May, 11th 2016

Annual Report 2015

International Energy Agency

Technology Cooperation Programme

on Energy Conservation through Energy Storage

Content

Front page image: ECES TCP Executive Committee Meeting, May 2015, Beijing, China

Chairman's Report

I start my last report by thanking you all very much as your Chair! If I have achieved anything during my term, it has been because of your support.

My joining ECES TCP happened over twenty years ago. You elected me as your Chair for the past five years, for the second time. We made ECES TCP stronger, building on its solid foundations that were laid out by Germany during our previous term. I believe we made significant contributions to storage world. Our End-of-Term-Report for 2011-2016 points out many of our success stories. We must all be proud of ECES TCP's achievements over the last five years.

2015 has been especially important, its highlight being GreenSTOCK 2015 - The 13th Conference on Energy Storage that was held in Beijing, China on 19-21 May 2015. The Conference was organized by our Chinese colleagues from China Academy of Building Research and Tsinghua University. 260 participants from 27 countries contributed with 173 papers to another of our triennial STOCK conferences – "Storage Olympics".

We also added two new annexes in 2015: Annex 27 "Quality Management in Design Construction and Operation of Borehole System" and Annex 30 "TES for cost-effective energy management and CO_2 mitigation". Bright, new ideas on cutting-edge materials and models for energy storage are in pipeline to become our next annexes.

We continue to have very good co-operation with other IEA bodies. We participate at annual meetings of Building Coordination Group and CHP/DHC Collaborative and contributed to IEA Energy Technology Perspectives 2015. Our joint Annex 29 with SHC TCP will be completing next year, and we are considering another new joint annex. My presentation at the EUWP meeting on 16-18 September 2015 was well received and the EUWP has decided to recommend extending our term until 2021 to CERT.

We are reaching out to more new members. Antofagasta University of Chile has participated as an observer in our ExCo 80, and is now interested in being a sponsor member of ECES TCP.

I must thank our delegate Jennica Broman from Sweden, and our alternate delegates for Japan, Yuriko Terao, and the University of Lleida, Spain Albert Castell. I hereby present a very warm welcome to our new delegates who have joined us in 2015: Sara Malmgren, delegate of Sweden, Kouichi Ishida the alternate delegate of Japan, and Camila Barreneche the alternate delegate of the University of Lleida, Spain.

Last but not least, I wish to thank all the delegates of our Executive Committee, our Operating Agents, the experts of Annexes, our secretary team Hunay Evliya and Yeliz Konuklu, and the IEA desk officer John Dulac each, for their invaluable contributions to the success of ECES TCP.

The Greek philosopher Epicurus said that there are three requirements of happiness: Friendship, thought, and freedom. Each and every one of you have made me very happy by sharing their friendship and valuable thoughts under what I want to call "our roof" of free ECES TCP. I believe we need strong friendship more than ever to bring about what is all in our mind: innovation. I do not have any doubts at all that my successor, our new Chair, Teun Bokhoven shall continue our ECES TCP's mission with extraordinary success.

Halime Paksoy, Chairman ECES TCP

New Chairman's welcome

It is an honor and pleasure to take over the ECES TCP ExCo-chair from Halime as of 2016. It is a challenge to meet the high standard Halime and her team have set, but I happily accept and I hope on your support.
We can look back at a very constructive five year period in which Halime, Hunay and Yeliz have carried out a lot of work for ECES TCP. On behalf of all, I thank them very much and share our high appreciation for what they have achieved!

Teun Bokhoven, Chairman ECES TCP

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 by examining the full spectrum of energy issues and advocating 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 a number of specialised 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 programmes. 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 specialised 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 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 organisations from over 50 countries. TCPs are governed by a flexible and effective framework and organised through an Implementing Agreement. TCP activities and programmes are managed and financed by the participants. To learn more about the TCPs, please consult the short promotional film, the Frequently Asked Questions brochure, or the IEA website www.iea.org/tcp.

The Technology Cooperation Programme on Energy Conservation through Energy Storage (ECES TCP)

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

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

The ECES TCP accomplishes this through:

- Research and dissemination activities on both thermal as well as electrical storage technologies
- Storage technologies as a main driver for the transformation of the energy system toward a renewable based supply
- The international collaboration is to be 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. 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.

Background

The energy sector will undergo prominent changes in the near future. The percentage of renewable energies will increase, mainly in the uses of wind, solar, and hydro-power. These variable sources shall all provide challenges for national grids. The amount of fluctuating energy - both on the supply and demand sides – compels us to control these energy flows and capacities. Grid expansion will be necessary on the global system level, but is not always the best solution from energetic and economic points of view and this option may not be possible for all parts of the world.

Many electric storage systems are currently being considered to balance the demand. Pumped-hydro plants, CAES, and various electrochemical storages have been developed. Further R&D activities shall improve the efficiency of e.g. redox flow cells and NaS-batteries as well as decrease their costs. Even thermal energy storages may be suitable for balancing the electricity grid.

Energy storage can significantly contribute to increasing overall energy efficiency in the industrial sector through the use of 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 measures applicable to the building stock. Passive measures can reduce the heating and cooling demands of buildings. Cold storages help you to decrease the total power demand during summer and help to avoid black-outs. Seasonal storages 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 the renewables on the other. Solar assisted heating and cooling systems in combination with storage provide very promising solutions. Transforming surplus solar or wind energy and storing it in decentralized storages like latent heat may become very energy-efficient and economical solutions.

