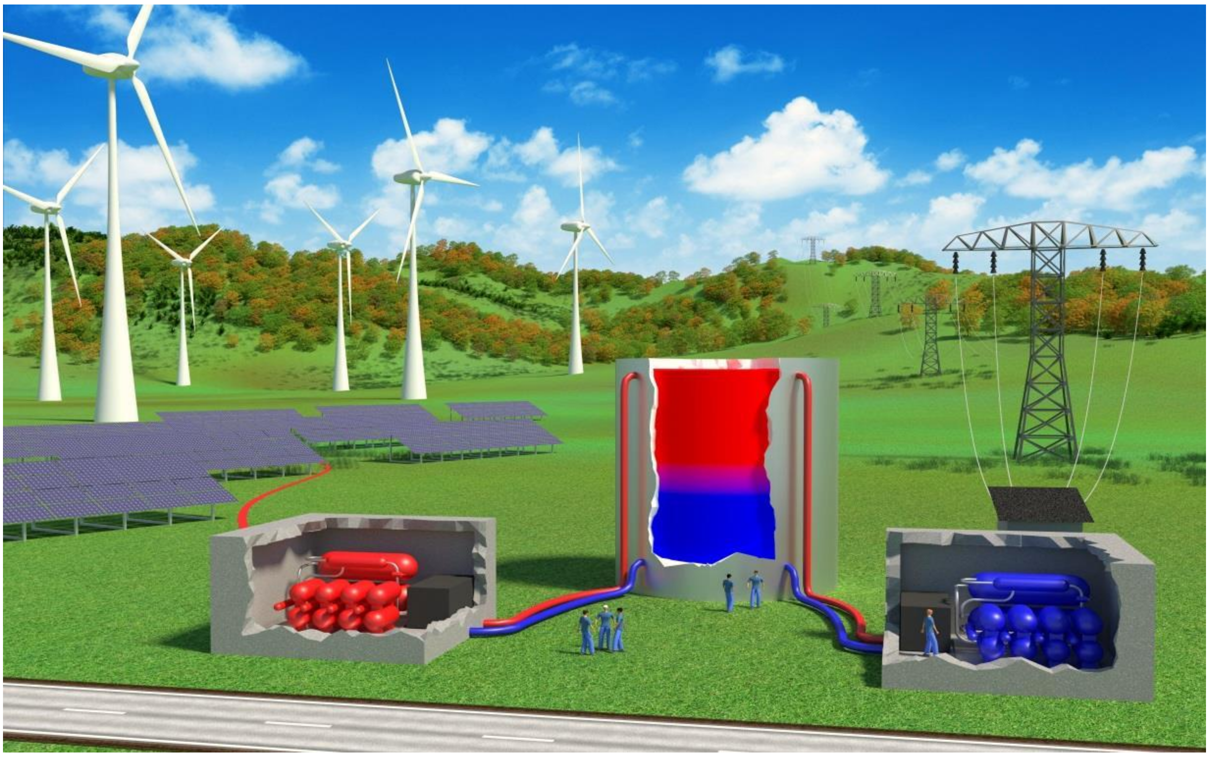
energy storage

IEA Technology Collaboration Programme

Annual Report 2019



Technology Collaboration Programme

by iea

COLOPHON

Contributors to this Annual Report 2019:

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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

Main Technology Policy Messages/Recommendations

Based on the objectives of the Paris Climate Change Agreement 2015, a carbon-neutral energy system using mainly renewable energy sources will require huge amounts of energy storage in all sorts and capacities in order to provide the essential flexibility such a system requires.

The challenges are to provide renewable energy at the right place and time and in the right form within the integrated energy system of the future. Flexibility between the time of use and time of renewable energy production, as well as interaction between sectors ("sector coupling") is required for a stable, new (and renewable based) energy system. Energy storage in any form is required for this flexibility to provide robust and economically viable solutions. Whether that is storage solutions at a large scale (such as pumped hydro storage or the conversion of surplus electricity into hydrogen) or more decentralised thermal or electrical energy storage solutions in the build environment, industry or mobility sectors; all will be needed. In this respect the "value" of energy storage is gradually recognised and realised, both in terms of monetary value and in terms of the crucial value of increased flexibility and stability of the future energy system.

Due to a growing scientific and political interest in energy storage, better conditions are being developed for the deployment of energy storage in various markets. A more holistic approach towards the entire energy system (and the interaction between the use of electricity, heat, cooling and mobility, and variable renewable energy production), referred to as sector coupling ,drives the need for more and improved energy storage solutions. Energy Storage TCP, further referred to in this report as ES TCP has the ambition to enhance international cooperation on research, development, demonstration and deployment of energy storage technologies and systems within the IEA Energy Technology Network, and other external bodies and organisations with similar ambitions, such as Mission Innovation (MI).

Policy Priorities

Being an enabling technology supporting the overall energy system, energy storage needs to be better understood and, therefore, needs to receive more public attention, being an essential part of the energy transition. More exposure and information on the potential of energy storage translates into more attention for subsidy schemes, stimulation programmes and pricing mechanisms. The increased awareness and visibility of energy storage technologies and their role in the energy transformation needs our support.

ES TCP, as a platform for international collaboration in research, will stimulate effort to demonstrate the use and deployment for affordable and innovative energy storage solutions as part of the overall transition to a carbon-neutral energy system. Each new Annex or joint activity will also be required to provide policy recommendations for the further implementation of energy storage in the overall energy system.

Annexes

Progress on current ongoing Annexes can be reported as follows:

- Annex 27: "Quality Management in Design, Construction and Operation of Borehole TES Systems" is completed; the final report will be presented at the 2020 Executive Committee (ExCo) Spring Meeting. The Annex had a very strong industry involvement and contributes to pre-normative standards work to accelerate the use of borehole energy storage. In Annex 27 quality issues were addressed and it has contributed to a large extent to the work of the CEN Technical Committee (TC 451- WG2) and subsequently to the development of EU standards, which are expected in 2020.
- Annex 33: "Material and Component Development for Thermal Energy Storage" is a joint Annex/Task with TCP Solar Heating and Cooling – SHC – (Task 58) and is a further continuation of work aimed at developing more compact thermal energy storage systems. Innovative thermal energy storage technologies like phase change materials or thermochemical energy storage systems can contribute to the integration of renewable energy (e.g. by demand-side integration) or to increased energy efficiency (e.g. by industrial

waste heat utilisation). For such systems, the question of appropriate novel storage materials is crucial. An earlier annex on this topic (Annex 29) focused on the development and characterisation of new materials and their integration into the storage system. This current annex will conclude in 2020 with some workshops to evaluate options for a possible extension on this important subject. The ExCo has provided guidance for more focused and dedicated application areas.

