presented their research on thermochemical and latent energy storage. Two colleagues from industry (Sanki Engineering Co. Ltd and Japan Facility Solutions, Inc.) later presented their commercial products for thermal energy storage. The closed sessions gave the opportunity for Annex 30 members to present their current research. Furthermore, the current progress in the subtasks themselves was presented and discussed. In these sessions, the following work was completed: further information for the process analysis methodology was shared, possibilities for categorizing the submitted processes were collected and discussed and a newly-developed methodology for determining key performance indicators of a TES system in an application was presented. Additionally, several important decisions were made: applications for mobile energy storage, cooling and thermal inputs/outputs from electrical sources will all be considered in Annex 30. A rough definition on the system boundary of a TES system was also agreed-upon.

Figure: Participants of the Annex meeting in Tokyo in October 2016

Annex 30 still has a presence online, both for collaborative and informative purposes. An external team-site has been established through involvement of the DLR-institute and will act as a platform for collaboration and the dissemination of work within the annex. Additionally, an external website has been created for the annex and can be found at: www.eces-a30.org.

The fourth biannual workshop will be held in Lleida, Spain on April 24th-26th, 2017.

For more detailed information, please refer to the work program online or contact the Annex Manager Duncan Gibb at duncan.gibb@dlr.de.

9.4 Annex 31: Energy Storage with Energy Efficient Buildings and Districts: Optimization and Automation

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Annex duration

May 2014 - December 2017.

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Scope overview

The general objective of this Annex is to address the integration, control, and automation of energy storage with buildings, districts, and/or local utilities. The focus is on the development of design methods, optimization, and control tools related to predicting, operating, and evaluating the performance of energy efficient buildings and districts when energy storage is available.

Activities/achievements

Extensive research was carried out on the development of simplified models both at the component and district levels. There are number of challenges in the design, and operation of energy-efficient district heating systems (DHS); simulation tools are among the essential missing items when such systems are designed and implemented. Over the past few decades, many simulation tools have been developed for predicting the performance of energy efficient buildings such as Energy plus, TRNSYS, eQUEST, etc. These simulation tools are broadly used to investigate the effectiveness of integrating energy storage and renewable energy resources to the building. Nonetheless, only limited research has addressed toward the development of simulation tools associated with the prediction of the energy demand at the district level. Furthermore, detailed building simulation tools (e.g., TRNSYS, EnergyPlus) are utilized for the energy analysis of the district energy networks; while other tools, such as HOMER Pro, utilize the predicted demand profile from other software or measured data in the form of a user-defined profile as an input to the DHS. In both scenarios, existing tools cannot satisfy the current need for a dynamic, reliable, and accurate tool that can envisage the demand profile of a large-scale district network in a timely manner. Development of a practical and simplified demand load model for a building stock is a complex task that requires a high-level proficiency, particularly as the demand profile of a building is varying as a function of time. As a result, simplified methods emerged as popular options for prediction of the demand profile of district networks. As part of this Annex a simplified model was developed to predict the profile of a district system - see Figure 1.

Optimization of a district energy system is a complex task for several reasons. Firstly, it includes both the spatial aspect associated with location and the temporal aspect associated with consumption, production, and price profiles. Second, many combinations can be considered for locations of buildings, size of energy units, and linkage between the possible end user candidates. Third, the consumption profiles vary in a stochastic manner during the day and from day to day, thus requiring much more sophisticated techniques to tackle the multi-period problem. Finally, the temperature level of different buildings may vary from one building to the other and during different periods even for the same building. Extensive works are underway to develop a simplified optimization tool.

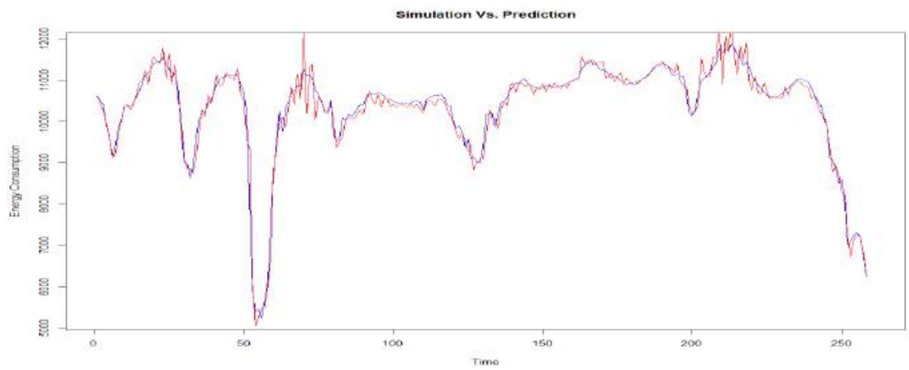

Figure : Predicted heating demand schedule vs. simulated demand profile of community 1; Last 11 Days of December

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