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

There is a tremendous potential for the use of energy storage, in all kinds of applications and for all kinds of different business cases. Every situation requires a different technical storage based solutions. Apart from the technical development on component and sub-system level, very efficient solutions with regard to storage are found within the overall energy system. All kind of storages have to be taken into account to find the optimum in a given supply and demand situation.

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	Jens Windeleff, Per Alex Sørenson
Finland	Pirkanmaa ELY-Centre	Jussi Mäkelä
France	Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME)	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	Mario Conte
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	Uros Stritih, Vincenc Butala
Spain	University of Lleida (Sponsor)	Luisa F. Cabeza, Camila Barreneche
Sweden	Energy Technology Department, Swedish Energy Agency	Sara Malmgren
Turkey	Çukurova University	Halime Paksoy, Hunay Evliya
USA	U.S. Dept. of Energy	Imre Gyuk

GreenSTOCK Conference

The 13th Conference on Energy Storage was held in Beijing, China on 19-21 May 2015. Chinese Academy of Building Research (CABR) and Tsinghua University hosted the conference with support from ECES TCP. The scientific chairs of the conference were Xu Wei (CABR), Yinping Zang (Tsinghua University) and Halime Paksoy (ECES TCP) and scientific secretary was Zhang Shicong (CABR). 260 participants from 27 countries participated with 173 papers.

In the opening session welcome addresses were given by:

- Chunheng Wang, Director, Ministry of Science and Technology
- Qingqin Wang, Vice President, China Academy of Building Research
- Halime Paksoy, Chair, IEA ECES TCP

The keynote addresses in the plenary, following the opening session were:

- The storage story, Halime Paksoy, Chair, ECES TCP
- Apply energy storage in buildings: new understanding and approach, Yinping Zhang, Tsinghua University
- High priority R&D themes in buildings sector for IEAs 2C Scenario towards 2050, Takao Sawachi, Vice Chair, EBC TCP
- R&D progress in electrical energy storage in China, Haisheng Chen, Director, China Academy of Science.
- Heat pumps and storage a great potential in the future energy including large amounts of intermittent power, Roger Nordman, Manager, IEA Heat Pump Center

The awards given during the GreenSTOCK Conference are:

CLIMATOR Best PCM Paper Award

This award is given by the CLIMATOR Company in the memory of their founder Rolf Ulvrengen to the best PCM paper at every Stock Conference.

This year's award was given to: S. Gschwander, T. Haussmann, G. Hagelstein, A. Sole, L.F. Cabeza, G. Diarce, W. Hohenauer , D. Lager, A. Ristic, C. Rathgeber, P. Hennemann, H. Mehling, C. Penalosa, A. Lazaro for their work on "Standardisation of PCM characterisation via DSC".

Fredrik Setterwall Award

The Fredrik Setterwall award is given to an individual, company, or private/public institution that has shown outstanding leadership or achievements in the field of energy storage, and that supports the work of the ECES TCP.

Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ) has been chosen as the 2015 winner for the Fredrik Setterwall award. With the 2015 award, the IEA ECES recognizes not only the excellent achievements of HPTCJ, but also the pioneering spirit of the center. The HPTCJ has covered different thermal energy storage technologies over the last decades and always strengthened an intense collaboration with Japanese industry. It is significantly responsible for Japans leading role in this field. The award winning lecture was delivered by Prof. Motoi Yamaha from Chubu University, who received the award on behalf of HPTCJ.

Best Papers Award

- C. Rathgeber, H. Schmit, L. Miro, L. F. Cabeza, A. Gutierrez, S. N. Ushak, S. Hiebler, A. Hauer: "Analysis of supercooling of phase change materials with increased sample size-Comparison of measurements via DSC, T-History and at pilot plant scale"
- A. Stamatiou, A. Ammann, L. J. Fischer, D. Gwerder, J. Worlitschek: "Combined Storage of Heat, Cold and Electricity"
- H. Liu, K. Kubo, T. Katsura, K. Nagano, K. Kubota, A. Okamoto: "Discussion on methods of achieving a high-efficiency ground source heat pump (GSHP) for space heating"

Best Posters Award

- B. Beyhan, K. Cellat, H. Paksoy, Y. Konuklu, O. Karahan, C. Dundar, C. Gungor: "New Microencapsulated Phase Change Material for Thermal Energy Storage in Building Applications"
- J. Wang, Y. Wang, W. Wang, R. Yang: "Preparation and Thermal Property of Flame Retardant Shape-Stabilized Phase Change Materials for Energy-Saving Buildings"
- J. Kariya, J. Ryu, Y. Kato: "Reaction Performance of Calcium Hydroxide and Vermiculite Composite for Chemical Heat Storage Application"

Annex 27 - Quality Management in Design, Construction and Operation of Borehole Systems

Operating Agent

Manfred Reuss

Duration of Annex

March 2016 – March 2019

Background

Learn from experiences, don't make a mistake twice! The thermal use of the underground is an important technology to increase energy efficiency for heating and cooling in domestic and commercial applications. In Europe, North America and Asia the market for underground thermal energy storage (UTES) for heating and cooling and especially for ground source heat pumps (GSHP) was growing rapidly in the last years. The different technologies applied are depending on the local geological situation. Aquifer based systems like ATES or groundwater heat pumps or systems with borehole heat exchangers like BTES or heat pumps with BHE's are the most popular applications which cover a wide range from family homes for heating or cooling 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 …).

