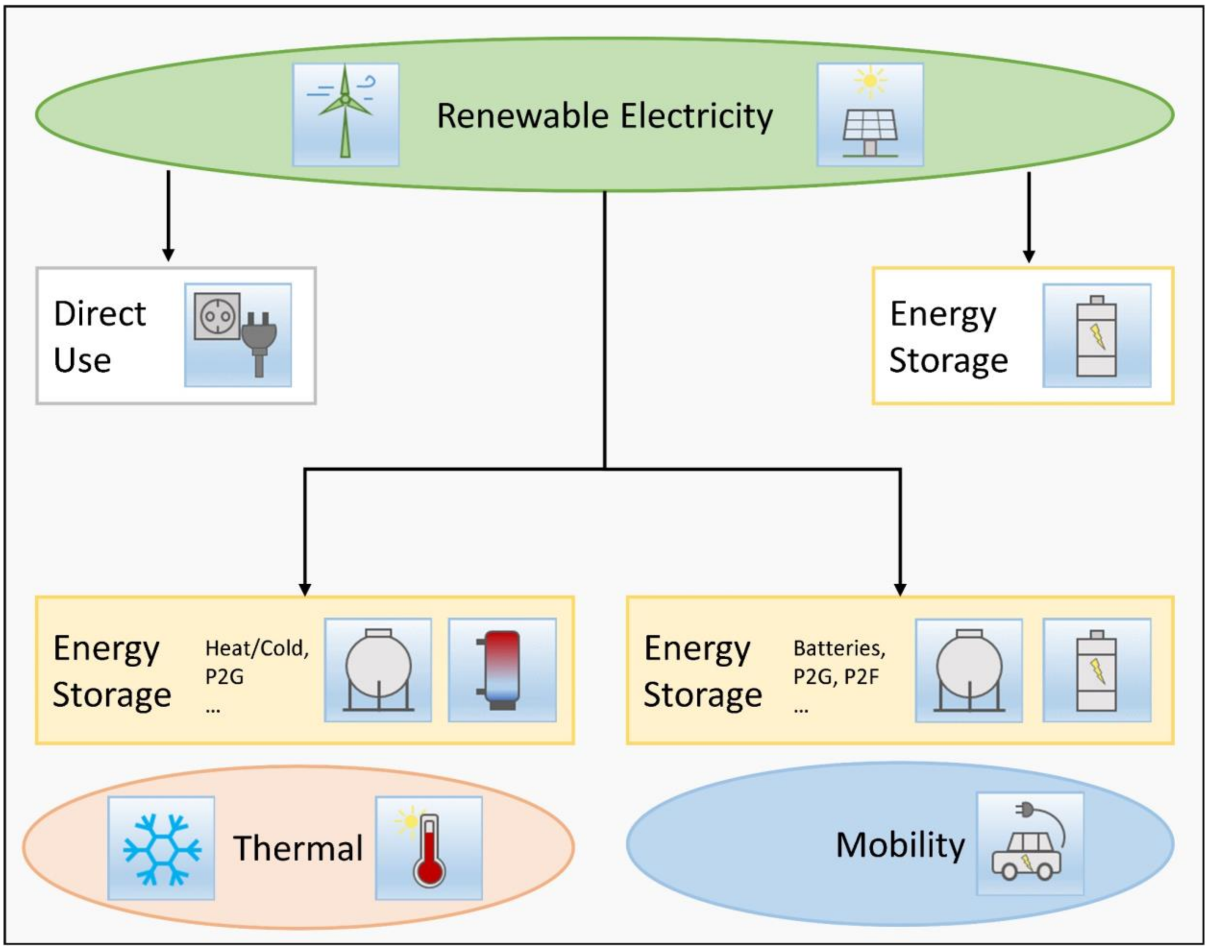
energy storage
IEA Technology Collaboration Programme

Annual Report 2020



COLOPHON

Contributors to this Annual Report 2020:

Dan Bauer, Teun Bokhoven, Christian Doetsch, Andreas Hauer, Wim van Helden, Hanne Karrer, Ryozo Ooka and Peter Wagener

International Energy Agency, Technology Collaboration Programme

ES TCP - Energy Storage TCP (original name ECES TCP - Energy Storage through Energy Conservation)

www.iea-eces.org

Content

CHAIRMAN'S REPORT

General

Despite the complications of the Corona Pandemic, 2020 has been a productive year for the Energy Storage TCP. Of course, COVID19 had great impact on meetings both for the Annexes/Tasks as well as the ExCo and required new ways to organize ourselves; but we seem to have managed it well and work is progressing, despite the lack of physical meetings.

Additionally, to the main work in the TCP, two processes needed our attention in 2020: The Request for Extension (including a new Strategic Plan, an Overview of achievements and End of Term report) and the Modernization of the Implementing Agreement (including a new amended text for the Implementing Agreement, harmonised TCP wording and a Handbook for internal procedures). Both activities were successfully completed. The Energy Storage TCP agreed on a modernised Implementing Agreement and CERT approved our request for extension for another term (2021-2026).

Work in the Tasks (previously called Annexes) progressed very well. Discussions in the ExCo around the new strategic plan 2021-2026 led to a more dedicated portfolio of research topics, communication and policy priorities.

Strategic priorities, ongoing and new Tasks

Energy Storage TCP operates seven Tasks at the end of 2020. Five new tasks, two ongoing and 2 Tasks (formally known as Annexes) were completed.

The five new Tasks were approved and initiated in 2020 and began their work or will do so in 2021. They fit well in the newly approved scope of the new Strategic plan (2021-2026), which calls for the following priorities: System Integration (addressed by Task 32, 34, 35, 36), Electrical Storage (addressed by Task 35, 36) Thermal Storage (Task 34, 35, 37, 38 and 39).

The new 2020 ExCo approved Tasks are:

- Task 32: Open Sesame – Open-Source Energy Storage Models
- Task 36: Carnot batteries
- Task 37: Smart Design and Control of Energy Storage Systems
- Task 38: Ground Source de-icing for Infrastructure
- Task 39: Large TES for District heating

The Ongoing Tasks are:

- Task 34: "Energy Storage with Heat Pumps – Comfort & Climate Box" (joint Task with Heat Pump Technologies (HPT) TCP, also connecting to MI)
- Task 35: Flexible sector Coupling by the implementation of Energy Storage

Completed Annexes (from now on called Tasks) in 2020

Two Annexes/Tasks were completed in 2020:

Annex 27 – *Quality Management in Design, Construction and Operation of Borehole Systems.*

This Annex/Task has contributed very strongly to the CEN standardization work and has delivered a very practical handbook and guidelines to speed up further deployment of this technology. The policy recommendations derived from this Annex/Task are:

- The continued and expanded use of the earth as a reliable heat source / heat sink combined with efficient heat pumps to heat and /or cool buildings will take on significant importance in the move to beneficial electrification and the replacement of fossil fuels.
- Currently the vast majority of systems have not encountered problems. However, it requires special extra attention to the local geological and hydrogeological situations.
- The new European CEN Standard developed by CEN TC451 WG2 "Borehole Heat Exchangers", was developed in close collaboration with IEA ES TCP Annex 27. This was considered a significant step forward.

Annex 33- *Material Component Development for Thermal Energy Storage (joint ES/SHC TCP Task)*
This Annex/Task has delivered a methodology and database for materials to be used in compact thermal energy storages. The policy recommendations derived from this Annex/Task are:

- Collaboration in the IEA Annex/Task between materials experts and application experts leads to improved understanding and therefore accelerates development.
- Standards for measurement are prerequisite for rapidly addressing challenges and advancing TES technologies.
- While standardized reference conditions can be defined for the building sector, for industrial applications the diversity of processes makes it very difficult.
- A number of innovative and improved materials were developed and continuously are being developed, tested and introduced in components for further development of compact storages.
- The developed characterization methods (technical performance, stability and compatibility) created the basis for material evaluation and comparison and will be included in a permanent database. This is planned to be maintained and managed by the TCP.

Policy Priorities

In the past energy storage was mainly considered as a technological option, however today we need to position energy storage also as an economic parameter in the energy transition. There is a need to contribute with background knowledge on various aspects, which can serve to develop the regulatory framework for better use of energy storage. The IEA can build on the ES TCP work to include the impact of the various storage technologies in their scenarios in order to have a clear picture of policy priorities. This will also require improved partnerships between other international bodies (like UN, World bank, MI, CEM, IDO, CEN) and affiliated initiatives (like other TCP's). The policy message emphasizes the value of energy storage as major contributor to CO_2 reduction technologies and energy transition. The ExCo's ambition is to seek better and convincing exposure and visibility of the impact energy storage will have on the energy system and demand side. Furthermore, there is a need to establish an analytical regime of metrics for valuing energy storage across energy technologies, end use profiles and jurisdictions. This requires improved communication efforts such as better visualization, successful demonstration projects and show case applications, simpler language and communication of results of ES TCP work in our networks.

Communication and Outreach

ES TCP has contributed actively to the development of the 2020 Energy Technology Perspective by submitting various back-ground information and actually supporting the ETP team with a secondment of an esteemed expert in Paris (in 2020). Furthermore, two storage cases were selected in the first round, presented on October 22nd of the IEA initiative: Today in the Lab, tomorrow in Energy. The ES-TCP is closely connected to the MI challenge #7 (affordable heating and cooling). There are bi-monthly co-leaders calls on the various subjects related to this challenge and ES-TCP actively contributes by reporting the progress of Task 34 (CCB) and other storage related subjects. Recently discussions started to establish a IC7 Platform as part of MI 2.0.

In Task 35, new collaboration on energy storage is established with the World Bank.

Membership

Current membership (per December 31st 2020) includes 19 countries and 1 sponsor. Unfortunately, two sponsors have left. University of Lleida (due to funding) and Dublin Institute.
A formal letter of invitation was sent to Israel and Czech Republic for full membership commencing in 2021.

To conclude

In 2020 we have been able to continue a constructive relationship both within and outside of the IEA community: This has involved our TCP (alternate) delegates on our ExCo, our various Task Managers (former called Operating Agents), the ES TCP secretariat, colleagues in other TCPs, the Building Coordination Group, the Working Party on Energy End-use Technologies, the IEA Secretariat and legal department (who were a great help during the RfE and TCP Modernization process) and the colleagues in Mission Innovation and EERA-JP. It is a real pleasure to be part of this inspiring network.

Teun Bokhoven
Chair, ES TCP (original ECES TCP)

ES TCP (ENERGY STORAGE TECHNOLOGY COLLABORATION PROGRAMME) CONTRACTING PARTIES AND SPONSORS

Name	(Alternate) Delegate/Sponsor	Country
Contracting Partners		
Christian Fink	Delegate	Austria
Sabine Mitter	Alt. Delegate	Austria
Bert Gysen	Delegate (Vice Chair)	Belgium
Adam Tuck	Delegate	Canada
Wei Xu	Delegate	China
Zhang Shicong	Alt. Delegate	China
Mads Lyngby Petersen	Delegate	Denmark
Per Alex Sørensen	Alt. delegate	Denmark
Jussi Mäkelä	Delegate	Finland
Paul Kaaijk	Delegate	France
Kévyn Johannes	Alt. Delegate	France
Hendrik Wust	Delegate (Vice Chair)	Germany
Stefan Busse-Gerstengarbe	Alt. delegate	Germany
Raffaele Liberatore	Delegate	Italy
Margherita Moreno	Alt. Delegate	Italy
Masaya Okumiya	Delegate	Japan
Takayoshi Shuto	Alt. delegate	Japan
Yeon Sun-Hwa	Delegate	Korea
Cho Hyun-Choon	Alt. delegate	Korea
Rajinder Kumar Bhasin	Delegate	Norway
Uros Stritih	Delegate	Slovenia
Alenka Ristic	Alt. delegate	Slovenia
Emina Pasic	Delegate	Sweden

Name	(Alternate) Delegate/Sponsor	Country
Contracting Partners		
Paul Westin	Alt. Delegate	Sweden
Andreas Eckmanns	Delegate	Switzerland
Michael Moser	Alt. delegate	Switzerland
Stefan Oberholzer	Alt. delegate	Switzerland
Stan van den Broek	Delegate	The Netherlands
Teun Bokhoven	Alt. delegate (Chair)	The Netherlands
Halime Paksoy	Delegate	Turkey
Yalcin Katmer	Alt. Delegate	Turkey
Chloe Lianos	Delegate	UK
Philip Sharman	Alt. delegate	UK
Imre Gyuk	Delegate	USA
Lynn Stiles	Alt. delegate	USA
Sponsor partner		
Andreas Hauer / BVES	Delegate	Germany
Urban Windelen / BVES	Alt. Delegate	Germany

As an outlook for 2021, it should be said that there have already been some delegate changes. We would like to take this opportunity to thank Jussi Mäkelä (delegate Finland), Chloe Lianos (delegate UK), Philip Sharman (alternate delegate UK), Imre Gyuk (delegate USA), Lynn Stiles (alternate delegate USA) for their excellent contributions to the ES TCP and welcome Aila Maijanen (new delegate Finland), Georgina Morris (new delegate UK), Eric Hsieh (new delegate USA).