- Annex 34: "Affordable Heating and Cooling for the 21st Century" was initiated as a joint annex with Heat Pump Technologies (HPT) TCP, also connecting to MI. The work started in 2019 and has a strong link to industry with a focus on testing and demonstrating combined heat pump/storage combinations. The Operating Agent for this combined Annex is funded by the Netherlands. The European Commission has a special interest in this subject and has reached out through targeted Horizon 2020 calls. The Annex was highlighted particularly at the MI Ministerial Meeting in Vancouver, Canada, in May 2019 (see also https://www.youtube.com/watch?v=fe3xs_aK1DA).
- Annex 35: "Flexible Sector Coupling". The scope of this Annex includes all energy storage technologies suitable for sector coupling applications. It is important to focus strictly on energy storage only. The Annex will address the following topics: Assessment of all storage technologies; investigation of all applications in the heating and cooling sector; investigation of all applications in the mobility sector; and all propulsion technologies (electric vehicles, fuel cells, hydrogen systems, etc.). The ExCo approved the workplan in 2019 and the Annex will start in 2020.

A number of new annex proposals have been approved to start in 2019/2020 as follows:

- Annex 32: The preparation work for this new Annex on modelling of energy storage for simulation/optimisation of energy systems has been approved and the Annex will start in 2020. It will use the name: "Open Sesame – Open Source Energy Storage Models". Experts from the IEA modelling team will also be involved in the Annex work.
- Annex 36: "Carnot Batteries". The workplan was approved by the ExCo and the Annex will start in 2020. There is a strong participation from universities, scientific institutes and industry (approximately one-third from each).

Several subjects for possible new annexes have been discussed and proposals are in preparation for consideration by the ExCo during 2020:

- Smart design and control of energy storage systems, including artificial intelligence (proposed Operating Agent – Japan).
- Ground source de-icing for transport infrastructure (proposed OA – Germany).
- District heating and use of energy storage (proposed OA – Austria).
- Stationary battery development and life-cycle analyses (proposed OA – Germany).

Achievements and Recent Developments

Secretariat ES TCP

The ES TCP secretariat and communication functions have been outsourced to a new party since July 2019. Prior to this, the standing practice had been that the Secretariat was connected to the office of the ExCo Chair. It was decided that more continuity was required while simultaneously increasing the flexibility to seek candidates for the role of ExCo Chair. Following a call for proposals, five institutes submitted proposals for this function to the ExCo. A selection sub-committee of the ExCo recommended (based on a number of criteria) that ZAE Bayern (the Bavarian Centre for Applied Energy Research e. V.) be selected as the new ES TCP Secretariat; this recommendation was approved unanimously by the ExCo.

Mission Innovation

ES TCP is closely connected to MI Challenge #7 (affordable heating and cooling). There are bi-monthly co-leaders calls on various subjects related to this Challenge, and ES TCP contributes actively by reporting progress on Annex 34 and other storage-related subjects.

European Energy Research Alliance Joint Programme on Energy Storage
The EERA Joint Programme on Energy Storage (JP ES) was due for periodical review and evaluation in 2019 and the ES TCP Chair participated as member of the review committee. Further collaboration between ES TCP and EERA JP ES is envisioned in the future.
IEA's World Energy Outlook
The ES TCP is member of the peer-review team for the IEA's WEO report with regard to energy storage aspects in the appropriate chapters in the WEO.
IEA's Energy Technology Perspectives
ES TCP has contributed actively in the development of the upcoming 2020 ETP report by not only submitting various background information to the ETP team, but also by supporting them with the secondment of an esteemed expert in Paris (in 2020).
IEA's Today in the Lab / Tomorrow in Energy
ES TCP contributed to this IEA initiative for ETP 2020 with the submission of three projects (QEWS II for Annex 27, HT-VSI for Annex 35 and iAST for Annex 30). Spoiler alert! One project was selected from 52 submissions as one of five projects to be promoted by the IEA (more on this topic in the next annual report).

In 2019 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 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 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)

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.

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 Sørenson	Alt. delegate	Denmark
Jussi Mäkelä	Delegate	Finland
Paul Kaaijk	Delegate	France
Patrick Canal	Alt. Delegate	France
Hendrik Wust	Delegate (Vice Chair)	Germany
Stefan Busse-Gerstengarbe	Alt. delegate	Germany
Pier Paolo Prosini	Delegate	Italy
Raffaele Liberatore	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
Andreas Eckmanns	Delegate	Switzerland

Name	(Alternate) Delegate/Sponsor	Country
Contracting Partners		
Michael Moser	Alt. delegate	Switzerland
Stefan Oberholzer	Alt. delegate	Switzerland
Lex Bosselaar	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		
Luisa F. Cabeza / University Lleida*	Sponsor delegate	Spain
Camila Barreneche / Uni. Lleida*	Sponsor alt. delegate	Spain
Mick McKeever / DIT**	Sponsor delegate	Ireland
Aidan Duffy / DIT**	Sponsor alt. delegate	Ireland
Andreas Hauer / BVES	Delegate	Germany
Urban Windelen / BVES	Alt. Delegate	Germany

** The University of Lleida has indicated that it will not to be a sponsor from 2020.*
*** The Dublin Institute of Technology (DIT) has not been an active sponsor for some time and continuation of its sponsorship will be reviewed in 2020.*

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CONFERENCES, WORKSHOPS, EVENTS AND COMMUNICATION

CONFERENCES, WORKSHOPS AND EVENTS IN 2019

An overview of all the ES TCP attended conferences, workshops and events in 2019:

- Kick-off meeting with Mission Innovation, European Commission and ES-TCP for joint Mission Innovation/TCP HPT- ES TCP Annex – January 17-18th – Utrecht, NL
- Building Coordination Group meeting – February 27th – IEA HQ, Paris, France
- ESE/ES-TCP mini-symposium 2019 –March 13th – Düsseldorf, Germany
- EUWP/RSE/ENEA workshop: "Flexibility for a sustainable energy system" – March 20th – Rome, Italy
- EUWP meeting, March 21st – Rome, Italy
- Review meeting EERA JP, April 30th – Barcelona, Spain
- ExCo 87 ES TCP – May 23rd, 24th – London, UK
- 3rd Universal meeting of TCPs, June 18-19th – Paris, France
- Peer review WEO, August
- 8th SCCER Heat and Electricity Storage Symposium – November 5th – Dübendorf, Switzerland
- ExCo 88 – November 6-7th – Zurich, Switzerland
- TCP modernisation (telephone) meetings – August-December
- Various Mission Innovation update (telephone) meetings.

COMMUNICATION ACTIONS IN 2019

WEBSITE AND NEWSLETTER

The IEA's new general TCP logo (i.e. the blue bar on the cover page of this document) has been integrated into the website to show the connection between the different TCPs and the IEA. 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.

Two newsletters for ES TCP activities were sent out in 2019. 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.

Together with the webmaster for the ES TCP homepage, Gerard Vink, the possibility of annex subsites was investigated. These can be managed by the Operating Agents and edited by the participants themselves, as well as offering the possibility of exchanging documents via such subsites.

PARTICIPATION IN EVENTS, MEETINGS AND NETWORKS

ES TCP Symposium at Energy Storage Europe 2019

Energy Storage Europe (ESE) is one of the world's leading energy storage trade fairs and takes place every March in Duesseldorf, Germany, coupled to a scientific conference. The ESE Conference addresses all issues that arise on the way from research to the market-mature product, whether these are business models, security issues, financial aspects or studies on future storage requirements. In 2019 the conference attracted some 400 participants from more than 60 countries. The ES TCP organised its own mini-symposium within this event: Two sessions presented the ongoing Annexes and concluded with a panel discussion between all the Operating Agents and Teun Bokhoven, Chair of the ES TCP.