Overview of Scope

The overall objectives of the proposed annex are to avoid mistakes and failures related to the borehole system in design, construction and operation. 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 enforced 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
- Work out handbooks and guidelines for design and construction in order to avoid future mistakes
- Investigate operational failures
- Work out preventative guidelines for monitoring, maintenance and rehabilitation measures
- Identify related problems in order to establish further R&D

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 Annex will cover the following topics:

Design phase

- Energy concept
- Pre-feasibility
- Feasibility
- Detailed planning
- Approval procedure
- Call for tenders

Construction phase

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

Operation

- Supervision of operation
- Maintenance – not needed

Problems, failures, investigation and solution

- Common problems with BHEs and BTES
- Problems from poor grouting
- Problems deriving from modification of design parameters
- Description of methods how to avoid and how to solve these problems – remediation

Environmental assessment

Activities

In 2015 a task definition workshop was held at ZAE Bayern in Garching (Munich) October 14th – 16th with 24 participants from 9 different countries (Canada, China, Denmark, Finland, Germany, Japan, Slovenia, Sweden and Turkey. Two more countries (Belgium, The Netherlands) are interested in participating but couldn't attend this meeting.

Figure 1: Task definition workshop at ZAE Bayern in Garching (Munich) October 2015

During the workshop a working program based on the objectives and scope was discussed. Following the above mentioned topics a very detailed work plan was elaborated and finally agreed.

Additional to the international experts group it is recommended to form national teams in each country with members from relevant industries, technical associations and regulatory bodies to establish an intensive exchange of information from the national to the international level and vice versa. These national teams will be an important factor in technology transfer and communication into practice.

At the ECES TCP ExCo Meeting in Aalborg (Denmark) in November 2015 Annex 27 was finally approved and will officially start in March 2016.

The first experts meeting of Annex 27 is planned beginning of May 2016 in Horsens, Denmark.

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

Operating Agents

Dr. Andreas Hauer, Prof. Dr. Christian Doetsch

Duration of Annex

Start: January 2014 - End: December 2017.

Overview of scope

A rapidly growing contribution by renewable energies 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 energies energy storage /energy balancing capacities are needed. So far the focus is on large, central and 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 renewable energies 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 energies in future energy systems.
Distributed energy storages (DES) can be defined by their location within an energy system. In this perspective DES can either be located

- at the consumer side (household up to small industrial application), or
- decentralized in the distribution grid, or
- at decentralized power generation sites (e.g. small biogas plants or wind farms).

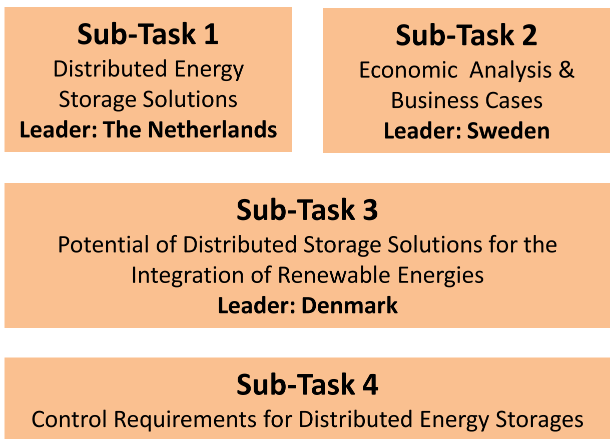

Figure 2: Organization matrix of Annex 28

The Annex work is structured in Subtasks. The structure is shown in the figure 2. 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 has to identify the general potential of DES solutions (TRL 3-9) in different countries. In this Subtask also actual business cases have to be reported. Subtask 4 is focussed on the necessary control requirements for the operation of DES solutions, especially when operated in order to provide flexibility measures for the grid.
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 properties requirements depending on the different renewable energy sources will be reviewed and possible control and operation strategies for DES and technologies by smart grids will be studied. Finally the potential of DES systems for the integration of renewable energies based on the actual final energy demand

shall be quantified and guidelines for choosing the most suitable DES technology for the actual application will be developed. Best practice and success stories examples will be given.
The scope of this Annex includes all energy storage technologies suitable on the consumer side. Three main fields of application – households, trade and commerce and industry – will be investigated.

Participants of Annex 28

Country	Research Group
Germany	Fraunhofer ISE
Germany	ZAE Bayern
Spain	University of Lleida
Sweden	KTH Royal Institute of Technology
The Netherlands	TNO
Turkey	Çukurova University

Activities / Achievements

In 2015 two workshops and experts meeting were held in Arnheim, The Netherlands, and Paris, France. At these meetings over 40 scientists participated and gave over 20 presentations on their ongoing R&D activities covering various aspects of DES.
Within the Subtask 1 a table was compiled listing different applications for DES systems by different sets of energy source, DES system and consumer (figure 3).
These combinations were categorized as DES solutions. The proposed schematic representation of such an application, including energy source, storage technology and consumer, leads to over 20 DES systems. In this compilation already existing energy systems with DES as well as DES systems and technologies under development are considered. An exemplary schematic figure is shown below.