TASK MANAGERS (FORMER NAME OPERATING AGENTS)

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CONFERENCES, WORKSHOPS, EVENTS AND COMMUNICATION

CONFERENCES, WORKSHOPS AND EVENTS IN 2020

An overview of all the ES TCP attended conferences, workshops and events in 2020:

The ES TCP chair, vice chairs and delegates contributed to a number of events and meetings.

January	Reporting to IEA secr. Annual report (for EUWP and BCG)
January 22nd	BCG meeting Paris
January /Febr	Input provided for ETP- thanks to Volkmar Lottner, Bert Gysen and others
March 19th	EUWP meeting –online; presentation outline SP and RfE
May 18/19th	ExCo meeting 0nline
May-June	Development of Strategic Plan
June – July	Preparation of the RfE documentation, including IES secr. Feedback loop
August 17th	Submitting RfE package for EUWP review
August	Modernization IA process; calls with vice-chairs and IEA legal depart.
August 19th	Review and input WEO
September 8th	Presentation RfE before EUWP + Q&A session
September 10th	Launch of ETP- online event
September 29th	IEA REWP Workshop, Role of Storage beyond Electricity
October 8th	TCP chairs meeting Universal; Innovation Dialogue / session rapporteur
October 16th	Presentation ES TCP JPP SES and Geothermica – heating and cooling developments
October 22nd	Today in the Lab - Tomorrow in Energy / IEA Academy- 2 storage prop.

October 28th	Q&A session IEA legal / delegates Modernization IA
Nov. 12th	Workshop on possible follow up on CCB / Mission innovation – cooling project
Nov. 18,19	ExCo meeting Online
December 9, 10	IEA End-Use Working Party Webinar on Deep Decarbonization in Industry
Quarterly	Mission Innovation Update calls on MI#7- project-team

COMMUNICATION ACTIONS IN 2020

WEBSITE AND NEWSLETTER

The new Annex subsites for Annex 32, 34, 35, 36, 37, 38, 39 have been integrated to the ES main website and have been filled and updated continuously by the Operating Agents. These sites can be managed by the Operating Agents and edited by the participants themselves, as well as offering the possibility of exchanging documents.

The general information on the website, as well as highlights such as completed Annex reports, agendas for upcoming events (international workshops, conferences, Annex meetings, …), etc., have been updated continuously. The Final Report on Annex 27 "Quality Management in Design, Construction and Operation of Borehole Systems" can be found here: https://iea-eces.org/publications/final-report-annex-27/ and the Final Report on Annex 33 "Material and Component Development for Thermal Energy Storage" can be found here: https://iea-eces.org/publications/final-report-annex-33/

Four newsletters for ES TCP activities were sent out in 2020. The contact list is gradually growing.

In addition to communication via the IEA ES TCP mailboxes, the contact page of the website has also been maintained.

DRAFT HANDBOOK

To get a quick overview about the structure und the work done within the ES TCP a draft handbook was created. It also includes the different ways to become a member of ES TCP as well as the responsibilities and obligations of Task Managers and how to propose a Task.

NEW TERMINOLOGY ANNEX/TASK AND OPERATING AGENT/TASK MANAGER

To stay consistent with the terminology of the IEA and the Framework document of the IEA two changes in the terminology in the ES Implementing Agreement (IA) and in general were decided. This is the terminology of Annex and Task. The Annex is only the written text (the work plan etc.), which is connected to the IA as appendix, describing the work plan etc. of the Task, which is the project. And it is the terminology of Operating Agent and Task Manager. The Operating Agent is now defined as the institution responsible for the leading role of a Task and the Task Manager is the individual doing the job in the name of the Operating Agent (the institution). These changes were and will be adapted over the time.

PARTICIPATION IN EVENTS, MEETINGS AND NETWORKS

ES TCP contributed in the following (online) events

IEA REWP Workshop, Role of Storage beyond Electricity

This online event, organized by the Renewable Energy Working Party, on September 29th highlighted the use and need of energy storage as it becomes urgent to develop flexible solutions in order to mke optimal use of renewable electricity production.

Presentation ES TCP JPP SES and Geothermica – heating and cooling developments

As in the renewable electricity sector, also the heating sector requires more thermal energy storage in order to maximize output. This meeting on October 16th, addressed the developments in this area.

Today in the Lab- tomorrow in Energy / IEA Academy-

On October 22nd, two storage proposals were presented in this attractive program and underlined the potential energy storage has.

COMMUNICATION PLAN FOR 2021

ES TCP plans to increase its communication and outreach further with the following activities. Major effort will be devoted to increasing the interest in, and sharing the results of, the ES TCP work in the Tasks and to anticipate growing interest in deploying energy storage.

- Finalizing the draft Handbook for publication on the ES TCP website, including the guides "How to become a member of ES TCP" and "How to submit a new Task proposal";
- Further developing of the website and integrating an information platform on energy storage, and arranging for permanent updates related to ongoing and finished Annexes/Tasks, international events (workshops and conferences), relevant publications from within the IEA ES TCP and other resources;
- Compiling programme and project bibliography on the basis of the information from previous Annexes (requires digitalisation of earlier reports);
- Preparing and distributing the ES TCP newsletter quarterly;
- Extending the mailing- and contact-list for the newsletter;
- Supporting the organisation of the tri-annual Stock conferences (2021 conference in Slovenia) as liaison between ExCo members and conference committees;
- Developing and maintaining a social media strategy;
- Compiling ES TCP standard presentation about energy storage in general and the ES TCP activities;
- Setting up a webinar programme based on Task activities; and
- Managing the contact page of the website and the IEA ES TCP mailboxes.

FINANCING

All Contracting Parties and Sponsors make an annual financial contribution to the common fund used for ES TCP general, administration and communication matters. The following table outlines the budget contributions from participants.

The overall ES TCP 2020 budget from the common fund was $ 67,800[1]. Per ultimo 2020, not all contributions have been received. For the USA contributions for more than one year are overdue. In total there is still an amount due of $ 24,000.

Table: ES TCP common fund distribution in 2020.

Contracting Party	No. of Countries X Common Fund/ Country (USD)	Total Common Fund (USD)
Canada, China, Italy, Japan, France, Germany, Norway, UK, [USA], Switzerland	9 [10-1] X 4,800	43,200
Austria, Belgium, Denmark, Finland, Korea Netherlands, Sweden	7 X 3,000	21,000
Slovenia, Turkey	2 X 1,200	2,400
Sponsor: BVES (Germany)	1,200	1,200
TOTAL (USD)		67,800

Due to the TCP Common Fund not receiving any contributions from the USA since 2016, the ExCo decided to "freeze" US membership for the time being. They are indicated in the text as well as in the number of countries in the table above with square brackets. The sponsorship of DIT was terminated as there were no contributions received since 2017 and no real communication possible.

The completed and ongoing Annexes/Tasks in 2020 were all 'task-shared' (not 'cost-shared') activities. The additional effort for the co-operation within the IEA is usually 3 man-months (MM) per year. The work of the respective Operating Agents / Task Managers requires funding of about 3-6 MM/year.

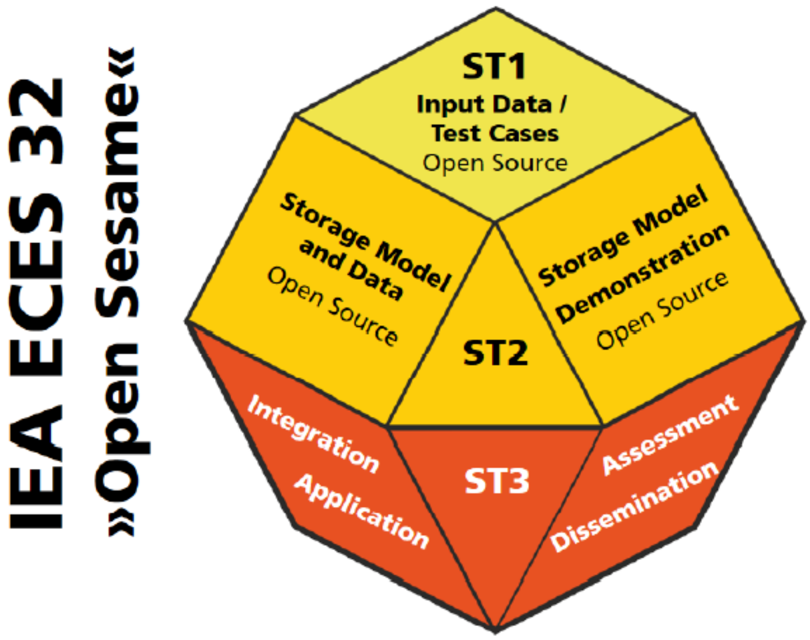
[1] This excludes the payments from the USA (since 2016), which haven't fulfilled their contribution commitments.

ONGOING TASKS (FORMER NAME ANNEXES)

TASK 32: OPEN SESAME »OPEN SOURCE ENERGY STORAGE MODELS«

TASK INFORMATION

GENERAL



Duration: Start: February 2020 – End: March 2023

Website: https://iea-eces.org/annex-32/

TASK MANAGER

Contact Details TM

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ABOUT TASK 32 – OPEN SESAME

The energy system is changing due to variable energy production. This requires new and more storage devices to balance demand and production and additionally to increase flexibility. The aim is to select always the best fitting storage systems with the best fitting operation mode to balance the energy system. The challenge is that there are hardly any, scientific proven, source models for energy storage systems, which are an indispensable prerequisite for operation or structural optimisation and for assessing the value of storage systems. The goal is to develop a standardised and scientifically proven approach and methodology to asses various storage devices for various applications: grid connected and grid operated, island grids/ remote areas, industrial sites and residential areas. The results are generic open source models and data sets. These scientifically proven models should be used to find answers to current storage questions (technical, economical and regulatory). The overall aim of this task is smart energy conservation and to understand and foster the role of energy storages in the energy system by optimising applications and operation modes and by assessing the benefit to the energy system.

CONTRACTING PARTIES / SPONSORS

Institution	Country
Fraunhofer UMSICHT DLR Steinbeis SOLITES	Germany
Berner Fachhochschule CSEM Paul Scherer Institute	Switzerland
KIER	South Korea
EMD International Aalborg University	Denmark
NRC Carleton University University of Calgary	Canada
VITO	Belgium
ISQ	Portugal
CETHIL	France
AEE INTEC	Austria
University of Izmir	Turkey

OVERVIEW OF SCOPE:

The overarching aim of task 32 is smart energy conservation and to identify the crucial role of energy storages in the energy system by optimizing applications, structures and operation modes and by assessing the benefit to the energy system.

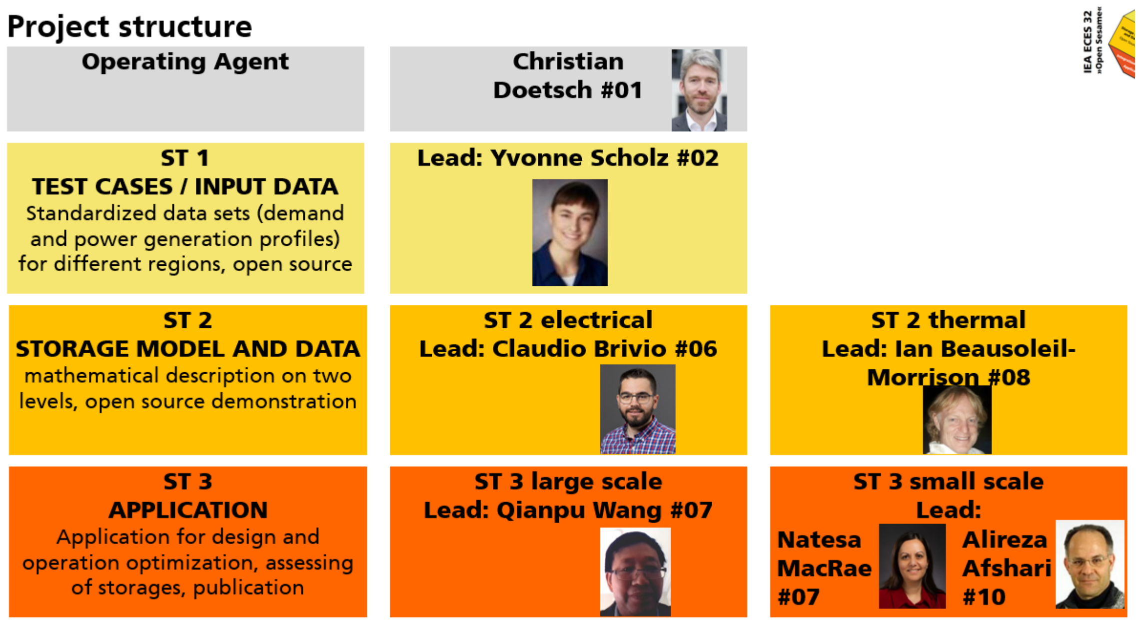
The technological aim of Open Sesame is the development of comprehensive models for relevant energy storage devices and input data sets for simulation. These models must be scientifically proven, open source and implementable.