Workshop: Flexibility for a Sustainable Energy System

On March 20th 2019, RSE/ENEA organised a workshop on increasing flexibility options, including energy storage. The workshop was organised in conjunction with the EUWP meeting in Rome. On behalf of ES TCP, a presentation was given to inform the audience on the work in ES TCP.

8th SCCER Heat and Electricity Storage Symposium

PSI organised an international symposium in Switzerland on electrical energy storage in conjunction with the autumn ExCo meeting of ES TCP. It provided an opportunity to share the latest developments and work in the Annexes of the TCP and match those with the latest insights of various Swiss research groups on his subject.

ERA-Net Smart Energy Systems

Since 2019, ES TCP has been an associated partner of the ERA-Net Smart Energy Systems (SES). ERA-Net SES provides a sustainable, reliable and efficient management structure for multilateral joint programming. The main task of this platform is the funding of transnational research projects in various fields such as smart power grids, regional and local energy systems, heating and cooling networks, digital energy and smart services, etc. In 2019, for example, a call on Energy Storage Solutions was launched, in which 17 countries participated. Beyond that, ERA-Net SES is well coordinated with the European SET-Plan Action 4 initiatives. From the perspective of TCP ECES, this partnership is another important step towards international networking with relevant actors and stakeholders. The contact person for ERA-Net SES at ES TCP is the Austrian delegate Christian Fink. https://www.eranet-smartenergysystems.eu/

COMMUNICATION PLAN FOR 2020

With the new secretariat now in place, ES TCP plans to increase its communication and outreach 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 Annexes and to anticipate growing interest in deploying energy storage.

- Supporting the development of the annex subsites on the ES TCP website for new annexes, as is currently done for Annexes 32, 35 and 36;
- Preparing a guide on "How to submit a new Annex proposal" for public use on the website;
- Further developing of the website and databases, and arranging for permanent updates related to ongoing and finished annexes, international events (workshops and conferences), relevant publications from within the IEA ES TCP and other resources;
- First steps towards creating an "ES TCP Handbook" with all official procedures and templates used;
- 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
- 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;
- Managing the contact page of the website and the IEA ES TCP mailboxes; and
- Supporting the development of a new Strategic Plan and End of Term Report (as part of the procedure for a further TCP extension).

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 2019 budget from the common fund was $ 69,000[1]. Per ultimo 2019, not all contributions have been received. For some countries, contributions for more than one year are overdue. In total there is still an amount due of $ 24,600.

Table: ES TCP common fund distribution in 2019.

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: University of Lleida (Spain)	1,200	1,200
Sponsor: BVES (Germany)	1,200	1,200
Sponsor: [Dublin Institute of Technology] (Ireland)	[1,200]	
TOTAL (USD)		69,000

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. The same applies to the Sponsor DIT (no contributions received since 2017). They are indicated in the text as well as in the number of countries in the table above with square brackets.

The completed and ongoing annexes in 2019 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 requires funding of about 3-6 MM/year.

[1] This excludes the payments from the USA (since 2016) and the sponsor DIT (since 2017), which haven't fulfilled their contribution commitments.

ONGOING ANNEXES

ANNEX 27: QUALITY MANAGEMENT IN DESIGN, CONSTRUCTION AND OPERATION OF BOREHOLE SYSTEMS

ANNEX INFORMATION

GENERAL

Duration: March 2016 – December 2019

Website: http://www.eces-boresysqm.org

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ABOUT ANNEX 27

The thermal use of the underground with its different technologies and applications is an important measure to increase energy efficiency. This results in an increasing market for ground source heat pumps and underground thermal energy storage. Borehole heat exchangers play an important role in this context.

Unfortunately, failures in design, construction and operation can, in the worst-case, result in serious damage to buildings and the environment. Thus, quality management is an important issue in all project phases.

To elaborate reliable measures of quality management within the IEA ECES implementing agreement an international experts' group has been set up to analyse this technology and failures in the different markets worldwide. This group will work out preventative measures and recommendations for national and international guidelines and standards to avoid problems, but also solutions for fixing and remediation.

The results will be transferred to practice by national teams recruited from involved parties including members from related industries, technical associations and regulatory bodies through workshops and publications.

CONTRACTING PARTIES

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

OVERVIEW OF SCOPE: "LEARN FROM EXPERIENCES, DON'T MAKE A MISTAKE TWICE!"

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

The overall objectives of the proposed Annex are to avoid mistakes and failures related to the borehole system in design, construction and operation. Information and knowledge collected should serve as a basis for national and international standards. Additionally, the compiled experiences of the international experts' group will be a valuable contribution for education of consultants, drillers, installers and operational staff.

This will make BTES technically safer, more cost effective and will strengthen the future usage of this technology. Consequently, the knowledge and confidence of the regulation bodies in this technology should be enforced to avoid ineffective restrictions resulting in increasing costs.

The specific objectives are:

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

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

TOPICS AND PHASES

The annex will cover the following topics:

Design phase	**Construction phase**
Energy concept	Site preparation
Pre-feasibility	Drilling methods
Feasibility	Grouting
Detailed planning	Borehole heat exchangers
Approval procedure	Final test methods
Call for tenders	Start-up

Operation	Problems, failures, investigation and solution, environmental assessment
Supervision of operation	Common problems with BHEs and BTES
Maintenance	Problems from poor grouting
	Problems derived from modification of design parameters
	Description of methods: how to avoid and how to solve these problems - remediation

Subtasks 4 and 5 are merged together as they correlate significantly. The subtask structure follows the headlines of the Annex topics.

Subtask 1
Design phase
Leader: Sweden

Subtask 2
Construction phase
Leader: Denmark

Subtask 3
Operation phase
Leader: Japan

Subtask 4
Problems, failures, investigation and solution
Leader: Germany

Figure: Organisation matrix of Annex 27

The whole work programme can be subtitled with the slogan: *"Learn from experiences, don't make a mistake twice!"*

ACTIVITIES AND ACHIEVEMENTS

During 2019, two expert meetings were held in Osaka, Japan, hosted by HPTCJ – Heat Pump & Thermal Storage Technology Centre of Japan and Hokkaido University, and in Garching, Germany, hosted by ZAE Bayern. The meeting in Osaka started with a joint workshop of Annex 27 and the Japanese Study Group on Ground Thermal Energy and Heat Pump Systems and was attended by 50 persons from Japanese research organisations and industry. At these expert meetings 40 scientists and engineers from research institutions as well as from industry and governmental institutions participated giving presentations related to topics included in the Annex.

At first, the participating countries presented a brief overview on the national market situation, new developments as well as new and current research activities.

In subtask 1 the typical design process from the energy concept via detailed planning to the call for tenders was discussed. The chapter on the design phase prepared by the Swedish members is finished and accepted by the Annex 27 experts.

Subtask 2 covers the construction phase from site preparation via drilling, installation of heat exchanger loop and borehole grouting to the system start-up. The responsibility for this subtask was taken by Denmark. Construction methods used in the countries are related to the geology but also to the common local drilling technology. The information collected from the countries was compiled into a draft subtask report by the Danish team and discussed in detail at the meetings. After including minor final corrections, the subtask 2 report was finalised by the end of 2019.

