Carnot Batteries

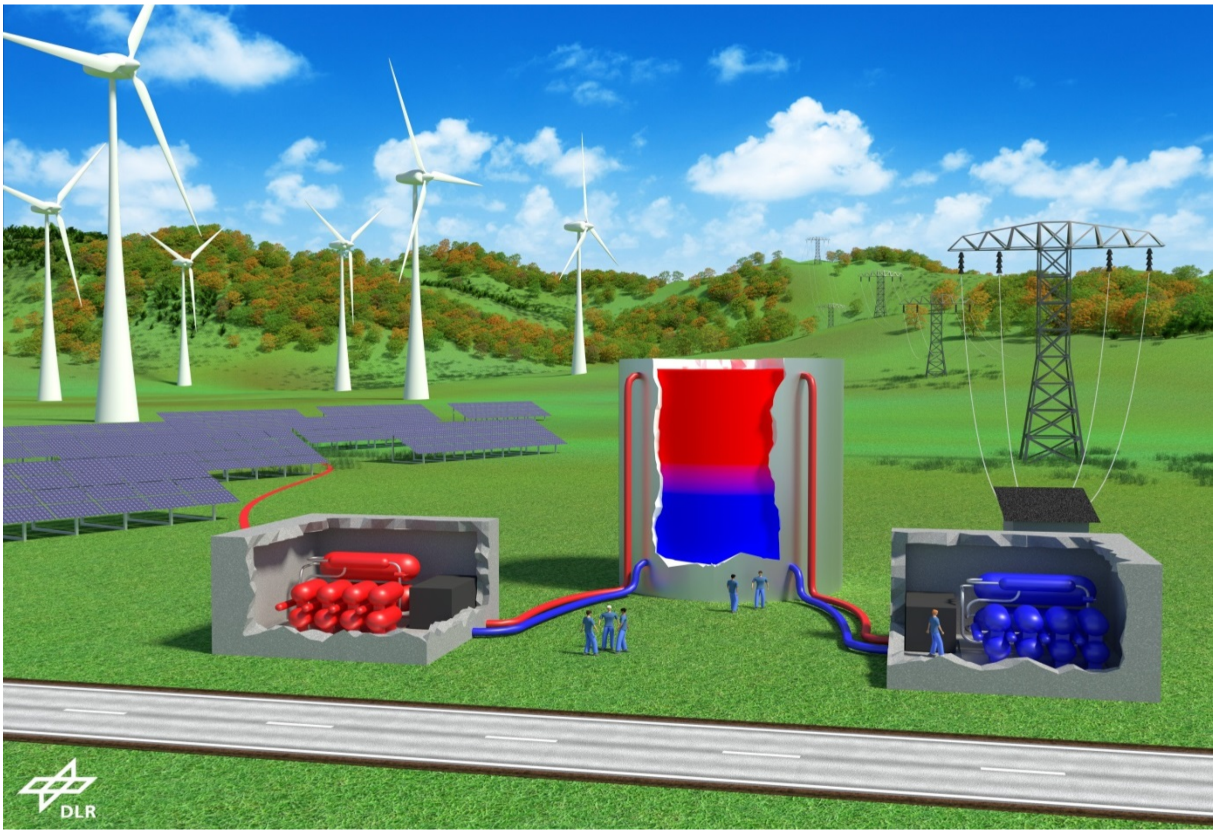
A new Annex proposal within the International Energy Agency (IEA) Energy Conservation through Energy Storage ECES TCP

Motivation

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

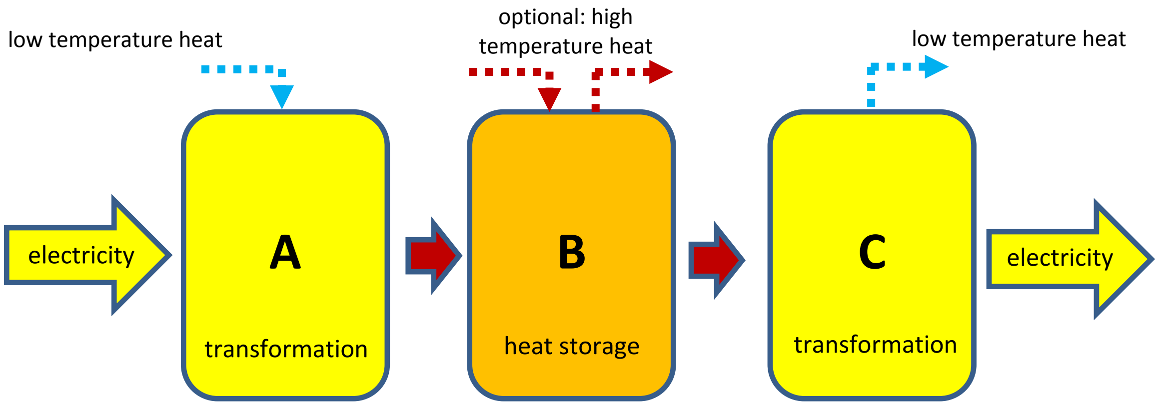
Reaching from a few megawatt hours up to the gigawatt hour scale, Carnot Batteries have the potential to solve the global storage problem of renewable electricity in a more economic and environmentally friendly way than conventional batteries. Although several concepts have been proposed for Carnot Batteries, there exists neither a comprehensive techno-economic assessment of this technology nor laboratory or plant-scale demonstration facilities that provide the energy storage community with scientific data.