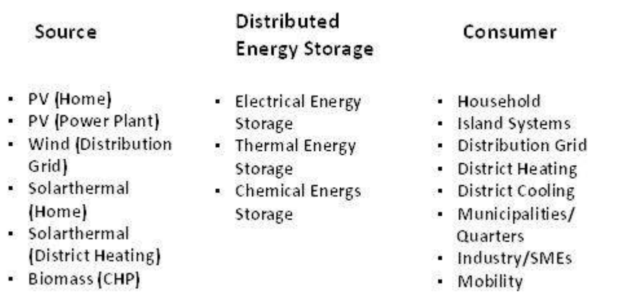

Figure 3: Different applications for DES systems by different sets of energy source, DES system and consumer

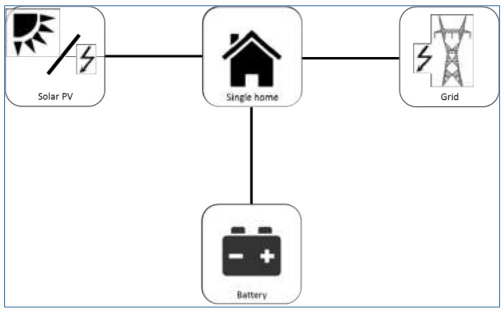

Figure 4: Single home with a PV-installation and a battery combined, connected to the grid

The energy source is shown in figure 4, the consumer in the middle and the applied storage technology is placed below the consumer. Additionally, it is indicated, whether the system is connected to the grid or not (on the right). The example shows a home battery combined with a PV-installation and connected to the grid. This scenario can be realized by Li-Ion-batteries as well as Lead-Acid-batteries.

Goal of this activity is to compile a complete overview of possible applications of DES technologies and by this enable a rough estimation of the potential contribution in future energy systems.

During the workshops several ongoing R&D project were presented and discussed as fora project from Dundalk (Ireland). The campus at Dundalk Institute of Technology was equipped with wind power. To improve the system performance a flow battery system and ice storage (see pictures below) were installed as well. It was reported, that the economics changed substantially during the project period. PV became much more feasible due to its falling prices, which influences the storage demand significantly.

Figure 5: Other examples for DES applications were given from Denmark, Germany, The Netherlands, UK and Sweden

Annex 29 - Material Research and Development for Improved TES Systems

Operating Agent

Dr. Andreas Hauer

Duration of Annex

January 2013 - December 2015

Overview of scope

The overall goal of this task is to develop advanced materials and systems for an improved performance storing thermal energy. Therefor new materials and composites for compact thermal energy storage should be identified, designed and developed. For these materials measuring and testing procedures have to be put in place in order to characterize their potential performance within actual storage applications. The material requirements for relevant applications should be proofed, by means of numerical simulation on the material micro-scale as well as on the system level. Finally the impact of new materials on the performance of thermal energy storage in the different applications should be assessed.
A secondary objective of this task is to further expand and intensify the collaboration between material researchers, system developers and industry working in the field of thermal energy storage.
This task deals with advanced materials for latent and chemical thermal energy storage. The activities include the material scale as well as the system level. This task will include multiple application areas from cooling to heating and domestic hot water or to high temperature applications in industry and power generation.

Participants of Annex 29

Country	Research Group
France	University of Bordeaux
Germany	Fraunhofer ISE
Germany	ZAE Bayern
Japan	Chubu University
Spain	University of Lleida
Sweden	KTH Royal Institute of Technology
Turkey	Çukurova University

The Task is organised in a matrix-like structure. Such a structure

- maximises the interaction between materials researchers and application experts
- maximises knowledge exchange between groups working on adjacent topics
- gives the task an organisational structure that reflects the different emphasis in this Annex

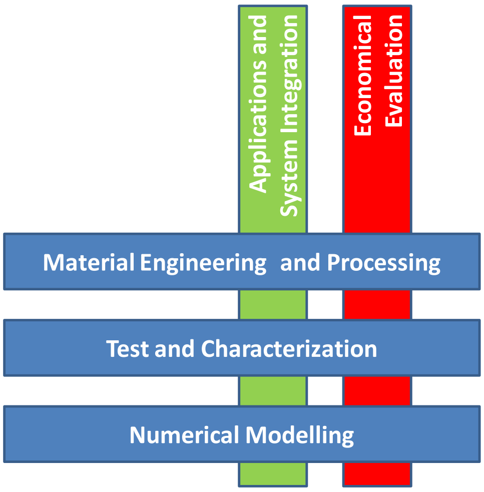

Figure 6: Organization matrix of Annex 29

The horizontal axis represents materials-related categories. It is divided into groups of similar activities: Materials engineering and processing, Test and characterisation, Numerical modelling. The vertical axis represents application and system related categories.
This Annex will focus on system integration for actual applications and the predicted performance under application conditions. Finally the economical evaluation of new developed materials shall be evaluated. Each category corresponds to a Working Group. Each Working Group is coordinated by a Working Group Leader.

Activities/Achievements

In 2015 two workshops and experts meeting were held in Vienna, Austria, and Zaragoza, Spain. At these meetings over 90 scientists participated and gave over 31 presentations on their ongoing R&D activities. 2 Highlights will be presented in the following text.
One of the material properties, which came into focus of several working groups, was the thermal conductivity in many cases responsible for the thermal power output of the storage. One approach for the heat transfer enhancement was the use of highly porous carbon monoliths. With their high open porosity (equal or higher than 86-88%) they provide thermal conductivity within the range of 2 –7 W/m/K at cost less than 6 €/kg. Figure 7 on the left shows such a carbon monolith. Thermal conductivity measurement workshop was held in the 2nd half of 2015. The focus of this workshop was on laser flash characterization of PCMs.