The Japanese team evaluated the situation in the operation phase (subtask 3). In most countries, monitoring in the operation phase is not common. However, the feedback shows a quite heterogeneous picture regarding the situation of monitoring guidelines. While larger systems typically have an advanced control system, which allows monitoring without big effort, small systems like those for family homes require additional investment as long as the heat pump control does not allow a minimal monitoring. Therefore, it is recommended to include minimal monitoring requirements as an option in the control of the heat pumps. This option should be included in guidelines as well as in national and international standards.

Subtask 4 on problems, failures and solutions and subtask 5 “environmental assessment” are merged together in subtask 4 because of the close correlation of the subjects. It covers issues deriving from design errors, common problems in the construction phase, problems deriving from modification of design parameters and the description of methods of how to avoid and how to solve these problems. In the design phase, mistakes mainly derive from incorrect determination of the load or misunderstanding of the geology. During construction, there are a series of potential mistakes while drilling and installation of the BHE loop or grouting with possibly serious consequences. While operating the risk of mistakes is minor. However, it has to be emphasised that in most of all cases, there are no problems, but one has to be aware of the risk of problems occurring.

France has initiated a European standard on water wells and borehole heat exchangers. The standard committee CEN TC 451 decided to split this activity into two working groups. Working Group 1 (WG 1) is developing the standard on water wells, which include those for drinking water production as well as those for geothermal application. WG 2, covering borehole heat exchangers, started in 2017. As there is significant overlap between the technical subject of IEA ECES Annex 27 and the CEN TC 451 WG 2, collaboration of both experts’ groups is extremely important. Several members of Annex 27 are also involved in the CEN committee, which allows an ideal knowledge transfer from Annex 27 to the new CEN standard. Due to this close collaboration, the working group 2 (WG 2) committee makes good progress in developing the standard. Several physical and web-based meetings were held to achieve this progress. The draft standard was finished by the end of 2019 and will be published for public commenting before it is finally implemented. The final standard is expected in 2020. The development of this standard is a major outcome of Annex 27.

ANNEX 33: MATERIAL AND COMPONENT DEVELOPMENT FOR THERMAL ENERGY STORAGE

ANNEX INFORMATION

GENERAL

Duration: January 2017 – December 2019

Website: https://iea-eces.org/annexes/material-component-development-thermal-energy-storage/

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ABOUT ANNEX 33

This joint SHC TCP Task 58 / ECES TCP Annex 33 deals with advanced materials for latent and chemical thermal energy storage, phase change materials (PCM) and thermo-chemical materials (TCM). The task deals with these materials on three different scales:

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

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

CONTRACTING PARTIES

Institution	Country
Univ. Mons	Belgium
INSA-Lyon	France
ZAE Bayern, Fraunhofer ISE	Germany
NIC	Slovenia
University of Lleida	Spain
KTH	Sweden
Cukurova University	Turkey

OVERVIEW OF SCOPE

This Annex deals with advanced materials for latent and chemical thermal energy storage, phase change materials (PCM) and thermo-chemical materials (TCM). It is a joint activity with the Solar Heating & Cooling TCP. The task deals with these materials on three different scales:

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

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

The main outcomes of the preceding Task/Annexes are a well-defined and tested characterisation method for PCM, an increased knowledge of a first set of salt hydrates and of new combinations of sorption – salt hydrate composite materials.

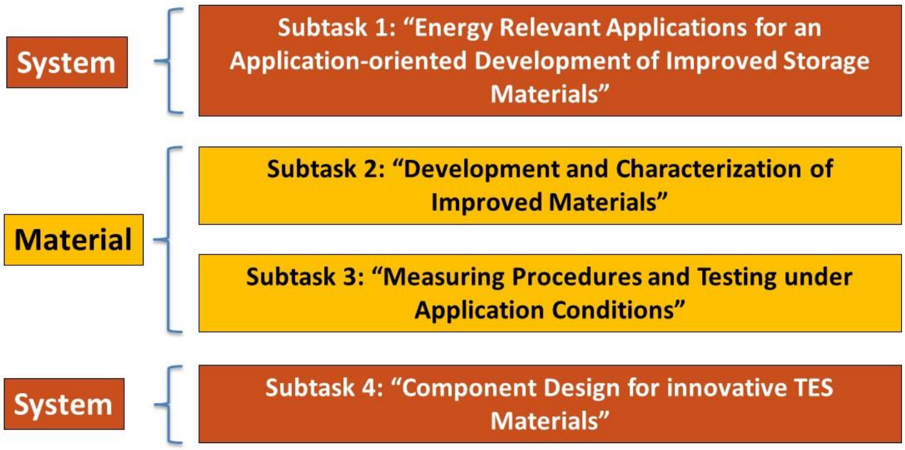
Numerical modelling was further developed to give a first understanding of the mechanisms at molecular scale and on a microporous scale. Models of components containing compact thermal storage materials were developed and validated.

A further finding was that the knowledge on proper design of critical components, like reactors and heat exchangers, is still missing.

Therefore the focus of the new Annex/Task is on the further understanding and development of PCM and TCM, on the development of measuring procedures and test methods for validating the performance of PCM and the development of characterisation procedures and test methods for TCM and on getting better design approaches for components.

TOPICS AND PHASES

The topics have been divided onto the subtasks:



Two of the planned subtasks will concentrate on the material itself, its characterisation and the definition of testing procedures. Subtask 1 and 4 deal with the relation between the new material and the storage component and the actual application, respectively.

ACTIVITIES AND ACHIEVEMENTS

In 2019 two workshops and experts meeting were held, first one in Ottawa, Canada from May 1-3 with 43 participants from 11 countries, the second one in Messina, Italy from October 9-10 with 42 participants from 13 countries attending. The first meeting was focused on internal discussion within the subtasks on the progress of the work programme. In the second meeting the experts continued the discussion on the key messages from the Annex and on the possibilities to continue the collaborative work beyond the time limit of the Annex.

As a result of the discussion, the following general key messages were formulated:

- Collaboration in the IEA Task/Annex between materials experts and application experts leads to improved understanding and therefore accelerates development;
- Standards for measurement and for reporting are prerequisite for constructive discussions and rapidly addressing challenges and advancing TES technologies.

Key messages were also found for each subtask:

<u>Subtask 1</u>

- A large number of relevant applications exist for compact thermal energy storage;
- These applications cover a wide range of temperature, capacity and power requirements, as well as different storage periods;

- While for the building sector reference operation conditions could be defined, this seems to be very difficult for the industrial sector, combined heat and power and district heating applications.

Subtask 2

- A number of innovative and improved materials were developed and are continuously being developed, tested in ST3 and introduced in components in ST4;
- Developed characterisation methods are the basis for material evaluation and comparison;
- The material properties cover not only the technical performance, but also questions like stability and compatibility.