Using the in this project developed open source models in existing energy system models to find answers to various technical, economical questions

The scope of task 32 covers the following types of storage devices: Electrical storages (power-to-power), thermal storages (heat-to-heat) and hybrid storages (two different storage devices technically combined and combined operated) – see below.

SUBTASKS

The work of the Task is split into three different subtasks with some subgroups.



ACTIVITIES AND ACHIEVEMENTS

Open Sesame started in 2020 (kick-off in May), so it was necessary to get an overview of the participants, to determine the structure and to distribute the work. All this happened in the current Corona pandemic situation, so that every meeting had to be virtual/online and the very important networking aspect of IEA-work was much more complicate. On the other hand, it was possible to hold three task meetings at a relatively short interval with high participation (May, October, December – e.g. 36 participants in December).

Subtasks:

2.1 Subtask 1 - Test cases / input data

ST1 started with the important challenge to evolve a common understanding of terms and definitions (e.g. test case, temporal resolution, spatial extent etc.). Another focus was the question how the data should be processed and in which way they should be shared between the participants of Open Sesame. The participants of ST1 are currently discussing options for open data (and code) servers where the results can be published – within the duration and afterwards. The search for suitable platform(s)/servers will go on in 2021. Currently under discussion are the NRC server, the open energy platform and Zenodo.

2.2 Subtask 2 – Storage model and data

ST2 electrical: ST2 started with an inventory of the storage technologies currently being worked on and the models that exist for them in the Task: CAES, PH, RFB, Li-ion, Na-ion, lead acid. For Li-ion two regional clusters emerged - Swiss and Canadian cluster. It is not clear now in which way they will collaborate. Probably the best way would be to start working and then start to exchange.

ST2 thermal: Scope of ST2 thermal includes sensible heat, PCM, seasonal storage, thermochemical storage, aquifers, pit stores, boreholes and industrial applications. There exists a wide range of models, so first an inventory must be made. Required information is more extensive than usually reported in journal articles. All significant assumptions and modelling simplifications, the property values and source code snippets will be regarded. A survey among ST2 thermal participants will start in early 2021.

2.3 Subtask 3 – Applications

ST3 will be divided in three subgroups after a common understanding of scales and boundaries is created. In future there will be a subgroup for large scale applications and the small scale applications will be divided into one electrical and one thermal part. Current status:

- To define a comprehensive list of energy storage applications by scale and type (thermal / electrical) – COMPLETE
- To define application model requirements for ST-1 (data) and ST-2 (models) – IN PROGRESS
- Data requirements: data inputs (temporal / spatial resolution), data format, validation data needs, etc.
- Technology model needs (type, level of fidelity), uses cases, interoperability requirements (language / simulation environment), etc.
- Discussed benefits of standardizing application model outputs (cost, emissions, LCOE, LCOS) as well as application use cases (for comparison of energy storage options / models).

Overview of the task meetings in 2020:

Date	# Participants/organisations/countries
5th - 7th May 2020	32/15/7
13th October 2020	39/17/9
3rd December 2020	36/18/10

The next complete task meeting is scheduled for February 23.

ANNEX/TASK 34: ENERGY STORAGE WITH HEAT PUMPS – COMFORT&CLIMATE BOX

ANNEX/TASK INFORMATION

GENERAL

Duration: January 2019 – December 2021

Website: https://iea-eces.org/annexes/comfort-climate-box/

OPERATING AGENT / TASK MANAGER

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ABOUT ANNEX/TASK 34

GENERAL BACKGROUND

Integrated systems consisting of heat pumps, storage and controls are in general considered to be an important technological option to accelerate the deployment of renewable energy in the domestic sector. Improving the coordination and integration of heat pump operation and storage, performance of the system can be enhanced in several ways: price, compactness, reliability, efficiency and serviceability etc. Meanwhile, a better smart-grid integration and a larger share of direct renewable energy use becomes feasible.

Under the combined direction of the IEA Technology Collaboration Programmes (TCPs) on energy storage (ES TCP) and heat pumps (HPT), EC TCP Annex/Task 34 started in early 2019 and will focus on improving combined systems of heat pumps, storage and controls.

Integrated systems consisting of heat pumps and storage are an important technological option to accelerate the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues may be tackled in one and the same process, such as:

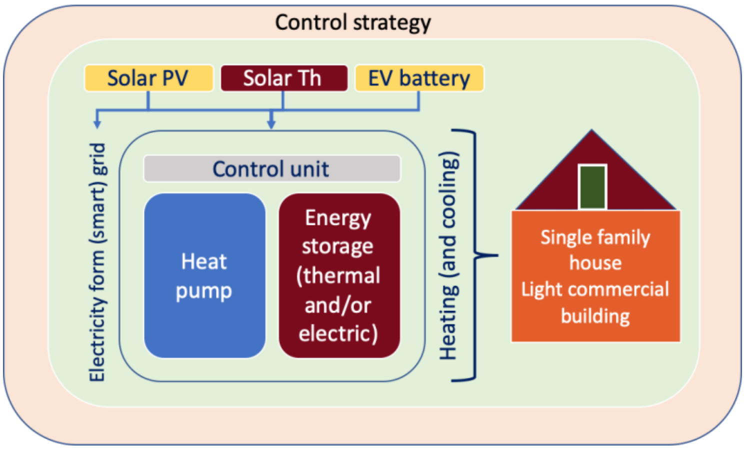
- Balancing and controlling electricity grid loads;
- Capturing a large(er) share of renewable (local/regional) energy input;
- Optimizing economics, CO_2-emissions, fuel use throughout time;
- Providing optimal supply security to buildings.

Commercial development of this type of solution is progressing very slowly so the combined Annex/Task 34 (HPT Annex 55) will accelerate market development of combined heat pump / storage packages (working title “Comfort and Climate Box”, or ‘CCB’). This will be the first

Annex/Task to integrate the work from the TCPs HPT and ES, building upon the earlier work in the fields of heat pumps and energy storage systems.

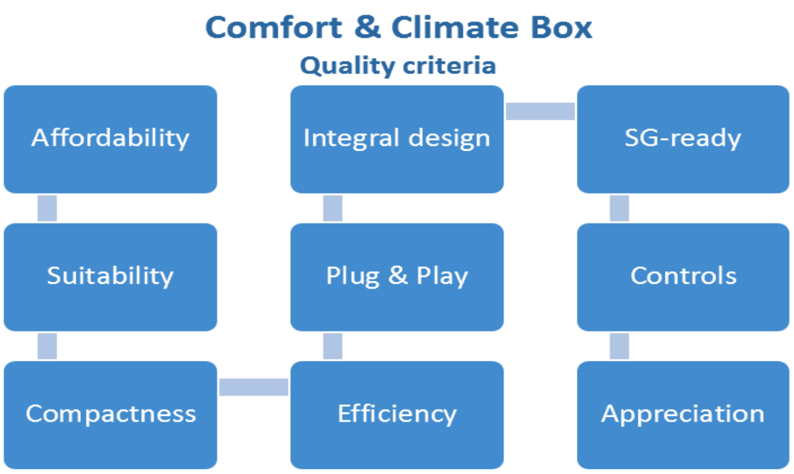
Comfort and Climate Box (CCB)

The central concept in Annex/Task 34 is the Comfort and Climate Box, a concept that denotes a combined package, consisting of a heat pump, an energy storage module and controls. This package may form an actual physical unit but can also consist of separate modules that form an integrated 'virtual package', where all components of the CCB should be designed to work together in a modular fashion and should be operated under a dedicated and optimal integrated control strategy.



Quality criteria

There are already several attempts to put CCBs on the market. However, market uptake is still slow and hesitant. Market access and potential success was analysed by looking at nine design criteria that play a role in developing CCBs.



Depending on the local market, available systems may need to improve performance with respect to one or several of these criteria. These criteria form the central reference to describe and measure CCB development and quality. Overview schemes based on scores on these criteria per country give an impression, at a glance, of how CCB developments proceed within the participants' countries.

Objectives and Scope

The general objective of Annex/Task 34 is to advance the implementation of thermal energy storage

(TES) technologies in order to reduce CO_2 emissions and improve cost-effective thermal energy management (i.e. increase energy efficiency).

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

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

Advancement of the process integration of thermal energy storage systems will make significant contributions to all of these fields. Crucial to the improved integration of TES systems is a better procedure for discussing the systems. A first objective of Annex/Task 34 is therefore to define a methodology for process analysis and specify technical and economic parameters of TES on a system level. Subsequently, determination of 'key performance indicators' (KPIs) will be an important step in the performance evaluation of a TES system. The ultimate objective of Annex/Task 34 is to evaluate TES systems for a given application. The methodology has been applied to various case studies originating from demonstration projects where TES systems are applied in a real environment. Thus, in a long-term perspective real-world examples of integration of TES systems can be discussed with stakeholders ranging from industry as process owner and turnkey or component supplier to national, European and other funding agencies as well as national governments.

CONTRACTING PARTIES

Institution	Country
AIT, University of Graz, University of Innsbruck	Austria
VITO	Belgium
Research Institute Canada	Canada
China Academy of Building Research	China
Ademe, CEA-INES	France
Fraunhofer ISE	Germany
ENEA, University of Marche	Italy
RVO, TNO, Stroomversnelling	Netherlands

RISE, KTH	Sweden
Cukurova University - Adana	Turkey
University of Ulster, BEIS	UK
Oakridge Laboratory	USA

OVERVIEW OF SCOPE

Annex/Task 34 is not meant to be a classic theoretical 'research and dissemination Annex/Task'. All contributing projects in the participating countries should aim to focus on developments that are 'almost market ready'. The goal of this Combined Annex/Task is to develop improved CCBs in existing buildings to speed up market development. We will focus on systems that will be close to market availability, i.e. technology readiness level (TRL) 7 and above, and have a high quality, adopted for their local market requirements. The work will be oriented around the nine quality criteria as mentioned to define the concept of improved quality. The underlying drive is to accelerate the market development for CCBs to enable rapid growth of the application of these systems in various climate zones. By exchanging the lessons learned from separate developments in each participating country, the aim is to enable the participants to help each other to speed up their local market development. Annex/Task 34 is also in twined with the Mission Innovation programme Challenge # 7. MI-7 functions as a non-hierarchical platform to enhance technology development within the building envelope.

WORK PACKAGES

This goal can be translated into the following explicit Annex/Task tasks for each participant:

1. Present state of market and system types
2. Prototyping & Criteria for CCB 1.0
3. Testing and pre-standardisation
4. Roadmap/Conditions for successful implementation

ACTIVITIES AND ACHIEVEMENTS

During the reporting period successful and productive online meetings and presentations were held at:
February 2020, Rome
General meeting, focusing on discussion on quality criteria: what defines a successful integration of heat pump and storage components?

June 2020, online
Presentation of 4 'archetypes' for CCBs, that share a specific focus on quality, and need specific support to achieve better market penetration.

October 2020, online
Discussion of barriers and opportunities for CCBs in the participating countries.