Figure 7: Highly porous carbon monolith

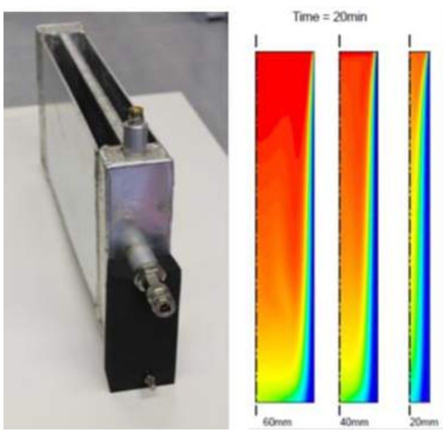

Figure 8: Metal containment for experimental investigation of eutectic mixtures of sugar-alcohols

Heat transfer and by this the propagation of the melting of a PCM during the charging step was also a topic within the working group on “Numerical Modelling”. The activities in this working group are aimed at developing and testing numerical models that help to understand and optimize the material behavior and the dynamic behavior of compact thermal energy storage systems and components based on Phase Change Materials (PCM’s) and Thermo-Chemical Materials (TCM’s). Different eutectic mixtures of sugar-alcohols were investigated within a metal containment (see Figure 8 on the right). The propagation of the melting was modelled and afterwards validated in an experimental set-up.

Publications

Kasibhatla R.R. Multiphase modelling of macro encapsulated phase change material. Poster session presented at: 9th International Renewable Energy Storage Conference (IRES 2015), 2015 March 09-11; Düsseldorf, Germany.

S. Metchueng Kamdem, K. Johannes, F. Kuznik, H. Bouia, J.J. Roux "Sensitivity analysis of the energy density in a thermo chemical heat storage device", SHC 2013, International Conference on Solar Heating and Cooling for Building and Industry, Freiburg (Germany), September 25-23, 2013, Energy Procedia, vol. 48, pp. 405-412, 2014.

Pierre Tittelein, Stéphane Gibout, Erwin Franquet, Kevyn Johannes, Laurent, Zalewski, Frédéric Kuznik, Jean-Pierre Dumas, Stéphane Lassue, Jean-Pierre Bédécarrats, Damien David. Simulation of the thermal and energy behaviour of a composite material containing encapsulated-PCM: Influence of the thermodynamical modelling. Applied Energy, 140 (2015) 269-274

Seasonal thermal energy storage with aqueous sodium hydroxide - reaction zone development, manufacturing and first experimental assessments. Xavier Daguenet-Frick, Paul Gantenbein, Elimar Frank, Benjamin Fumey, Robert Weber, Tommy Williamson, EuroSun 2014, France.

Lan, S. Zondag, H.A., Steenhoven, A.A. van & Rindt, C.C.M. (2015). An experimentally validated numerical model of interface advance of the lithium sulfate monohydrate dehydration reaction. Journal of Thermal Analysis and Calorimetry, under review.

Long term thermal energy storage with stable supercooled sodium acetate trihydrate, Mark Dannemand, Jørgen M. Schultz, Jakob Berg Johansen, Simon Furbo, Applied Thermal Engineering 91 (2015) 671-678.

Daguenet-Frick, X., Gantenbein, P., Frank, E., Fumey, B., Weber, R.; Development of a numerical model for the reaction zone design of an aqueous sodium hydroxide seasonal thermal energy storage. Solar Energy. In press, 2015.

J. Mazo, M. Delgado, A. Lázaro, P. Dolado, C. Peñalosa, J.M. Marín, B. Zalba. A theoretical study on the accuracy of the T-history method for enthalpy-temperature curve measurement: analysis of the influence of thermal gradients inside T-history samples. Measurement Science and Technology 26 (2015) 125001.

Jessica Giro-Paloma, Camila Barreneche, Monica Martínez, Bostjan Sumiga, Ana Ines Fernandez, Luisa F. Cabeza. Mechanical response evaluation of microcapsules from different slurries. Renewable Energy 85 (2016) 732-739.

Tittelein P., Gibout S., Franquet E., Johannes K., Zalewski L., Kuznik F., Dumas J.-P., Lassue S, Bédécarrats J.-P., David D. (2015) Simulation of the thermal and energy behaviour of a composite material containing encapsulated-PCM: influence of the thermodynamical modelling. Applied Energy, 140, pp 269–274

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

Operating Agent

Dr. Antje Wörner

Duration of Annex

July 2015 – June 2018

Overview of scope

The general objective of Annex 30 is to identify and enable the potential for the implementation of thermal energy storage as a cross-sectoral technology. This will involve improving energy efficiency and process integration, increasing system flexibility as well as expanding utilization of renewable heating and cooling resources.

Participants of Annex 30

Country	Research Group
Austria	Austrian Institute of Technology
Belgium	Energyville (KU Leuven & VITO)
France	Atomic Energy and Alternative Energies Commission (CEA)
France	University of Pau
Germany	German Aerospace Center (DLR)
Germany	ZAE Bayern
Germany	Leuphana University
Germany	Technische Universität Chemnitz
Italy	Italian National Research Council (CNR-ITAE)
Japan	Tokyo Institute of Technology
Spain	University of Lleida
Spain	University of the Basque Country UPV-EHU
Sweden	KTH Royal Institute of Technology
Sweden	Chalmers University of Technology
Sweden	Swedish Centre for Shallow Geothermal Energy
Turkey	Çukurova University

Ultimately, Annex 30 will create a methodology for characterization and evaluation of thermal energy storage systems. This comprehensive approach will be focused on 4 sectors: industry, power plant applications, non-residential buildings and transport. The methodology will be applied to various case studies originating from demonstration projects where thermal energy storage systems are applied in a real environment. Industrial involvement is critical to this annex and the crucial goal of harmonizing research and industrial needs will be endeavoured.