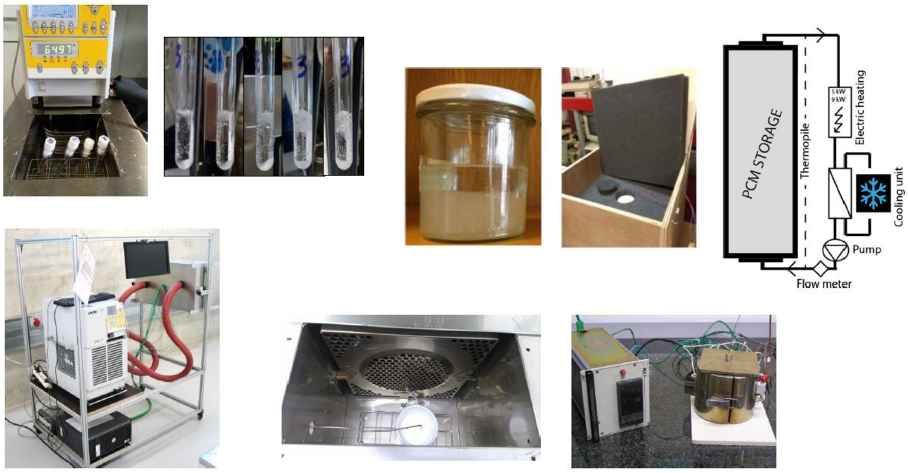


Figure: Pictures of stability testing devices that are used by the experts to investigate the thermal cycling stability of PCM

Subtask 3

- Only testing under application conditions helps identifying the appropriate material for an actual application;
- The actual storage capacity, reachable charging/discharging power and material stability have to be tested under real conditions and requirements.

Subtask 4

- Identification of parameters to enable the comparison of compact storage concepts is important.

Annex 33 concluded at the end of 2019. The final report will be published in mid-2020. In 2020 two task definition workshops (in Vitoria-Gasteiz, Spain, May 6-8 and in Graz, Austria, October 13) are planned in order to define a work plan for the next phase of activities. Basically the discussion leads towards a continuation of characterising newly developed materials for thermal energy storage, of developing measuring procedures for quantifying relevant material properties and of maintaining and expanding the material database. Also new topics like digitalisation, sustainability and life cycle analysis will be discussed.

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

ANNEX INFORMATION

GENERAL

Duration: January 2019 – December 2021

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

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ABOUT ANNEX 30

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 (ECES) and heat pumps (HPT), ECES Annex 34 started in early 2019 and will focus on improving combined systems of heat pumps, storage and controls.

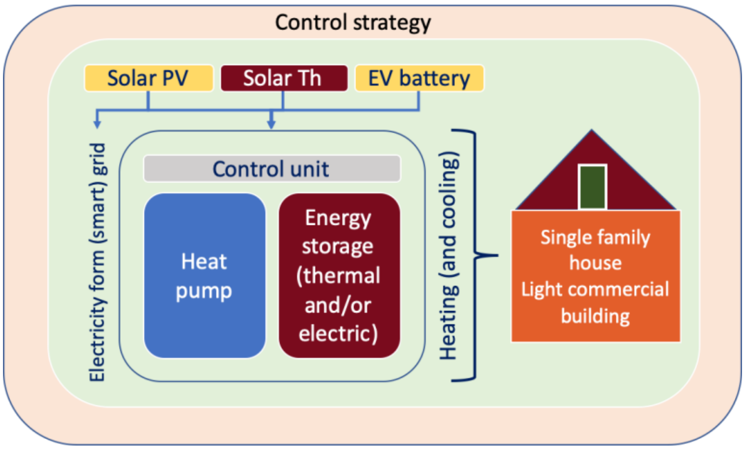
Integrated systems consisting of heat pumps and storage are an important technological option to accelerate the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues may be tackled in one and the same process, such as:

- 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 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 to integrate the work from the TCPs HPT and ECES, building upon the earlier work in the fields of heat pumps and energy storage systems.

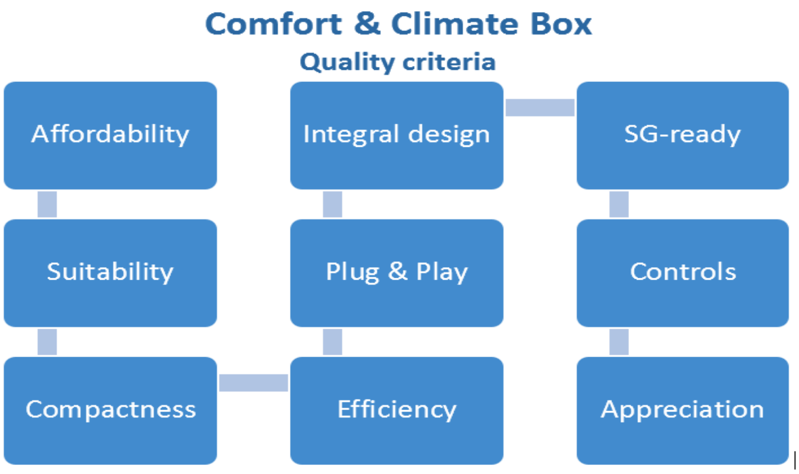
Comfort and Climate Box (CCB)

The central concept in Annex 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.

The general objective of Annex 30 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 utilizsation 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 30 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 30 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
China Academy of Building Research	China
Ademe, CEA-INES	France
Fraunhofer ISE	Germany
ENEA, University of Marche	Italy
RVO, TNO, Stroomversnelling	Netherlands
RISE,	Sweden

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

OVERVIEW OF SCOPE

Annex 34 is not meant to be a classic theoretical 'research and dissemination Annex'. All contributing projects in the participating countries should aim to focus on developments that are 'almost market ready'. The goal of this Combined Annex 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 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 tasks for each participant:

1. Investigate the present market status;
2. Develop or assemble market prototypes;
3. Test prototypes and controls and standardisation;
4. Provide input for the roadmap;
5. Knowledge dissemination and communication.

ACTIVITIES AND ACHIEVEMENTS

January 2019

Utrecht, NL	Kick-off together contributions from the Dutch Ministry, Mission Innovation and participating countries;
Utrecht, NL	Dutch national team meeting with participants from manufacturers, government, grid operators and knowledge institutes.

May 2019

London, UK	ExCo Meeting ECES, final approval of the Annex, presentation of the process start-up;
Helsinki, FN	ExCo Meeting HPT, presentation of the process start-up;
Utrecht, NL	Annex 34/55 involved in MMIP4, multi-year innovation funding programme.

June 2019

Paris, FR	International team meeting with 10 participants on board.

October 2019

Freiburg, GER International team meeting with 10 participants on board;
Nurnberg, GER Heat Pump Summit 2019, presentation of the Annex 34/55 at this bi-annual international heat pump conference.

November 2019

Zurich, CH ExCo meeting ECES, progress reporting and discussion;
Tennessee, USA ExCO meeting HPT, Dutch ExCo delegate present written progress reports.