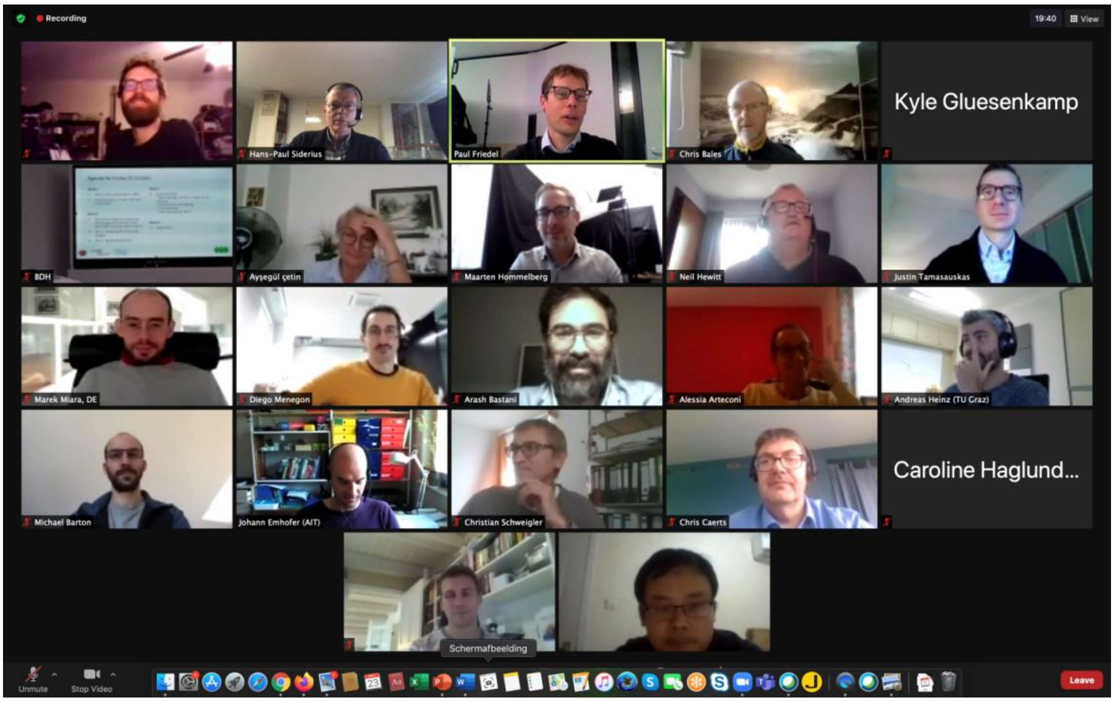


Figure 34-1: The Annex/Task 34 group online in action.

Work package 1 - Present state of the market and system types
Turkey, by means of the University of Adana, made a jump start in the role of WP leader for working package #1 in early spring 2020. Therewith we could maintain our progress as projected. We're extremely pleased by the means how Turkey filled in this gap.
Draft final report WP1 expected to be available start of 2021.

Work package 2 - Prototyping & Criteria for CCB 1.0
Together with the University of Ulster, we're slowly but surely picking up pace in this package. Mostly COVID related hick-ups made us that we we're at a certain point some-what behind. Anyway, no concrete results yet, but expecting output and measurements from 7 - 8 projects which will be useful for guidance for prototyping. Some lab testing, and also some field testing.
RISE from Sweden and the Technische Hochschule from Munich will also contribute results from concrete prototyping developments.

Work package 3 - Testing and pre-standardization
This WP lead by the Politecnico de Marche from Italy, was and is fully on track. Working on recommendations for testing standards that give 'recognition' to HP/storage/controls integration. Satellite working group starting off, recommendations and report expected at next meeting (February 2021).

Work package 4 - Roadmap/Conditions for successful implementation
Sweden as WP leader already initiated the boundaries and raw content for this WP in the early stages of the Annex/Task. This pays out now handsomely. Development in WP 4 will proceed parallel to here fore mentioned working packages. Draft report expected to be available at start of 2021. After that, discussions will follow for specific questions with invited group of external experts. Final report for WP in late Q1 2021.

CCB, or integrated systems of Heat Pumps and Storage Units, can achieve much better performance if they are designed to function as a single unit, with a specific optimization goal in mind. Therefore, it is important to realize that there is no single 'perfect CCB'. Depending on the circumstances, system performance may be very different across performance criteria, such as SPF, compactness, investment, or ease of installation.

To achieve a good match between optimized CCBs and the local market conditions, it is very important for policy makers to consider which goals are to be met. High market volume? Excellent performance of single systems? Or maximum flexibility and grid balancing capacity?

We have developed a set of four CCB 'archetypes' that should help policy makers to design appropriate support mechanisms to achieve their policy goals within the local market context (Figure 34-2).

1. 'Budget CCB'
   Focus on lowest investment, and, consequentially, rapid market growth and high volume.
2. 'Flexible CCB'
   Maximum flexibility, to allow optimal grid balancing and auto-consumption of renewable energy.
3. 'Compact CCB'
   Small components and easy installation, to allow the use of Heat pumps in densely populated areas where space constraints are dominant.
4. 'Top quality CCB'
   Maximum performance in terms of energy efficiency. This comes with a higher investment, less flexibility and a large installed footprint.

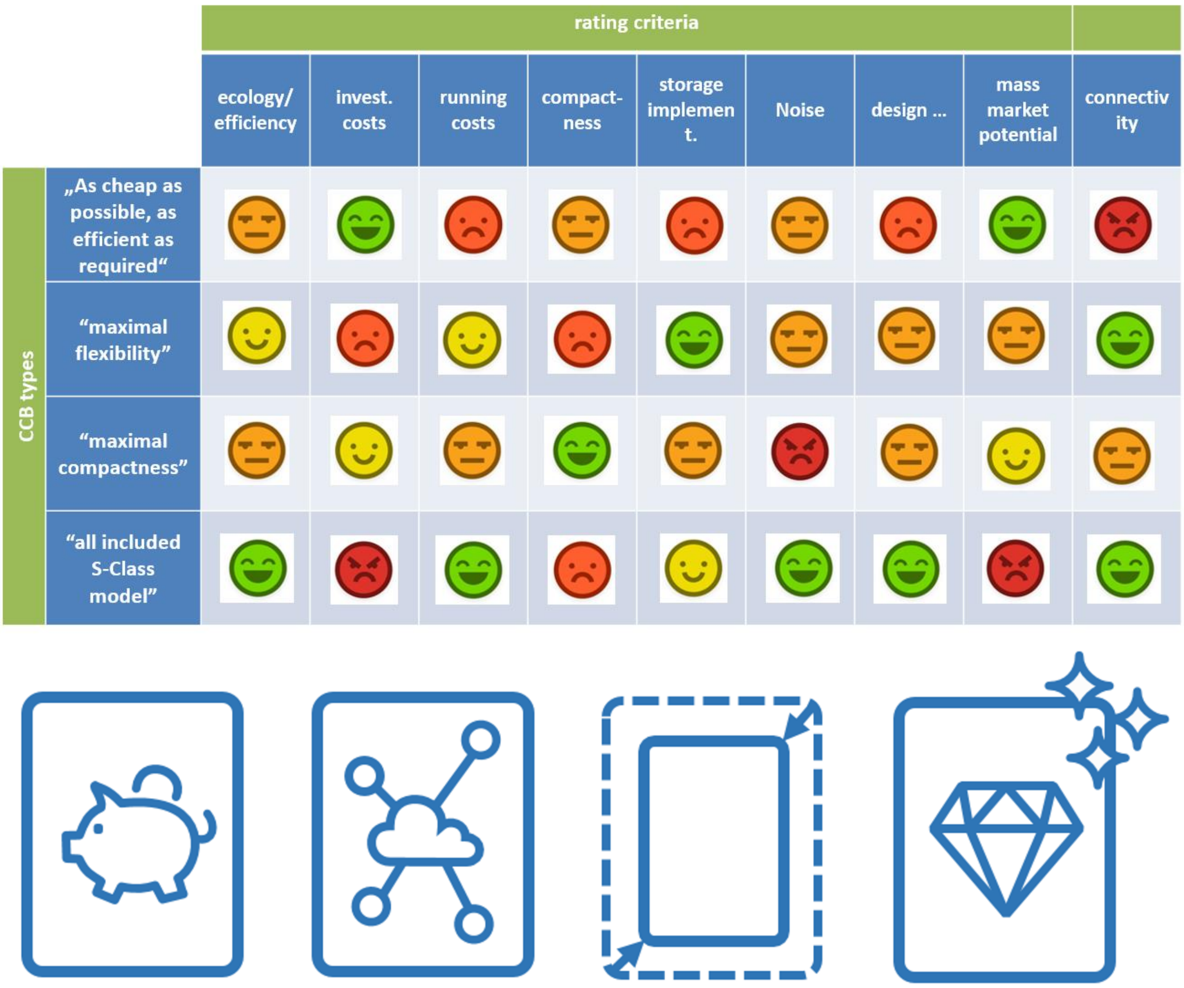


Figure 34-2: Four archetypes for CCBs: budget, flexibility, compactness, and top quality.

Other developments

Comparative modelling:

VITO (BE) has offered to run their model on smart operation modes with data from all participating countries. This will be further developed and organized. Modelling results to be presented and discussed during the next meeting (February 2021).

Technical Achievements in the Annex/Task

Since this Annex/Task its functionality is less hard technological and perhaps more on combining and integrating running or existing developments into an integrated solution, thus hard-core technical achievements are not directly projected. Anyhow we expect especially WP 2 to provide us with some tangible technical achievements from the various prototyping activities in 2021.

Deviations compared to legal text/Work plan and suggested corrective actions

1st Draft of final report scheduled for early summer 2021. Final report for comments to ExCo in late summer 2021. Final presentation of results of Annex/Task 34 in ExCo Energy Storage and ExCo HPT in second half of 2021.

TASK 35: FLEXIBLE SECTOR COUPLING BY THE IMPLEMENTATION OF ENERGY STORAGE

TASK INFORMATION

GENERAL

Duration: Start: June 2019 – End: May 2022

Website: https://iea-eces.org/annex-35/

TASK MANAGER

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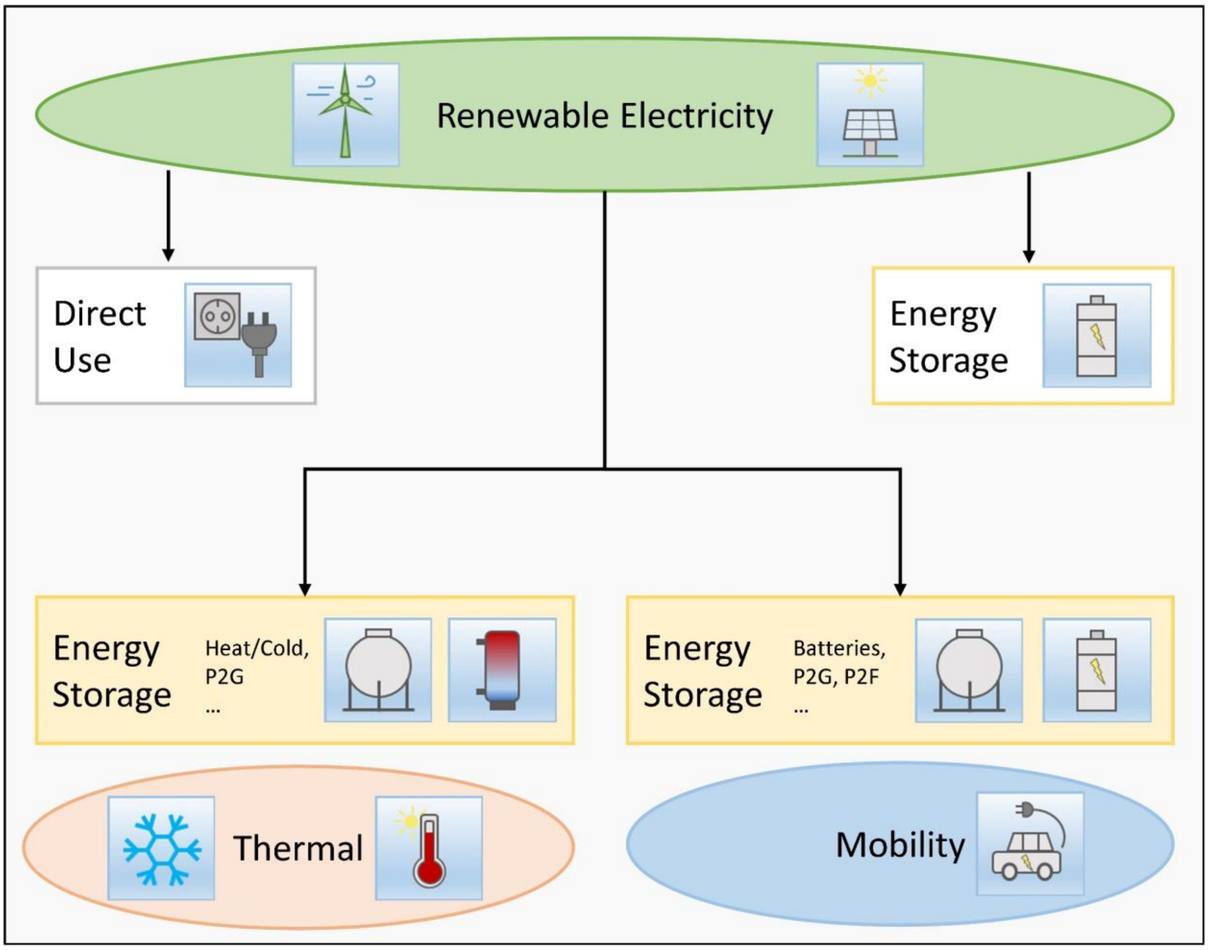
ABOUT TASK 35

IEA ES TCP Task 35 deals with the impact of implementing energy storages in sector coupling. The aim of this task is to evaluate the possibilities and the influence of energy storages in the context of Flexible Sector Coupling (FSC) in order to develop policy and research recommendations.