Annex 30 has been broken down into three phases: definition, methodology and application. The work will begin with the identification of the storage requirements for thermal energy storage systems in the aforementioned sectors, followed by the development of the characterization and evaluation methodology. The third phase applies the methodology to various case studies commonly implemented within industry and then uses industrial feedback to further refine the methodology.

Activities/Achievements

Annex 30 has several notable accomplishments to report from 2015. The work program was finalized in June and approval was granted to move the official start date of the annex to July 2015. Following the three year plan, the annex will end in June 2018.

Annex 30 now has a presence online: both for collaborative and informative purposes. An external team-site has been established through DLR 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 first biannual workshop was held at KTH in Stockholm on October 29-30th, 2015. One main goal of the workshop was to introduce partners with their research areas and relevant projects and initiate exchange with interested participants to establish a collaborative framework. Short 'elevator pitches' of all partners and a poster exhibition were a good basis for exchange and discussion between the 27 participants from 18 different institutions. A second goal was to elaborate a better understanding of the work to be done in subtasks 1 through 4 and brainstorm ideas in all four areas. Therefore, the workshop was conducted in a 'world café' format, with four 45 minute brainstorming sessions held for each of the four subtasks. Participants had the chance to participate in a session to each subtask and were encouraged to discuss the relevant topic based on some preliminary statements ans questions in this field. All ideas were collected via a whiteboard. At the end of the second day, members worked with the subtask leaders to finalize conclusions and future work for each subtask. These results were then presented to the whole group

The second biannual workshop will be held in Frankfurt, Germany from May 2nd - 4th, 2016.

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

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

Operating Agent

Fariborz Haghighat

Duration of Annex:

May 2014 - December 2017

Overview of scope

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

Eleven countries (including three observers, Australia, Czech and Estonia) are participating and contributing to this Annex.

Participants of Annex 31

Country	Research Group
Canada	Concordia University
Canada	Lab. des Techn. de l'énergie d'Hydro-Québec
China	Hunan University
China	Southeast University
France	ENTPE-University of Lyon
France	University of Savoie
France	University of Toulouse
Italy	Politecnico di Milano
Italy	Università degli Studi di Torino
Japan	University of Tokyo
Slovenia	University of Ljubljana
Turkey	Çukurova University
UK	University of Strathclyde
UK	Cambridge University

Activities/Achievements

Extensive research are underway on the development of simplified model both at the component and district levels, Task A. At the component level, the main challenge in modelling the phase change process is the effect of natural convection in the process and especially in case of simultaneous charging and discharging, and whether or not to take it into account different geometries. It was revealed that still there is a challenge on how to weight the percentages of conduction and convection heat transfer and how the dominant heat transfer mechanism differs in various cases. Figure 9 shows the temperature and liquid fraction distributions for a triple tube heat exchanger (TTHX).

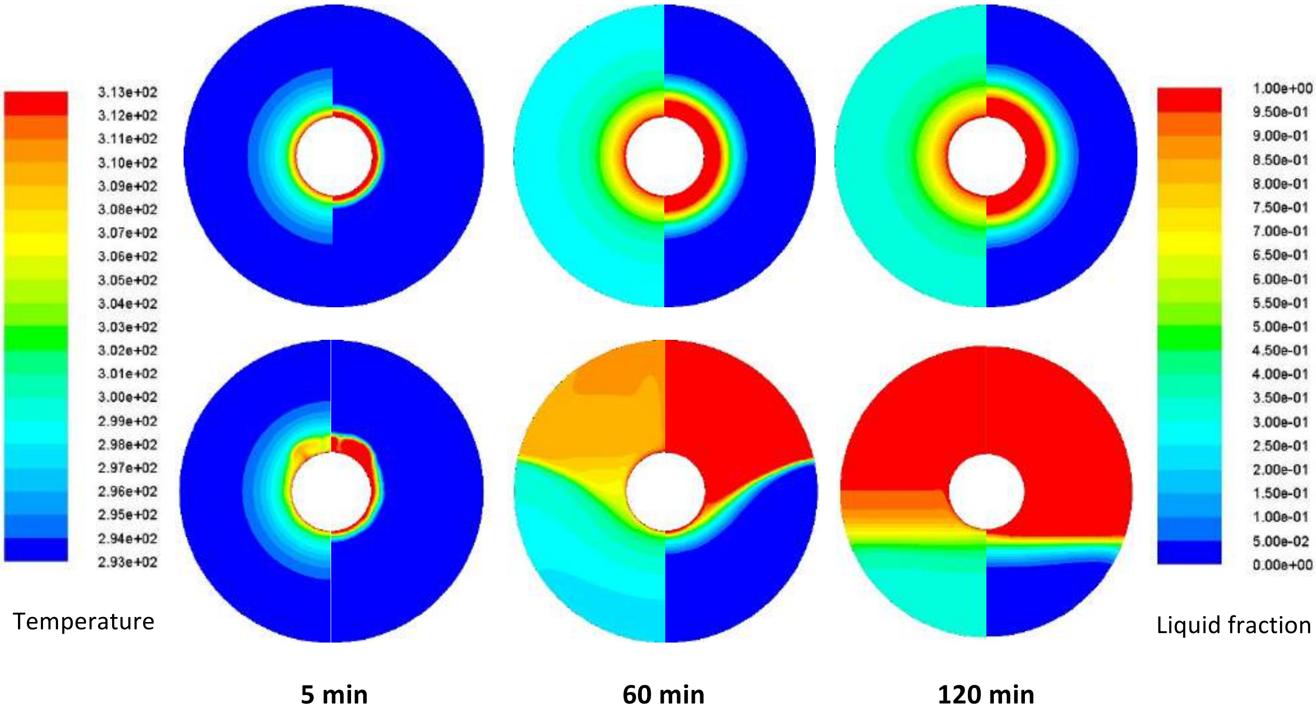

Figure 9: Temperature (left) and liquid fraction (right) contours for the PCM inside the TTHX if no natural convection was present (upper) and considering the effect of natural convection (lower)

In the area of optimization Task B, the design and operation of an integrated energy efficient building is the result of the global performance of the system where many interactions exist between the building, the primary and secondary systems, the energy resources availability, the outdoor and boundary conditions. In contrast to narrowed research activities that tend to increase the performance of single components, in this research the challenge of designing such system is approached with a systematic approach, for solving a complex optimization problem, see Fig. 10.