OVERALL PLANNING

IEA ECES Annex 34 / HPT Annex 55		2019		2020												2021								
		11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
Meetings	Rome																							
	Vienna																							
	tbd UK / SE / CH / BE																							
	tbd UK / SE / CH / BE																							
	Utrecht (final meeting)																				!!!			
WP 1 (CH)	Template country input available																							
	Country input ready --> discuss																							
	Final report for WP 1								!!!															
WP 2 (UK)	Inventarise 'focus areas' for each project. E.g. HP type, storage type, house type, etc.																							
	First testing results																							
	Final input for WP 2 report (projects may continue to run afterwards)																							
	Final report for WP 2																!!!							
WP 3 (IT)	Testing standards: what's going on in Asia/N-America/Europe																							
	Recommendations for standards																							
	Field trial results																							
	Final report for WP 3																				!!!			
WP 4 (SE)	Table of contents' for this WP. E.g. target group, topics to treat.																							
	Each meeting: 'lessons learned' to include into roadmap																							
	Final report for WP 4																				!!!			

ANNEX 35: FLEXIBLE SECTOR COUPLING BY THE IMPLENENTATION OF ENERGY STORAGE

ANNEX INFORMATION

GENERAL

Duration: June 2019 – May 2022

Website: https://iea-eces.org/annexes/flexible-sector-coupling/

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CONTRACTING PARTIES

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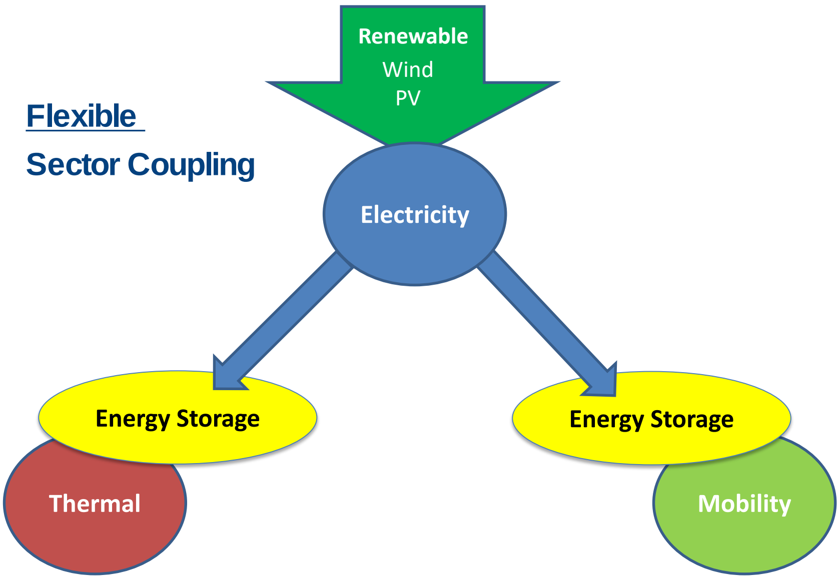
PlanEnergi	Denmark
ZAE Bayern, DLR	Germany
KIER	Korea
ECN / TNO	Netherlands
KTH	Sweden

HS Luzern, EMPA	Switzerland

OVERVIEW OF SCOPE

The main input of renewable energy in the future energy system will come from wind and PV, which supply renewable electricity to electricity grids. Reaching higher shares of fluctuating renewables in the grids may cause a variety of problems. In order to avoid this and at the same time to even further increase the overall share of renewables in the system, renewable electricity can be distributed to other sectors, like the heating (and cooling) and the mobility sectors. Other sectors can be defined in this context.

By coupling these sectors, the demand pattern of the "consuming" sectors, e.g. "thermal" and "mobility", a better utilisation of renewable electricity can be realised. By implementing energy storage technologies between the sectors, where the energy has to be transformed (e.g. into heat and cold) or stored anyway (for mobility applications), the match of fluctuating supply and demand can be managed. The figure below shows the flexible sector coupling approach.



By the implementation of energy storage technologies, like thermal, chemical or electrical energy storage, renewable electricity can be available on demand in the thermal and mobility sectors. This can relieve local distribution grids and improve decarbonisation of other sectors.

SUBTASKS

The work of the Annex will be structured in subtasks:

<u>Subtask 1: Flexible Sector Coupling (FSC) Concept Development</u>

The main concept of flexible sector coupling (FSC) shall be developed. 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 shall be clustered regarding market applications. 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

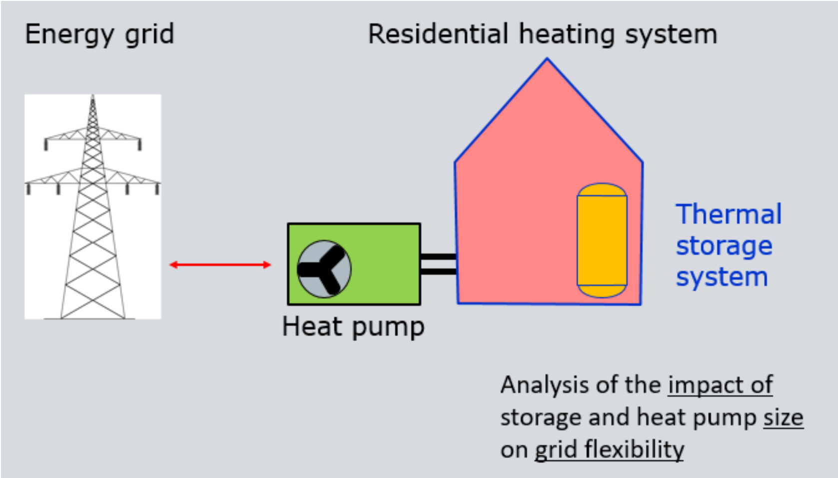
The goal is to analyse and quantify the potentials of energy storages in sector coupling from a national energy system perspective. The work will elaborate on the analysed scenarios in subtask 3 by putting them into the context of national energy system level activity and upscaling them to assess their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

ACTIVITIES AND ACHIEVEMENTS

In 2019 the first Workshop and Experts Meeting was held in Bad Tölz, Germany from October 16-18th. 22 participants from seven countries attended the meeting. Apart from the official participating countries, the World Bank / Energy Storage Partnership and IRENA were present as well. The meeting was focused on initial discussions concerning the definition of FSC in general, presentations from participants on their field of expertise and possible contributions to the subtasks. At the same time the work plan was approved and subtask leaders were nominated.

The main task at the beginning of the project is to identify energy storage technologies for actual FSC applications. This includes, amongst others, their properties and system requirements. At the Kick-off Workshop, several presentations showed different examples of suitable energy storage technologies. This includes a variety of options for power-to-heat applications with heat (and cold) storage systems, power-to-gas technologies (with the focus on power-to-hydrogen) – and additional direct electricity storage, mostly for use in the mobility sector. It was agreed that all kinds of sector coupling technologies could help to increase the share of renewable energy in the energy system and to reduce the amount of emitted greenhouse gases.

A main topic in the discussion was the heat demand for buildings. Space heating will be one of the major enabling technologies for FSC. In combination with heat pumps, there is a possibility to increase energy efficiency at the same time. Furthermore, the period of storing energy can vary from a couple of hours to several days. The figure below illustrates this example for a household application in Switzerland.



Flexible sector coupling with a heat pump system and thermal energy storage in a building [Hochschule Luzern].