The main input of renewable energy to the future power grid will be renewable electricity by wind and photovoltaics. Reaching higher shares of fluctuating renewables in the power grid may cause a variety of problems. One option to tackle these challenges, by simultaneously further increasing the share of renewable electricity in the overall energy system, is to distribute renewable electricity to other sectors, mainly the heating/cooling and the mobility sector. By leveraging the potential of different energy storage technologies, it is possible to supply a sector with previously stored renewable energy on demand. This approach can help to reduce the stress on the power grid at different levels (high, medium and low voltage). Possible energy storage technologies include thermal, chemical and electrical storages.

The figure below shows a qualitative approach of how an integration of flexible sector coupling with different storage technologies could look like. A perfect use case for energy storages is at the connection between different sectors. This way the energy is either stored in its input form or transformed to another energy form (e.g. electricity to heat/cooled, electricity to synthetic fuel, Power-to-Gas or Power-to-Heat). By doing so, the different demand patterns of the "consuming" sectors thermal and mobility can help to match the volatile energy supply to a specific demand.



CONTRACTING PARTIES / SPONSORS

Institution	Country
AEE INTEC, AIT	Austria
Natural Resources Canada	Canada
PlanEnergi	Denmark
ZAE Bayern, DLR, Fraunhofer IOSB-AST / Fraunhofer UMSICHT	Germany
RSE Italy	Italy
KIER	Korea
Moroccan Solar Energy Agency	Morocco
ECN / TNO	Netherlands

KTH	Sweden
HS Luzern, EMPA	Switzerland
Cukurova Üniversitesi, SHURA Institute	Turkey

OVERVIEW OF SCOPE:

The Task deals with the impact of energy storage implementation between the sectors when it comes to sector coupling. It is important to focus strictly on energy storage only – energy in and energy out – in this Task and to neglect other options like power-to-X (chemical products not used as energy storage) or demand side management. This does not mean at all that these options are not appropriate, but it is necessary to limit the scope in order to provide a manageable workload.

The Task is considering:

- All energy storage technologies
- All applications in the heating and cooling sector (heating and cooling of all kind of buildings, DHW, process heat/cold for industry)
- All applications in the mobility sector (cars, trucks, busses…) and all propulsion technologies (EV, fuel cell, hydrogen, …)

SUBTASKS

The work of this Task is split into four subtasks:

Subtask 1: Flexible Sector Coupling (FSC) Concept Development

The focus of subtask 1 is to develop the main concept of flexible sector coupling (FSC). A whitepaper as a delivery format to document the process of FSC concept development will be set up. Information on regulatory frameworks and identified bottlenecks will be collected. Finally, policy and R&D recommendations will be given based on the input from all subtasks.

Subtask 2: Configuration-related Storage Technology Specifications

The aim of subtask 2 is to collect existing and future sector coupling storage configurations to show the variety of examples existing already today and the technical potential for the future. The configurations will be clustered regarding market applications and the most promising configurations will be identified.

Subtask 3: Local Energy System Design and Operation

Subtask 3 aims to assess the energy storage potential in sector coupling applications on a local system level. The evaluation will consider the heating (and cooling), electricity and mobility sectors. Scenarios for local energy systems with time horizon of 2030 and 2050 will be developed, and techno-economic indicators for the assessment of the results will be defined.

Subtask 4: National-scale Energy System Analyses of FSC Potential

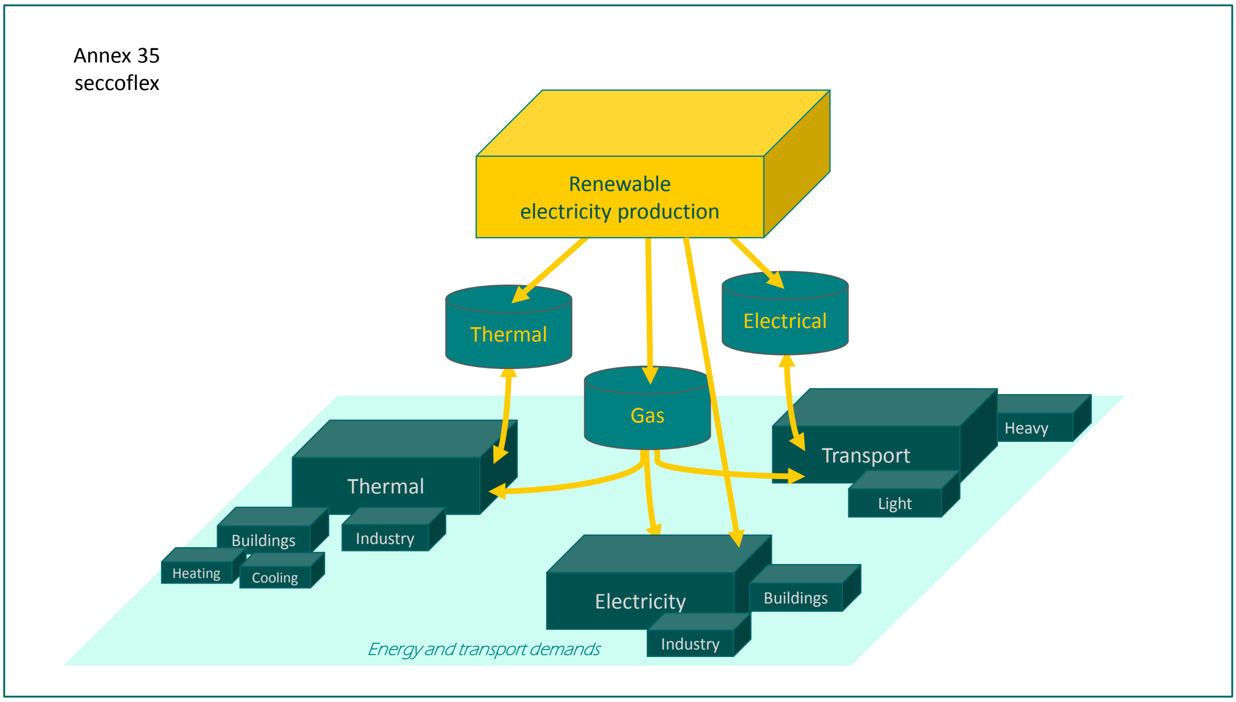
The goal of subtask 4 is to analyse and quantify the potentials of energy storages in sector coupling from a national energy system perspective. The work will elaborate on the analysed scenarios in subtask 3 by putting them into the context of national energy system level activity and upscaling them to assess their potential in a large-scale application of FSC.

ACTIVITIES AND ACHIEVEMENTS

Within the year 2020, three expert meetings (e.m.) took place, two of them including subtask specific workshops. Apart from the official participating countries, the World Bank / Energy Storage Partnership and IRENA were present as well. In addition, several subtask-leader-meetings allowed further discussions on FSC and on the next steps. Since all meetings this year had to be held online due to the ongoing Covid-19 situation, more meetings and meetings on shorter notice were possible.

The first e.m. included an introduction of participants, the IEA TCP framework and the work plan and structure of this Task as well as a discussion on the definition of FSC and scope of this Task. In the second e.m., 14 participants presented their recent work in the field of FSC. The main purpose was to provide a high amount of input from recent or current research and industrial activities in the field of FSC to all participants in order to create a basis for the further work. The third e.m. involved four subtask specific workshops, in order to further discuss the gained input of the previous e.m. and to plan the next steps of each subtask.

Within the work of subtask 1, a preliminary concept definition of FSC has been set, that starting from renewable electricity as the source considers energy carriers (electricity, heat, gas) as well as energy demands (e. g. transportation) while enabling flexibility by energy storage in various forms. This definition was also discussed in the last workshop of 2020 and will be further detailed as one of the next steps.

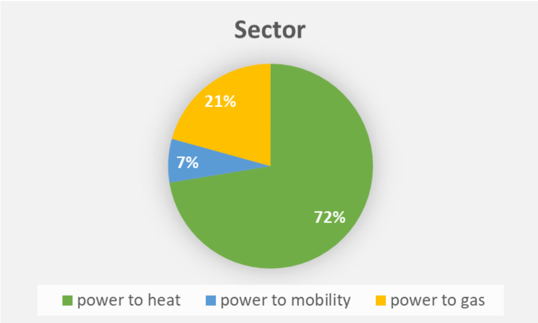


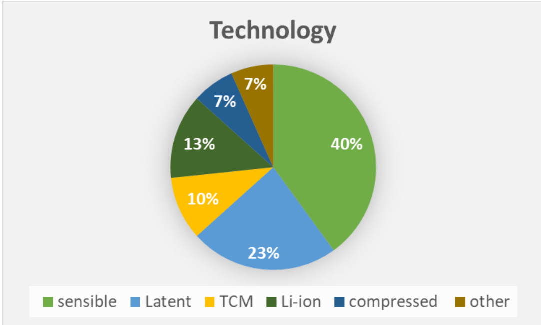
Furthermore, the basic structure of the white paper has been initiated. The key message will be related to:

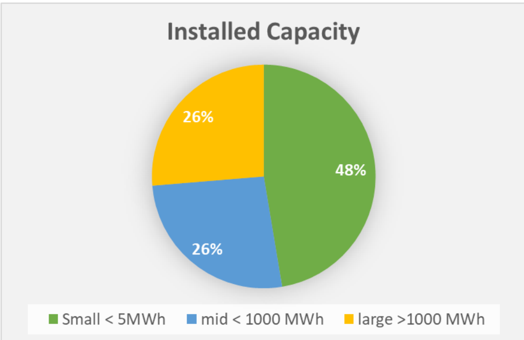
- The fundamental definition of flexibility and FSC relying on a variety of technologies for energy storage.
- FSC as an enabler for the transition towards sustainability – examples and impact assessment.
- The regulatory landscape – enabling and hindering.

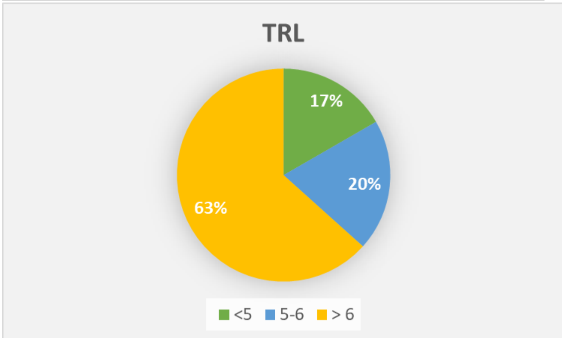
- The many opportunities for innovation, while mastering bottlenecks in technology/business plans/policy presently hindering FSC.

Subtask 2 (Configuration related storage technology specifications) and Subtask 3 (Local Energy System Design and Operation) have both been collecting data on project examples for an evaluation of different technologies and analysis approaches. The following pictures show first evaluations in terms of examples of storage technologies.









The aim of both subtask 2 and 3 is to collect further input and also to specify certain input in order to prepare a clustering of configurations and comparison of different analysis approaches.

Subtask 4 is looking at national scale energy system analyses of FSC potential, therefore the work is mainly based on the findings of Subtask 2 and 3. However, the work of ST4 has been started by collecting data and planning of the further work. In that respect, there have been discussions with the participants on how different scenarios should be considered (e.g. the role of energy transportation networks) and the proposal of Germany as a case study for a reference scenario. As one possible outcome of this subtask, a comparison of analyzing a common reference scenario with different simulation models has been suggested.

TASK 36: CARNOT BATTERIES

TASK INFORMATION

GENERAL

Duration: Start: January 2020 – End: December 2022

Website: https://www.eces-a36.org; https://www.iea-eces.org/annex-36/

TASK MANAGER

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ABOUT TASK 36

Carnot Batteries have the potential to solve the global storage problem of renewable electricity in a more economic and environmentally friendly way than conventional batteries by storing electricity as thermal energy. Although several concepts have been proposed for Carnot Batteries, a comprehensive techno-economic assessment of this technology has yet to be developed. Only a few laboratory or plant-scale demonstration facilities exist that provide the energy storage community with scientific data. Task 36 establishes an international platform that brings together experts from industry and academia in a structured way, assesses the state of the art of R&D for Carnot Batteries, deepens the understanding of their possible role in the future energy system and helps to make Carnot Batteries internationally visible through collecting and providing information on the technology.