The first draft of report of Task C on control is prepared and distributed at the last meeting for discussion and comments. In Task D, a set of indicators has been developed for evaluating the performance of a dynamic storage system.

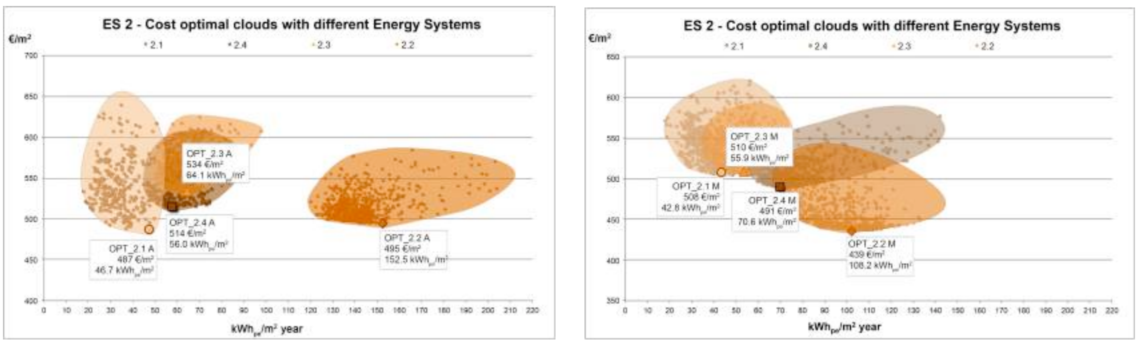

Figure 10: Clouds of design combinations for the determination of the cost optimal solution as a function of different energy systems

Publications

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Cellat, K., Beyhan, B., Gungor, C., Konuklu, Y., Karahan, O., Dundar, C., ; Paksoy, H. (2015) Thermal enhancement of concrete by adding bio-based fatty acids as phase change materials, Energy and Buildings 106 (2015) pp: 156-163.

El Mankibi, Zhai, M. Q.J., Al-Saadi, S.Nasser, and Zoubir A., (2015), Numerical modeling of thermal behaviors of active multi-layer living wall, Energy and Building, Pages 96-110.

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Fabrizio, E., Ferrara, M., Urone, G., Corgnati, S. et al. (2015) Performance Assessment of a Solar Assisted Ground Source Heat Pump in a Mountain Site, Energy Procedia, vol. 78, pp. 2286-2291.

Fadejev, J., Kurnitski, J. (2015), Geothermal energy piles and boreholes design with heatpump in a whole building simulation software, Energy Buildings 106, pp. 23-34.

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Tuohy, P. G., Kim, J. M., Samuel, A., Peacock, et. al (2015) Orchestration of renewable generation in low energy buildings and districts using energy storage and load shaping : Energy Procedia. p. 2172-2177 6.

Yu, Z., Huang, G.S., Haghighat, F., Li, H.Q, and Zhang, G.Q. (2015) Control strategies for integration of thermal energy storage into buildings: State-of-the-Art review. Energy and Buildings, pp.203-215.

Communications

Communicating with other groups on the energy technology network is an important part of our activities. ECES TCP has an on-going joint annex with SHC TCP (Annex 29-Task 42). This Annex will be completing next year, and another new joint annex is under development. Annex 28 also has a collaborative structure that allows communication with interested IAs to contribute in the annex work through participation in the annual workshops. Representatives from 7 different TCPs (HEV, EBC, HPP, ISGAN, SHC, DHC, ETSAP) participated in the workshops of Annex 28. ECES TCP participated at annual meetings of Building Coordination Group and CHP/DHC Collaborative and contributed to IEA Energy Technology Perspectives 2015. ECES TCP Chair gave a presentation at the EUWP meeting on 16-18 September 2015, which was well received and the EUWP has decided to recommend extending our term until 2021 to CERT.

The general publications of ECES TCP are the annual reports and brochure, which are available from the webpage. The final annex reports are published on the webpage also.

The webpage is managed by the ECES TCP secretariat. The number of visits per month to ECES TCP webpage reaches to 30000. There are two addresses for ECES TCP:

- www.iea-eces.org
- www.energy-storage.org

There are also web addresses for the following Annexes, which are maintained by operating annexes:

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

Furthermore, ECES TCP has contributed to scientific organisation of the Eurosun, the European conference on solar thermal energy and Solar World Congress of International Solar Energy Society and the Solar Heating and Cooling Conference of SHC TCP. ECES TCP was one of the supporting organizations of Energy Storage Europe in 2015, which is a major annual event that takes place in Germany. The delegates of the ExCo and experts of Annexes are giving presentations on energy storage as keynote speakers at these and other conferences and forums. 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. Industries engaged in annexes participated in workshops organized by annexes. The following workshops were organized in 2015:

- Annex 29 Workshop, Vienna, Austria, 9-11 February 2015
- Annex 31 Workshop during, 6th International Conference on Building Physics for a Sustainable Built Environment, Turin, Italy, June 16-18 2015
- Annex 27 Workshop, Garching, Germany, October 12-14 2015
- Annex 28 Workshop, Paris, 22-23 October 2015
- Annex 31 Workshop, Nanjing, China, 26-28 October 2015
- Annex 30 Kick-off Workshop 4 World Café sessions, Stockholm, Sweden, 28-29 October 2015
- ECES Workshop on Future Energy Storage Demand in Energy Systems, Aalborg, Denmark, November 4, 2015

Special editions on energy storage in distinguished journals are published with the joint efforts of the experts in different annexes. Annex 31 had a special issue in Energy and Buildings Journal, where 22 papers from Annex members were published.
The delegates and experts of ECES TCP are also supporting education and training activities and exchange programs through joint projects (e.g. EU programmes). Such activities for young professionals and early scientists enhance the network and quality of research and practice in this field. In

2015, a EU funded project titled "Inpath-TES PhD on Innovative Pathways for TES" started with the aim of supporting education on thermal energy storage on the graduate level.

In terms of international policies, ECES TCP has links with different organizations through delegates and operating agents. ECES TCP started sharing information on activities of European Energy Research Alliance (EERA), which is an integral part of EU Horizon 2020 through Operating Agent of Annex 30. Energy storage, one of 15 joint programmes in the organization, is the largest group in EERA. The operating agent of Annex 30 leads thermal storage and the ECES TCP delegate for Italy leads electrochemical storage within energy storage joint programme. ECES TCP also receives feedback from Intergovernmental Panel on Climate Changes (IPCC) and Cross-Cutting Panel of the European Technology Platform on Renewable Heating and Cooling through ECES TCP delegate from Spanish sponsor member.

Financing

All contracting parties and sponsors make an annual financial contribution to the common fund used for administration and communication matters of ECES TCP. The following table gives the distribution of the budget among the 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 MM/year. The work of the Operating Agent requires funding of about 6 MM/year.

Table: ECES TCP common fund distribution in 2015

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	6 X 3.000	18.000
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)		54.000

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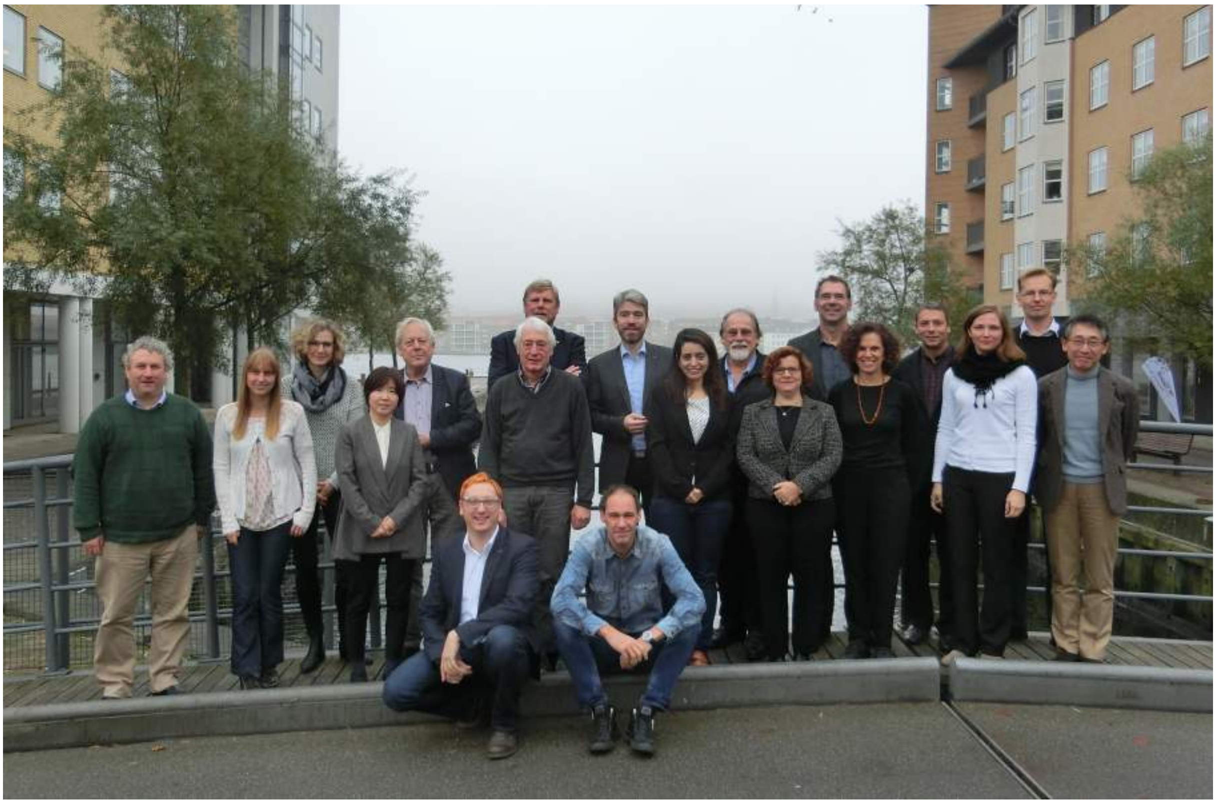

ECES TCP Executive Committee Meeting, November 2015, Aalborg, Denmark

International Energy Agency

Technology Cooperation Programme

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