Another crucial feature of FSC is its increasing importance in the context of decentralised, local energy systems in future scenarios. The evaluation of the potential of FSC on a local system level and the design and optimisation of local storage technologies is a key issue for the transformation of the overall energy system on a national scale. The main question here is how can decentralised, local energy storage help to decarbonise all energy sectors supplied by volatile, fluctuating renewable energies?

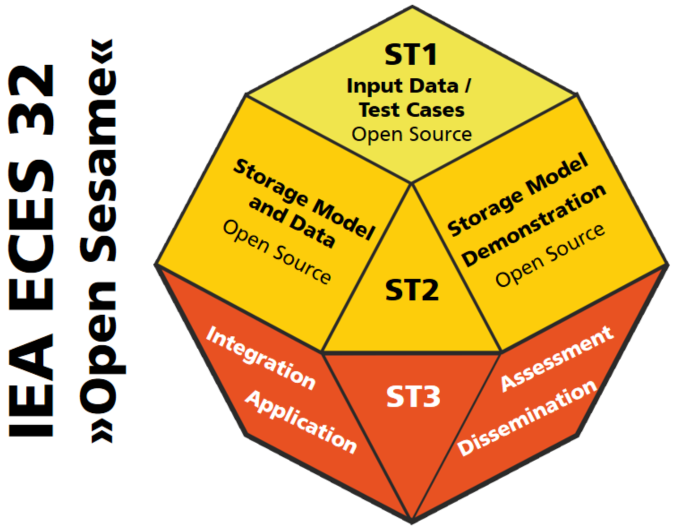
The project "Altdorfer Flexmarkt" (presented by Forschungsstelle für Energiewirtschaft FfE e.V., Germany) deals with the integration of renewable energy, combined heat and power, e-mobility and local storage systems (both heat and electricity) not only from a technical view, but also by the integration of a smart grid based flexibility market. The goal is to evaluate the availability of flexible power generation by considering different influencing factors, such as day of the week and temperature forecast. By clustering these power-generating units according to their respective flexibility characteristics, an aggregated system, including energy storage capacities, is set up which can help to lower the stress in the low-voltage electricity grid and at the same time integrate higher shares of renewable electricity.

PLANNED ANNEXES

ANNEX 32: MODELLING OF ENERGY STORAGES FOR SIMULATION/OPTIMIZATION OF ENERGY SYSTEMS "OPEN SESAME" – OPEN SOURCE ENERGY STORAGE MODELS

ANNEX INFORMATION

GENERAL



Duration: February 2020 – March 2023

Website: https://iea-eces.org/annexes/modelling-of-energy-storage-for-simulation-optimization-of-energy-systems/

OPERATING AGENT

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CONTRACTING PARTIES AND SPONSORS

Institution	Country
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NRC, Carleton University	Canada
Aalborg University, EMD international A/S	Denmark
Fraunhofer UMSICHT, German Aerospace Center - DLR	Germany
ISQ	Portugal
Berner Fachhochschule, CSEM, PV-Center, Paul Scherer Institute	Switzerland
IEA ETSAP Group	Various
Still looking for funding	
Steinbeis SOLITEM	Germany
KIER	South Korea
University of Bath	UK

OVERVIEW OF SCOPE

- The energy system is changing due to variable energy production, decarbonisation, decentralisation, cross-sectoral approaches etc., which requires new, more and various operated energy storage devices to balance demand and production.
- Energy storage models are needed for operation or structural optimisation and for assessing the value of energy storage systems.
- The challenge is that there are no open source energy storage models which are scientifically proven, based on highly sophisticated detailed models, but sufficiently simplified for use in optimisation systems.
- The task is to develop a standardised and scientifically-proven, generic, open source models and data sets to allow assessment of various storage devices for various applications.
- The result will be a generic open source ecosystem for energy storage models and data sets, which allows answers to current storage questions to be found (technical, economical, regulatory).
- The benefit for society is that everybody could use these open source models and data sets for further research, application etc.
- The overall aim of this Annex is to understand and optimise the role of energy storage in the future energy system (decarbonised, cross-sectoral) by modelling/simulation.

PLANNED ACTIVITIES AND ACHIEVEMENTS

IN	Model	OUT
Various data sets (time series) for generation and demand for different regions.	**ST 1** **TEST CASES / INPUT DATA** Standardized data sets (demand and power generation profiles) for different regions, open source	Scientifically proven, double checked simple test cases based on data sets (time series) in a standardized format.
Existing, very detailed (physical) models or "big data approach" for thermal, electrical storage devices	**ST 2** **STORAGE MODEL AND DATA** mathematical description on two levels, open source demonstration	Scientifically proven, coherent mathem. models (pseudo code) as simple (1st level) and complex models (2nd level) incl. demonstration in test cases (open source language)
Various questions regarding technology, combination of storage and R&D aspects	**ST 3** **APPLICATION** Application for design and operation optimization, assessing of storages, publication	Application of the models in complex energy system models (open source or proprietary); Messages to policy makers, stakeholders, companies, etc.; model publication

Open Sesame – Big Picture

The Annex 32 – Open Sesame Kick-off Workshop will be held most likely in Stuttgart, Germany May 6th, 2020.

ANNEX 36: CARNOT BATTERIES

ANNEX INFORMATION

GENERAL

Duration: January 2020 – December 2022

Website: http://www.eces-a36.org

OPERATING AGENT

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University of Liège,	Belgium

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Aalborg University (AAU), PlanEnergi, Technical University of Denmark (DTU), University of Southern Denmark (SDU)	Denmark
French Alternative Energies and Atomic Energy Commission (CEA)	France
Bayreuth University, German Energy Agency (dena), German Aerospace Center (DLR e. V.), Enolcon, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Fraunhofer, Kraftblock, Siemens Gamesa RE, **Steinmüller Engineering,** Stuttgart University, Technical University of Chemnitz, Technical University of Berlin, University of applied sciences Zittau/Görlitz	Germany
CNR – ITAE, National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), University of Pisa	Italy
Hokkaido University	Japan
Energy Transition (ECN part of TNO)	Netherlands
Korean Institute of Energy Research	South Korea
Climeon	Sweden
MAN ES	Switzerland
Durham University, University of Birmingham, Highview Power	UK