SUBTASK LEADERS AND CONTRACTING PARTIES / SPONSORS

Subtask Leaders	**Country**
Prof. Kurt Engelbrecht Technical University of Denmark	Denmark
Dr. Salvatore Vasta National Research Council – Advanced Energy Technology Institute (CNR – ITAE)	Italy
Prof. Zhiwei Ma Durham University	UK

Prof. Yulong Ding University of Birmingham	UK
Dr. Adrienne Little Google [X] on behalf of Malta Inc	USA
Institutions	**Country**
AEE INTEC	Austria
ENGIE-Laborelec Ghent University Liege University	Belgium
Aalborg University DTU (energy and mechanical engineering) PlanEnergi University of Southern Denmark	Denmark
CEA	France
Bayreuth University Carbonclean DENA DLR e.V. Enolcon GmbH FAU Erlangen Fraunhofer ISE, IFAM, UMSICHT Kraftblock KIT Siemens Gamesa ES GmbH Spilling Technologies GmbH TU-Berlin TU-Chemnitz Hochschule Zittau/Görlitz PT Jülich (observer)	Germany
CNR-ITAE ENEA Politecnico di Torino University of Bari University of Pisa	Italy
Hokkaido University Tokyo Tech	Japan
Energy transition (former ECN part of TNO)	Netherlands
Korean Institute of Energy Research	South Korea
Climeon Rise	Sweden

MAN ES Hochschule Luzern	Switzerland
BEIS Durham University Highview Power University of Birmingham ARPA-E Echogen Google [X] on behalf of Malta Inc Malta Inc NREL US Bipartisan Policy Center	UK
Czech Technical University in Prague	Czech Republic (Sponsor)

OVERVIEW OF SCOPE:

Carnot Batteries are an emerging technology for the inexpensive and site-independent storage of electric energy at medium to large scale. Also referred to as "Pumped Thermal Electricity Storage" (PTES) or "Pumped Heat Storage" (PHES), a Carnot Battery transforms electricity into thermal energy, stores the thermal energy in inexpensive storage media like water or molten salt and transforms the thermal energy back to electricity when required.

Carnot Batteries have the potential to solve the global storage problem of renewable electricity in a more economic and environmentally friendly way than conventional batteries. Although several concepts have been proposed for Carnot Batteries, there exists no comprehensive techno-economic assessment of this technology. Furthermore, only a few laboratory or plant-scale demonstration facilities exist that provides the energy storage community with scientific data.

In this context, the overarching aim of this Annex is to ease the transition from a fossil-fuel based to a renewable source-based energy system, through the promotion of novel energy storage systems, assisting their development, deployment, demonstration and their deep understanding.

Therefore, this Annex aims to stablish a platform that brings together experts from the industry and academia, to systematically investigate, assess the state-of-the-art of R&D of Carnot Batteries and strengthen the potential role of Carnot Batteries in the future energy systems gaining international attention.

SUBTASKS

The work and discussions carried out by the experts is divided in five different Subtasks as shown below:

Subtask 0 – Definitions; Lead by CNR-ITAE, Italy

This Subtask addresses the key definitions and classification of Carnot Batteries in order to standardize the Carnot Battery "language" (definition of acronyms etc.). Furthermore, the key performance indicators (KPIs) are defined among a group of pre-defined boundaries, such as operating conditions, materials, components and systems. Technical, economical and further non-technical aspects are considered for this task. Finally, state of the art determination for thermal energy storage as a component suitable for Carnot Batteries is carried out following a systematic analysis. This will serve as a guidance for determining the missing information and requirements to the deployment of these technologies.

Subtask A – Rankine Batteries; Lead by DTU, Denmark

Subtask A assesses the state of the art of Carnot Batteries based on Rankine cycles (so called Rankine Batteries) on a system level. Also, the identification of system configurations is carried out, identifying the sinks and sources and the storage temperatures of Rankine Batteries. Finally, the modelling and assessment of the systems are performed in order to get a common understanding of efficiency, dynamic behavior, scalability and the basis for economic evaluations. Experimental data from existing systems and know-how will be shared, as long as it is not confidential.

Subtask B – Brayton Batteries; Lead by Durham University, UK

In analogy to Subtask A, Subtask B assesses the state of the art of Carnot Batteries, based on Brayton or Joule cycles (so called Brayton Batteries), focusing on the identification of promising cycle designs, working conditions and working fluids. The experimental data and analysis of existing or planned systems as well as simulation results for promising system concepts are collected and assessed. The boundary conditions for TES are determined and provided as input for Subtask 0. Finally, the R&D demand will be determined.

Subtask C – Other concepts and combinations; Lead by University of Birmingham, UK

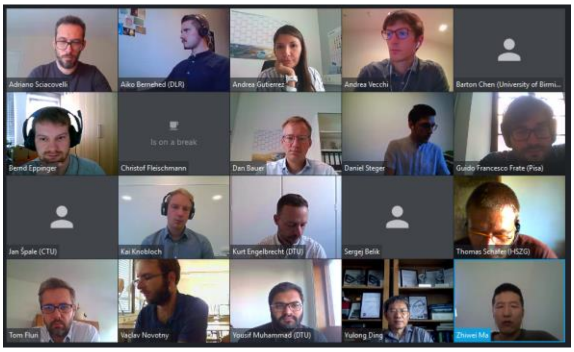
Subtask C investigates concepts that are not classified as Rankine nor Brayton Batteries, as well as combinations of different processes, e.g. the Lamm-Honigmann-Process, Liquid Air Energy Storage with thermal energy storage (TES), gas turbine-based technologies with TES and steam generation for enhancing the gas turbine performance, CO_2 based transcritical cycles for conversion with TES and material-based generation such as thermoelectric generators. System and component level-based data for KPI definition will be provided for Subtask 0.

Subtask D – Market analysis, energy system, policy and regulations; Lead by Google [X] on behalf of Malta Inc, USA

Subtask D focuses on promoting commercial acceptance of Carnot Batteries, by identifying market requirements for these technologies, assisting cost modelling and analyzing the Tech-to-Market transition. In addition, it will support policy and regulations as well as (non-scientifically focused) dissemination activities. Through education, lobbying and advertising, it builds support with hearts and minds.

ACTIVITIES AND ACHIEVEMENTS

In 2020 two workshops and expert meetings were held. Both events were held online due to the COVID-19 pandemic. The first one (Kick-off Workshop) on March 26, 2020 was held as a full day (09:00-18:00) web meeting over Skype for Business. An accompanying industry workshop already organized for local industry and policy makers on March 27th in Birmingham, UK, had to be cancelled due to the COVID-19 pandemic. A total of 51 participants from 13 countries attended the web meeting, considering those who attended only some sessions, whereas at least 43 participants where online simultaneously during the entire event. The second experts' workshop was held consisting of a two days online meeting on September 17-18, 2020 (See Figure 1). It was hosted by DLR in collaboration with the Institute for Building Energetics, Thermotechnology and Energy Storage (IGTE) from the University of Stuttgart. A total of 65 participants from 13 countries registered for the event.



(a)

(b)

Figure 1 Impressions of the IEA ES 2nd Expert Workshop - Annex 36 "Carnot Batteries". (a) Parallel session Subtask A, B and C on the first day and (b) Some participants during the main session on the second day.

Work within each subtask has taken place through regular conference calls and also during the workshops and expert meetings. The progress to date is described below:

Subtask 0 – Definitions

The **Wikipedia site on Carnot batteries** was released and can be reached on: https://en.wikipedia.org/wiki/Carnot_battery. This site will be further edited based on the following content:

1. Simplified definition + Overview [CNR ITAE, Italy]
2. Terminology [CNR ITAE, Italy]
3. Operating principle [DLR, Germany; CNR ITAE, Italy]
4. Power to thermal Energy Conversion (and vice versa)
    a. Rankine Cycle [SGRE and DLR, Germany]
    b. Brayton Cycle
    c. Heat Pumps
    d. Other concepts
        i. Lamm-Honigmann Storage [TU-Berlin Germany]
        ii. …
5. Thermal energy storage [ENEA, Italy; AEE, Austria; HSLU, Switzerland]
    a. Sensible
    b. Latent
    c. Thermochemical
6. Technical aspects [TU-Berlin, Germany; +input other SUBSTASKs]
    a. Performance
    b. Capacity
    c. Maturity of technology [DLR, Germany]
    d. …
7. Pilot plants, Applications [DLR, Germany; +input other SUBSTASKs: Malta Inc, USA; SGRE, Germany; etc.]
8. Sector Coupling examples [Malta Inc., USA]
9. References [CNR-ITEA, Italy]

A significantly progress has been done on the definitions of the **key performance indicators (KPI) method** which will make it possible to determine the boundary conditions of materials, components and systems.

Subtask A – Rankine Batteries

Some of the characteristics and work done within this subtask are shown below:

- The group is working on diverse conditions and on different configurations of the Rankine Battery, namely temperature range, storage medium, heat transfer medium, and heating method.
- The participants come from different types of institutions, from the research sector to business sector that are in the process of commercializing the technology.
- Subtask A has given, and will continue to do so, input to Subtask 0 for the elaboration of the Wikipedia page on Carnot batteries.
- Discussions are being conducted with MAN Switzerland to carry out a techno-economic evaluation of their CO2 ETES.
- Subtask A is working in collaboration with Subtask C participants to deliver cost and performance estimates for their techno-economic analysis.

Subtask B – Brayton Batteries

Within the subtask B a detailed thermodynamic analysis on Brayton batteries using different working fluid has been carried out at the Durham University, and the following conclusions were reached:

- Round-trip efficiency can be larger than 1 if the isentropic efficiency is larger than 1;
- If isentropic efficiency is lower than 1, gases with high adiabatic index, like Argon, and high-pressure ratio should be used to have high round-trip efficiency and discharge power;
- If isentropic efficiency is higher than 1, gases with low adiabatic index, like Nitrogen, ad low pressure ratio result in better round-trip efficiency;

Subtask C – Other concepts and combinations

In this subtask different system possibilities have been exposed, e.g. systems based on liquid air, such as liquid air energy storage (LAES)-based offshore renewable energy transportation and storage, Offshore-Onshore integrated systems for zero carbon energy future - using liquid air as an example and liquid air energy storage for combined cooling, heating, hot water and power (LAES - CCHHP). Additionally, an in-depth thermodynamic and technical analysis of the current and possible future combinations of the LAES-CCHHP has been discussed.

Joint work among Subtask A, B and C

The Subtasks A, B and C conduct joint activities due to the similarities of their tasks at this stage of the Task 36. Fact Sheets of the components, systems and concepts of the participants of the Task 36 are being elaborated and collected. This information will also serve as an input for the Subtask 0, to continue working on the definitions of technical aspects of Carnot batteries and to publish this information on the Wikipedia site. Furthermore, this information will be also grouped and organized in order to elaborate the different documents drawn up as outcomes for the three subtasks, such as publication of scientific papers or white papers on Carnot Battery systems.

Subtask D - Market analysis, energy system, policy and regulations

In this Subtask a document is being elaborated containing the most important points covered by this working group. The content of the Subtask D report is listed below:

1. Policy and Regulations Supporting Carnot Batteries [topic lead – Highview, UK]
    a. Innovation funding and support needs [Echogen, USA]
    b. Deployment needs [DENA, Germany; Malta Inc., USA]
    c. Required existing or future codes and standards [ENGIE/ Laborelec, Belgium]
    d. Acceptable policy language or tax code language/framework – avoid unnecessary penalization [Malta Inc, USA]

    e. Provide "world roadmap" for regionally acceptable policy and regulations [Highview, UK]
2. Commercial Acceptance Strategies [topic lead – Kraftblock, Germany]
    a. Tech-to-market transition recommendations [ENGIE/Laborelec, Belgium; Steinmüller Engineering, Germany]
    b. Definition of market requirements that need to be met [ENGIE/Laborelec, Belgium; Steinmüller Engineering, Germany]
    c. Staged market entry strategies, long and short term [ENGIE/Laborelec, Belgium; Steinmüller Engineering, Germany; PlanEnergi and AAU, Denmark]
3. Building Support with Hearts and Minds [topic lead - ENGIE/Laborelec, Belgium]
    a. Technical characteristic comparison with li-ion batteries [ENGIE/Laborelec, Belgium]
    b. One-page executive summary on policy recommendations [DENA, SGRE, Germany]
    c. Applications outside energy storage [ENGIE/Laborelec, Belgium; Steinmüller Engineering, Germany; Malta Inc, USA]

Finally, in 2020 the official website and the share point of the Task 36 have been released. The website can be reached on https://www.eces-a36.org (See Figure 2), while the share point can be reached only by the participants of the Task 36 who have requested access to it.

Figure 2 Official website of the Task 36

TASK 37: SMART DESIGN AND CONTROL OF ENERGY STORAGE SYSTEMS

TASK INFORMATION

GENERAL

Duration: Start: June 2020 – End: May 2023

Website: https://iea-eces.org/annex-37/

TASK MANAGER

Contact Details TM

Prof. Dr. Ryozo Ooka

Institute of Industrial Science, The University of Tokyo

ooka@iis.u-tokyo.ac.jp

ABOUT TASK 37

In this Task, we investigate the present situation of smart design and control strategy of energy storage systems for both demand side and supply side. The research results will be organized as design materials and operational guidelines. Specifically, artificial intelligence that has developed significantly in recent years can be expected to make a significant contribution to the smart design and control systems. This task also covers the availability of artificial intelligence.

SUBTASK LEADERS AND CONTRACTING PARTIES / SPONSORS

Subtask Leaders	**Country**
Prof. Fuzhan Nasiri Concordia University	Canada
Prof. Ruchi Chaudhary Cambridge University	UK
Prof. Frederic Kuznik INSA Lyon	France
Prof. Alireza Afshari Aalborg University	Denmark
Prof. Enrico Fabrizio Politecnico di Trino	Italy

Prof. Mariagrazia Dotoli Politecnico di Bari	Italy

Institutions	**Country**
BBA: Industrial Consulting Engineering Firm Concordia University Institut de recherche d´Hydro-Québec McGill University Oullet Canada Inc. Ryerson University	Canada
Southeast Jiaotong University Zhejiang University	China
Aalborg University DTU	Denmark
INSA Lyon Lyon University Universit Savoie Mont Blanc	France
Ulm University of Applied Sciences	Germany
Politecnico di Bari Politecnico di Torino	Italy
DAIDAN Co. LTD Nagoya University Tokyo City University Takenaka Cooperation Tokyo Electric Power Company Tokyo Institute of Technology University of Tokyo	Japan
IRESEN	Morocco
Oslo Metropolitan University	Norway
University of Ljubljana	Slovenia
KTH	Sweden
Cukurova University HVAC360 TTMD	Turkey

Alan Turing Institute The University of Nottingham University of Cambridge	UK
Oklahoma University	US

OVERVIEW OF SCOPE:

The general objective of this Task is to address the design/integration, control, and optimization of energy storage systems within buildings, districts, power grids, and/or local utilities. The focus will be on the development of design methods, optimization, and advanced control strategies for effectively predicting, evaluating, and improving the performance of Buildings and districts when energy storage is available. The Task shall deal with the fundamental of smart technology and its application to energy storage systems in buildings, districts, and grids.

SUBTASKS

The work of the Task is split into 6 subtasks.

Subtask 0 Smart Technologies and State of the Art
L: Fuzhan Nasiri, Concordia University
· Definition and Classification of Smart Technology
· Smart Tools (Predictive Analytics, Descriptive Analytics, Prescriptive Analytics)
· Smart Technologies (IoT & Cloud-based systems , BIM, BACS)

Subtask A
Demand & Supply Prediction
L: Ruchi Chaudhary
Cambridge University
· Demand Prediction
· RE G Prediction

Subtask B
Device/Component
L:Frederic Kuznik
INSA Lyon
· Component optimization and design
· Component control
· Guidelines for component modelling

Subtask C
Building and District Design
L: Alireza Afshari,
Aalborg University
· Definition of criteria
· Identification of design parameters and materials
· Design of optimal methods

Subtask D Optimal Building District Control /Operation
L: Enrico Fabrizio, Politecnico di Trino
· Identification of control
· Identification of components
· Examples of applications and case studies
· Guidelines for control and operation

Subtask E Optimal Grid Control/Operation/Cooperation
L: Mariagrazia Dotoli, Politecnico di Bari
· Configuration of ESS in power grid:
· ESS Control Strategies in power grids
· Distributed control and/or decentralized decision making

ACTIVITIES AND ACHIEVEMENTS

Kick off meeting was held online on 26 June 2020 with 39 participants. The purpose and the way to proceed were discussed. It was decided that several on line meeting would be held before the next ExCo meeting in order to know who can contribute to what to this Task. More than 10 people would make presentations related to their contribution and it would be useful to organize more appropriate structure.

Moreover, "Model predictive control of building energy system applied to thermal energy storage" was presented by Dr. Ooka, as a part of information collection.

Second meeting was held online on 10 July 2020 with 44 participants for purpose of information collection. Here five presentations were conducted.

- Artificial neural network simulation of energy performance of a sorption thermal energy storage system by Frederic Kuznik
- Energy Storage Operation: From Equilibrium and Agent-based solutions to Reinforce-ment Learning by Fuzhan Nasiri
- Pilot projects on district /building systems using MPC granted to the Electrical Energy Systems research group at Politecnico di Bari by Massimo La Scala
- Efficient Interaction Between Energy Demand Surplus Heat, Cooling and Thermal Storage in Hospitals by Trond Thorgeir Harsem
- Deep learning for the design optimization of energy storages in renewable energy systems by Maria Ferrara and Enrico Fabrizio

Third meeting was held online on 14 August 2020 with 35 participants for purpose of in-formation collection. Here six presentations were conducted.

- Trade–off between accuracy and fairness of data-driven building models by Yin Sun and Fariborz Haghighat
- Occupant-driven building electricity consumption using a Functional Data Analysis approach by Rebecca Ward
- Data driven model for demand prediction under time-of-use tariff by Yohei Kiguchi
- Thermal storage for distributed heat and power generation by Sergio Camporeale
- Thermal energy storage control in building design and Operation by Umberto Berardi
- Latent energy storage design and integration in building by Mohamed El Mankibi

Forth meeting was held online on 25 September 2020 with 35 participants for purpose of information collection. Here three presentations were conducted.

- Smart Vent project: Ancillary services to Smart Grid through multi-zone demand con-trolled ventilation systems in residential buildings by Samira Rahmana and Alireza Afshari
- Off grid northern hybrid community district energy system: modeling and optimiza-tion by Behrang Talebi
- Phase Change Materials in Building Envelopes for Energy Saving in Mediterranean Climate and New Opportunities by Halime Paksoy

Fifth meeting was held online on 26 October 2020 with 30 participants for purpose of in-formation collection. Here three presentations were conducted.

- Inverse Problems: For a Better Model Prediction and Optimal System Control by Wonjun Choi
- Using MPC for optimal energy scheduling of a smart microgrid with shared photovoltaic panels and storage by Mariagrazia Dotoli and Raffaele Carli
- Innovation in radiant systems: Use of phase change materials by Ongun Berk Kazanci.

TASK 39: LARGE THERMAL ENERGY STORAGES FOR DISTRICT HEATING

TASK INFORMATION

GENERAL

Duration: Start: October 2020 – End: September 2023

Website: https://iea-eces.org/task-39/

TASK MANAGER

Contact Details TM

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ABOUT TASK 39

MOTIVATION

Large thermal energy storages (LTES) offer more flexibility in DH Systems (also adding operational flexibility to power plants and industrial processes), they enable a higher share of renewables and waste heat, they can provide peak shaving functionality for electricity grids through Power-to-Heat (P2H) thus enabling sector coupling of the power and heating sector.

The market for large thermal energy storages is growing, with new plants built and planned in Denmark and Germany, mostly pit thermal energy storages (PTES) with volumes in the range of 400,000 to 500,000 m³ (in Denmark). In order to facilitate and accelerate the market uptake of these large storages, better materials and knowledge is needed to improve the service lifetime of the storages, better tools are needed for designing, planning and integrating the storages and more knowledge of the potential and integration possibilities of the storages is needed for decision makers.

AIM AND OBJECTIVES OF THIS TASK

The Task aims at determining the aspects that are important in planning, designing, decision-making and realising LTES for the integration into district heating systems and industrial processes, given the boundary conditions for different locations and different system configurations.

The key objectives of the Task are:

- Definition of a number of representative application scenarios, the connected boundary conditions and key performance indicators
- Improve LTES materials and materials performance measurement methods
- Prepare guidelines for obtaining proper water qualities
- Compare the performance and accuracy of simulation models for LTES
- Derive validation tests for LTES simulation models
- Generate information packages for decision makers and actively disseminate the information

CONTRACTING PARTIES / SPONSORS

Institution	Country
AEE INTEC, UIBK, AIT, JKU, SOLID	Austria
PlanEnergi, DTU, Ramboll	Denmark
Chalmers University, Absolicon	Sweden
SOLITES, siz energie+, TH Ulm, Solmax, AGFW	Germany
NRCan	Canada
newHeat, CEA	France
CREAR-UniFI	Italy
Ecovat	The Netherlands
Iller Bank.Inc.Com, Gazi University	Turkey
Nottingham Trent University, University of Birmingham	United Kingdom

OVERVIEW OF SCOPE:

The scope is determined by both technological and non-technological aspects:

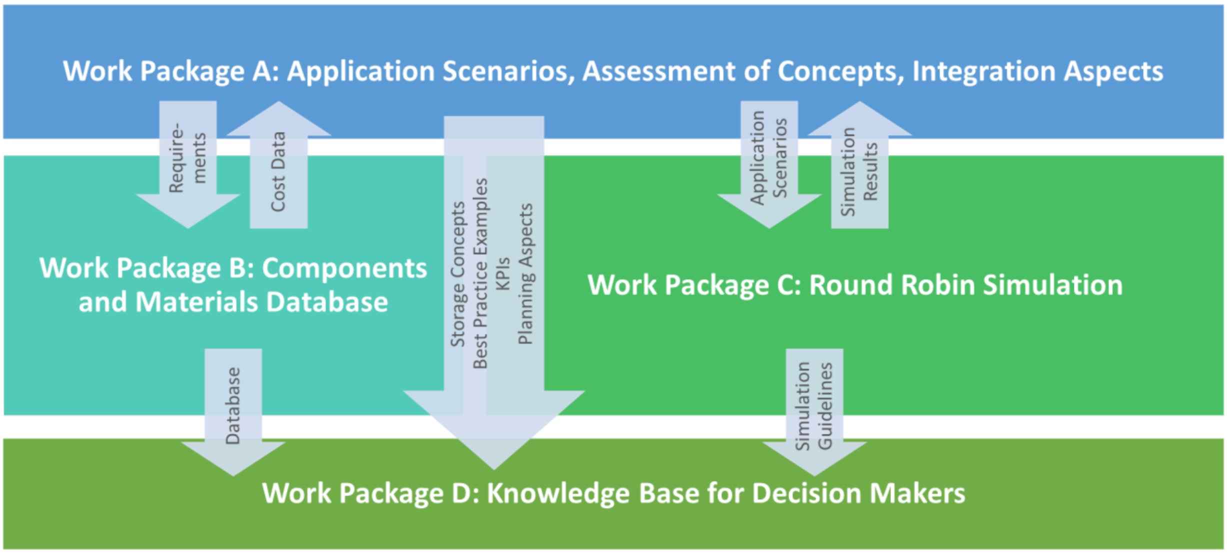
- 4 types of storages are considered:
  - Pit Thermal Energy Storages (PTES)
  - Tank Thermal Energy Storage (TTES)
  - Aquifer Thermal Energy Storages (ATES)
  - Borehole Thermal Energy Storages (BTES)
- Water is the storage medium with atmospheric pressure (or slightly overpressure) in PTES and TTES, aquifers in ATES and soil is the storage medium in BTES.
- The (water equivalent) volume of the storages are typically larger than 50,000 m^3, while for TTES and slightly over-pressurised storages the volumes can be much smaller.
- The storages are applied in district heating systems or in industries.
- Seasonal storages, daily storages and multifunctional storages will be included.
- Dissemination is targeted to decision makers in policy, municipalities, utilities and DH heating companies.

WORK PACKAGES

The Task is organised around 4 Work Packages.

Work Package A works on application scenarios, the definition of key performance indicators (KPI), the assessment of storage concepts in the scenarios and the detailing of integration aspects. Work

Package B aims at composing a database of suitable materials that can be used for LTES. Work Package C is dedicated to a round robin of the numerical simulation of LTES with real validation data sets. Work Package D has the goal to develop and distribute information packages for decision makers.



Schematic representation of the Task breakdown into Work Packages and the information flow between the Work Packages

WORK PACKAGE A: APPLICATION SCENARIOS, ASSESSMENT OF CONCEPTS, INTEGRATION ASPECTS

This Work Package aims to define application scenarios, storage concepts for these scenarios and key performance indicators for the storages in the different applications. The activities are subdivided into three groups:

1. Application scenarios and boundary conditions

On basis of a list of potential main uses of the storages, a number of reference application scenarios will be sketched and the boundary conditions for the LTES in these applications defined. A subset of the application scenarios will be used in the Work Package C for the round robin. These applications need to have real operation data sets for validation purposes.

2. Definition of storage concepts for application scenarios

Storage concepts will be defined that fit into at least one application scenario.

3. Definition of key performance indicators for feasibility determination

A techno-economic feasibility will be performed on the storage concepts for the different application scenarios. As much as possible existing work on this will be used, working first on a rough, less detailed level, pointing at the best concepts - and then performing more detailed calculations in Work Package C. In order to make a proper ranking, key performance indicators will be defined and used, of which the levelized cost of storage (LCOS) is the most important.