Echogen, Malta Inc., NREL, US Bipartican Policy Center, ARPA-E	USA

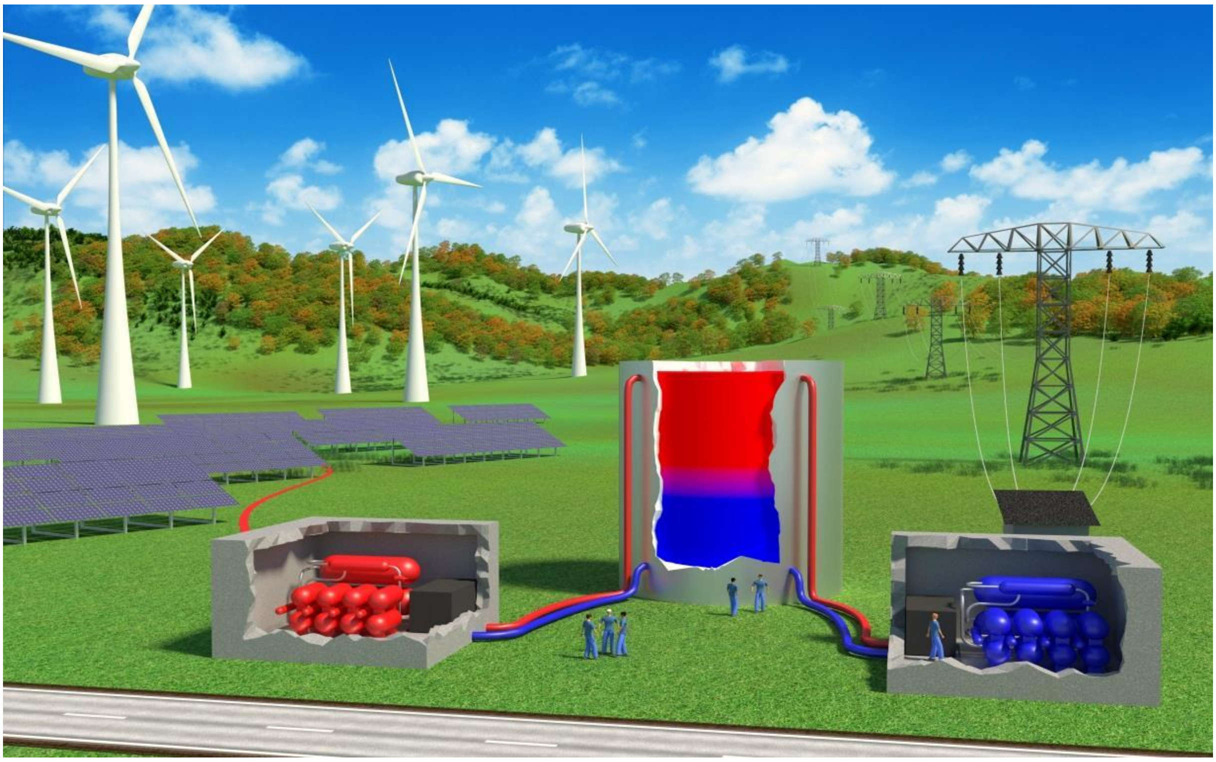
OVERVIEW OF SCOPE

Carnot batteries are an emerging technology for the inexpensive and site-independent storage of electrical energy at medium to large scale. Also referred to as "pumped thermal electricity storage" (PTES) or "pumped heat energy storage" (PHES), a Carnot battery transforms electricity into thermal energy, stores the thermal energy in inexpensive storage media such as 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.



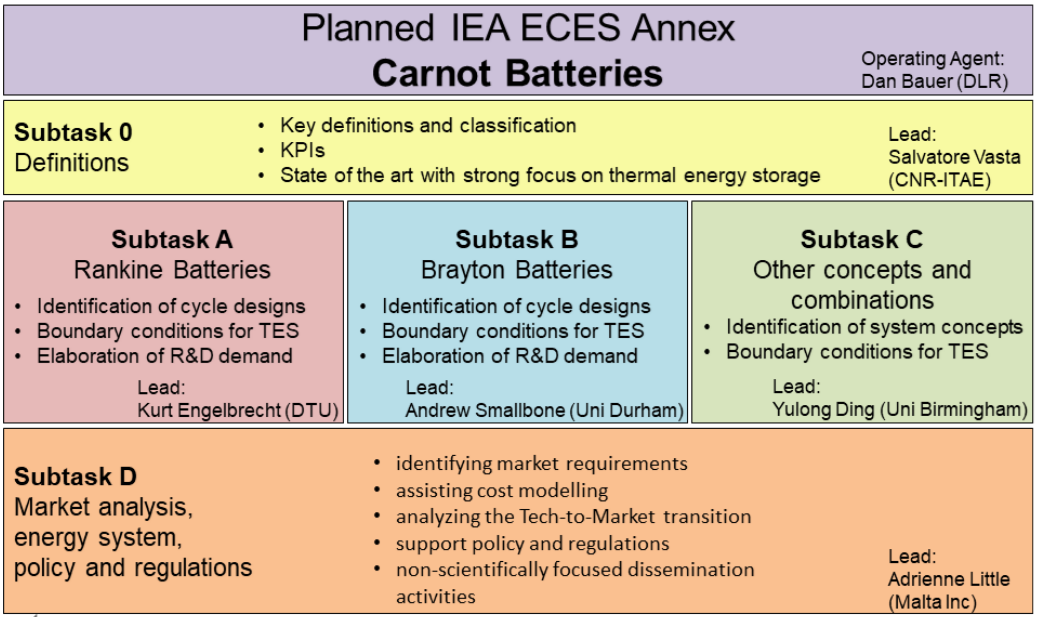
Graphical representation of a Carnot Battery installation

ACTIVITIES AND ACHIEVEMENTS

On May 10th , 2019 the 1st Pre-definition Workshop on Carnot batteries was held in Stuttgart Germany with the participation of about 40 attendees coming from Belgium, Denmark, France, Germany, Italy, Japan, the Netherlands, Sweden, UK and USA. Following presentations of potential contributions to Annex 36, the focus of the future work plan was discussed, namely the structure, objectives, scope and targeted results of the Annex 36. The work of this annex was clustered to be divided in six subtasks: (0) Definitions; (A) Rankine batteries; (B) Brayton batteries; (C) Other concepts and combinations; (D) Market analysis and energy systems; and (E) Cross-cutting issues. The summary of this pre-definition Workshop was presented to the ExCo Meeting in London, in May 2019, and received a positive feedback to continue with the pre-definition plan.

Annex 36 – Carnot Batteries - 1st Pre-definition Workshop in May 2019 at DLR-Stuttgart, Germany

Following with the pre-definition phase plan, on October 16th, 2019 the 2nd Pre-definition Workshop on Carnot batteries was held in Hamburg Germany, hosted by Siemens Gamesa RE with the participation of 35 attendees (due to room limit). At that time, Switzerland and South Korea confirmed their participation in this Annex in addition to the countries already named above. The new participants presented their current activities and projects, and their potential contributions were discussed. Furthermore, the previously proposed structure of the Annex was discussed, and the subtask (D) and (E) merged to form only one subtask (D) named "Market Analysis, Energy System, Policy and Regulations". Finally, the leaders of the subtasks were confirmed and the structure of the Annex agreed as follow:



Structure of the IEA Storage Annex 36 - Carnot Batteries

To close the 2nd Pre-definition workshop, a technical visit was arranged to the Siemens Gamesa ETES demonstration plant for all the attendees to this workshop.

ETES Demonstration plant - Siemens Gamesa RE In Hamburg, Germany

The results and material from the pre-definition phase were put together and a formal proposal was prepared and submitted to the ExCo for evaluation. Additionally, the summary and results of the 2nd pre-definition Workshop were presented to the ExCo at its meeting in Zurich in November 2019. At this meeting the Annex on Carnot batteries was officially approved to begin in January 2020.

The Annex 36 – "Carnot Batteries" Kick–off Workshop will be held in Birmingham, UK from March 25th–26th, 2020, followed by an industrial workshop on March 27th.

For more detailed information, please contact the Annex Manager Andrea Gutierrez at andrea.gutierrezrojas@dlr.de .