Outcome:

- Boundary conditions generated from chosen application scenarios
- Definition of storage concepts for the application scenarios
- Definition of key performance indicators
- Recommendations on LTES applicability

WORK PACKAGE B: COMPONENTS AND MATERIALS DATABASE

The goal of this Work Package is to define common test procedures for hygrothermal and mechanical tests for liner materials, to define the water quality and the ways to arrive at this and to create a database for LTES materials that go beyond the standard values. The activities are grouped as follows:

1. Hygrothermal and mechanical tests

The liner and insulation and protection materials mainly in PTES have to perform at higher temperatures and moisture levels than specified in the present standards. Thus, a combined hygrothermal test procedure/method is needed in order to fulfil the conditions. Furthermore, the mechanical behavior of the materials should be determined at operational conditions. Finally, testing of the weldings of the liner is another critical point which should be investigated for finding new/existing measurement methods.

2. Water condition and corrosion protection

Water condition, water quality and corrosion protection are some of the most important parameters concerning the lifetime of LTES. Guidelines, recommendations and procedures are needed for obtaining a proper water quality. Parameters of interest are pH, organic components, calcium content, salts and oxygen. In addition, guidelines/recommendations for corrosion protection are needed.

3. Materials database for LTES

Especially for use in non-standard conditions, as is the case in higher temperature LTES, there is a lack of information on materials that comply to these conditions. Information on these materials will be gathered in a dedicated, open accessible database.

Outcome:

- Proposal for novel hygrothermal and mechanical test methods
- Guidelines for proper water quality and procedures for obtaining this water quality
- Guidelines/recommendations for corrosion protection
- Material database for LTES

WORK PACKAGE C: ROUND ROBIN SIMULATION

The aim of Work Package C is to validate and compare numerical simulation models through round robins. Models for the storage will be considered for PTES, TTES, BTES and ATES.

Other system components like heat pumps etc. are not considered. The work focuses on accuracy, applicability and usefulness of the simulation models for LTES. The activities are subdivided in the following parts:

1. Inventory and work plan

An inventory of available data sets and possible system configurations for the simulations are made (together with Work Package A). To focus the work on the LTES models, the LTES is regarded with data interfaces such that no connected energy systems have to be modelled. Monitoring data of the operation of existing LTES is assessed to be the best.

2. Simulation round robin 1

A first round robin will be performed, probably with more simpler data sets for the interfaces. Then, the outcomes will be assessed and the criteria for the second round adapted.

3. Simulation round robin 2

The second round will be performed with monitoring data with the aim to evaluate the different LTES models. The outcomes will be assessed and the results described. Conclusions and recommendations for simulation of LTES in DH will be given.

Outcome:

- List/ Overview of existing simulation models of LTES
- Description of round robin tasks
- Report on outcomes and experiences of round robin simulation
- Recommendations for simulation of LTES

WORK PACKAGE D: KNOWLEDGE BASE FOR DECISION MAKERS

The aim and scope of Work Package D is to broaden the knowledge and increase the awareness of LTES and to inform relevant decision makers and stakeholders about the benefits and possible obstacles. This should be achieved by development and distribution of information leaflets and other electronic information and by hosting workshops to further increase the awareness internationally. The activities are subdivided in the following parts:

1. Determination of information need

Engaging groups of decision makers (utilities/energy companies, municipalities, etc.) and determination of the proper level of information.

2. Gathering and assessment of information for decision makers
   a. KPIs
   b. State-of-the-art, market potential and best practice examples
   c. Environmental, non-technical and planning aspects
   d. Financial aspects
3. Compilation and distribution of information material
   - Drafting the information leaflets and online materials
   - Cross-check of information with target groups, e.g. at workshops
   - Distribution of information materials at workshops, conferences, etc.

Outcome:

- Information material A): Technical matters; targeting utilities and energy companies
- Information material B): Targeting financial decision makers
- Information material C): Targeting authorities (municipalities, energy agencies, politicians and other non-technical decision makers)
- Conference papers and presentations
- Workshops for decision makers
  - Technical and non-technical topics

ACTIVITIES AND ACHIEVEMENTS

As the Task 39 started in October 2020 the reporting of activities and achievements is understandably short.

The work started with a virtual kick-off meeting on 27 October and 3 November. The meeting was attended by 27 experts, and the planned activities, goals and deliverables were discussed for the 4 work packages.

For WP A, a first inventory table was made of applications of thermal energy storages coupled to district heating systems, and which partners could provide more detailed data on these storages.

From the inventory, practical applications will be chosen for the application scenarios, that serve as basis for the key performance indicators definition and for the comparison of numerical simulation programs.

For the WP B on materials database, an inventory was made of the contributions that experts can make to the test methods. At least hygrothermal tests and tests to measure the effect of changing temperature on materials and corrosion will be input to the work package.

Regarding the round robin simulation, in WP C, the system boundary for simulation was discussed and an inventory of the available numerical models was started. A first distinction is made between LTES and system models and between pre-design, system simulation and TES design optimization.

As the work in WP D, Knowledge Base for Decision Makers, is dependent on the outcomes of the other WPs, there are no activities planned for the first period, except the gathering of general information.

PLANNED TASKS

TASK 38: GROUND SOURCE DE-ICING FOR INFRASTRUCTURE

This Task Proposal is under development. Its start was postponed to mid 2021.

APPENDIX

THE INTERNATIONAL ENERGY AGENCY (IEA)

Established in 1974, the International Energy Agency (IEA) carries out a comprehensive programme of energy co-operation for its 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 specialised standing groups and committees. For more information on the IEA, see www.iea.org.

IEA STANDING GROUPS AND COMMITTES

The IEA Energy Technology Network (ETN) is comprised of 6000 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 ES TCP (Energy Storage TCP) relates to the EUWP. Within that framework, the ES TCP is also part of the Building Coordination Group (BCG). Within the BCG the various building-related TCPs seek opportunities for collaboration (i.e. cross-cutting subjects) and exchange results and developments.

IEA TECHNOLOGY COLLABORATION PROGRAMMES

The IEA 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 2000 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 are organised 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.

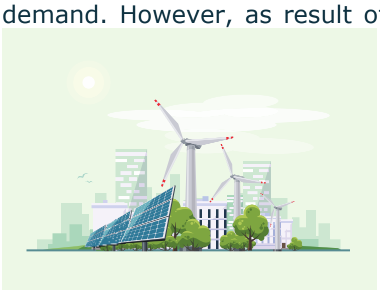
ES TCP (ENERGY STORAGE TCP – ORIGINAL ECES TCP)

The mission of ES TCP is to facilitate integral research, development, implementation and integration of energy storage technologies to optimise the energy efficiency of all kinds of energy systems and to enable the increasing use of renewable energy instead of fossil fuels.

Storage technologies are a central component in energy-efficient systems. Since energy storage is a cross-cutting issue, expert knowledge of many disciplines (energy supply and all end-use sectors, as well as energy transmission and distribution) must be taken into account. To use this widespread experience efficiently and gain benefits from the resulting synergies, high-level coordination is needed to develop suitable working plans and research goals. ES TCP is responsible for fulfilling this important task. ES TCP's strategic plan therefore includes research activities (strategies for scientific research and development, dissemination and market deployment), as well as co-ordination activities (aims and administration).

ENERGY STORAGE AND THE ENERGY TRANSFORMATION

To meet greenhouse gas emission reduction targets, as well as the 1.5-2 °C aim, a decarbonisation of the global energy system is required (see Climate Summit COP21 in Paris, December 2015). This implies the substitution of fossil energy carriers by low-carbon energy and closed carbon cycles, which means less carbon dioxide (CO_2) from fossil fuel power plants and a higher share of renewable generation. Renewable energy from solar and wind shows a high additional potential for electricity generation. Currently, the electricity sector only accounts for around 25 % of the final energy demand. However, as result of the energy transition, considerable changes in the other energy-intensive sectors such as heating and transportation are taking place whereby traditional sources of (fossil) fuels are gradually replaced by renewables and, in particular, a growing contribution of renewable electricity.



By using heat pumps, electric vehicles or synthetic fuels based on green hydrogen ("power-to-fuels"), renewable electricity will gain more and more importance and will contribute to the decarbonisation of the heating and transportation sectors as well. This global development – with its individual characteristics in each country – will determine the future relevance of energy storage. Today it is also often referred to as "flexible sector coupling". Energy storage is a key-technology within that process.

THREE SHAPES OF ENERGY STORAGE

By enabling the temporary balancing of supply and demand, energy storage has always been an important part of the energy system. Depending on the form of energy which needs to be balanced and the required storage period, different types of energy storage, such as thermal, electrical, material or virtual storage, can be used. While material and especially thermal energy storage systems have an intrinsic storage capacity (and with that are able to absorb short-term fluctuations), electrical energy storage systems are highly dependent on perfect balancing.

Thermal energy storage (e.g. hot water) is used when the final energy to be stored is heat – or cold. Due to their high efficiency and comparatively low investment cost, such systems can be used in various applications ranging from balancing highly volatile load peaks ("power-to-heat" or "power-to-cold") to decentralised island solutions or even in industrial environments (heat/cold integration).

Electrical energy storage (e.g. pumped hydro storage or various sorts of batteries) have experienced a very dynamic development, especially due to mobile applications such as electro-mobility. Compared to thermal energy storage systems, electrical energy storage systems are more cost-intensive and less efficient. They store electrical energy which makes them a key technology for grid stabilisation and balancing.

Material storage systems (e.g. gas – or hydrogen – storage) are mostly used for long-term or seasonal storage and to guarantee the security of energy supply. Virtual storage systems are controllable loads that can be switched on or off depending on the actual demand.

ENERGY STORAGE IN OUR ENERGY SYSTEM

Depending on the specific characteristics of respective national energy systems, the required type and capacity of energy storage varies. Although the electricity flow can be optimised by the interconnection of energy networks and international coupling points, still the national (or rather regional) energy systems are decisive. The differences in status quo as well as in past developments are significant. There are countries with a high share of nuclear power (e.g. France), coal-fired power (e.g. Poland), hydroelectric power (e.g. Norway), gas-fired power (e.g. the Netherlands), or wind and solar power (e.g. Germany).

Even though the development in the energy sector is very heterogeneous, a common trend can be recognised. Overall, wind and solar power show significantly growing capacities whereas the share of fossil energies – especially lignite and hard coal – is declining. The integration of fluctuating forms of energy, combined with a decline in base-load power plants, requires large structural changes in energy transmission and distribution networks. This requires solutions such as the development of energy storage capacities and/or flexibility in demand, or a combination of these two elements.

NEW INNOVATIONS FOR ENERGY STORAGE

As a result, the future role of energy storage will be more complex and more important than today. The value of storage continues to increase. In a growing number of applications energy storage is an indispensable key technology (e.g. electro-mobility, micro-grids, decentralised energy systems or integration of renewables) or, rather, a key enabling technology that increases value-creation and allows for technological degrees of freedom (e.g. thermal energy storage for demand-side management).

The two major innovation challenges for energy storage are:

- Techno-economic improvement: reduction of investment costs, longer lifetime, higher efficiency, compact design, safety.
- Economic-regulatory hurdles: non-discriminatory market access ("level playing-field"), business cases/market design, regulatory hurdles (e.g. taxation), security of investment in uncertain market development.

Both of these challenges need to be tackled simultaneously because an efficient, low-carbon, sustainable and stable energy system requires the large deployment of renewable (fluctuating) energies, and, with that, a balancing of energy supply and demand by energy storage is crucial.

BACKGROUND

The energy sector is undergoing significant changes. The percentage of renewable energy generation will continue to increase, mainly through the use of wind, solar and hydro-power. Variable generation sources such as solar and wind will provide challenges for national grid infrastructures and for matching demand and supply profiles. The amount of fluctuating energy – both on the supply- and demand-side – compels us to control these energy flows and capacities. In combination with the changing profiles in energy demand, the entire energy system requires a new design. Grid expansion, as well as flexibility mechanisms, will be necessary at all levels of the energy system. 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 energy storage systems are currently being considered to balance the energy system and to provide solutions to enable flexibility and sector coupling. Pumped hydro storage and various electrochemical energy storage solutions have already been developed. Further R&D activities will improve the efficiency of technologies (e.g. redox flow cells, sodium-sulphur batteries and Carnot batteries), as well as decrease their costs. Even thermal energy storage solutions may prove suitable for balancing the electricity grid ("power-to-heat"). Furthermore, decentralised energy storage is expected to make a significant contribution toward matching local supply and demand.

Energy storage can also contribute to increasing overall energy efficiency in the industrial sector through utilising 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 wide variety of energy efficiency and energy 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 energy 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 increased use of renewables on the other. Solar and heat pump assisted heating and cooling systems in combination with energy storage provide very promising solutions. Transforming surplus solar or wind energy and storing it in decentralised energy storage solutions, such as batteries or as 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, centralised or decentralised, autonomous or grid-connected energy storage solutions are becoming crucial components of the energy systems of the future.