So far, there is no international platform established that brings together experts from industry and academia in a structured way, assesses the state-of-the-art of R&D of Carnot Batteries, deepens the understanding of their possible role in the future energy system and makes it internationally visible.



Technological Concepts

The basic technological principle of a Carnot Battery is to transform (A) electricity into heat, store (B) the heat and transform (C) the heat back into electricity.



Existing R&D results show that (A), (B) and (C) must be very well matched to each other in order to reach high efficiencies. As plenty of technological possibilities exist, the proposed concepts are diverse, as are the targeted sizes and applications.

A transformation can be:

- a heat pump based on a Brayton cycle
- a heat pump based on a Rankine cycle
- another kind of heat pump
- direct resistance heating

B heat storage can be:

- molten salt storage
- latent heat storage
- regenerator storage
- a combination of different kinds of storage

C transformation can be:

- a Brayton cycle
- a Rankine cycle
- another kind of heat powered cycle

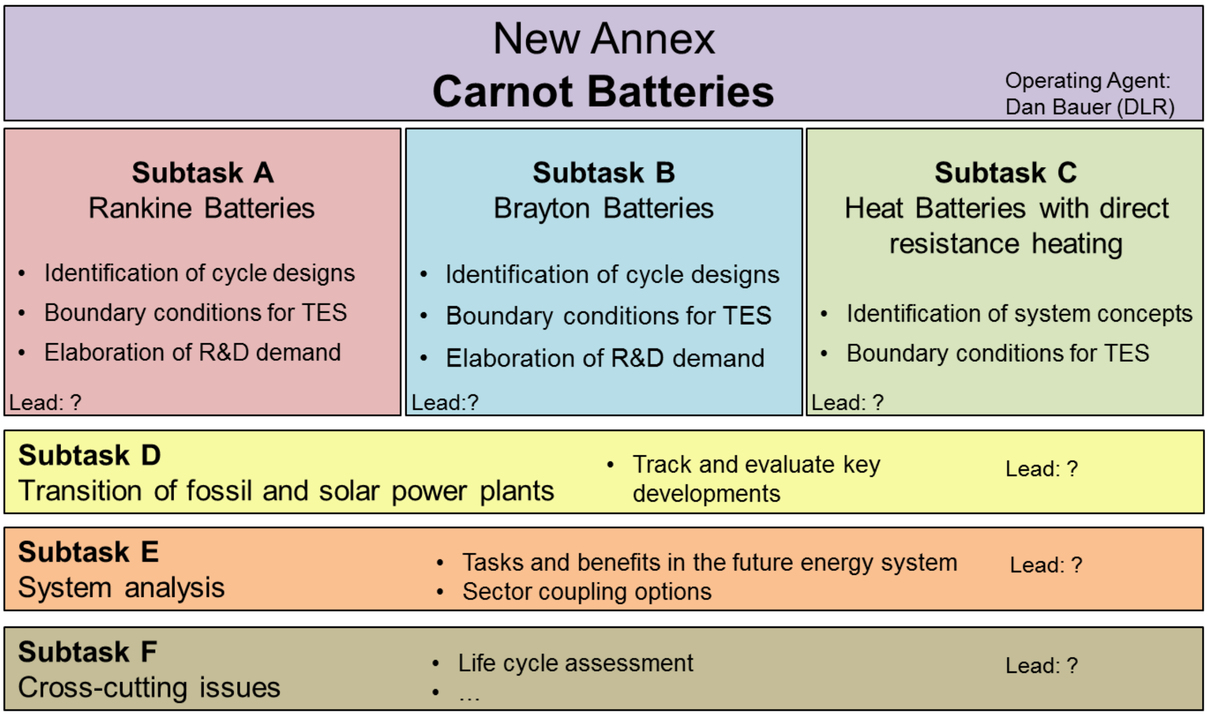
Low temperature heat as a heat source for (A) is needed in the case of (A) being a heat pump cycle. It can be heat from the environment, from cooling networks, waste heat or heat that is particularly produced to serve as a heat source, e.g. by solar thermal collectors. In the case of direct resistance heating, no low temperature heat source is needed. The reconversion (C) will always produce electricity and low temperature heat. This heat can either be released to the environment or produced at a useful level for heating purposes, e.g. in combination with district heating. High temperature heat might be additionally charged to or discharged from the heat storage. Overall, there is a strong possibility for sector coupling. Carnot Batteries are therefore a solution for electricity storage while increasing the share of renewables in the electricity and the heating sectors and providing flexibility to both of these sectors.

Structure of the Proposed Annex

The structure of the proposed Annex will be discussed during the task definition workshop based on the objectives. Some **key objectives** are:

- Identification and classification of the main Carnot Battery technologies
- Elaboration of R&D demand on the system and subsystem level (e.g. heat pump, thermal energy storage, heat powered cycle) and component level (e.g. compressors, heat exchangers)
- Clarify transition paths of existing technologies, in particular the transition of fossil and concentrating solar thermal power plants
- Description of the purposes and benefits of different kinds of Carnot Batteries in a future energy system
- Develop a common understanding of cross-cutting issues: legal issues, life cycle assessment, …

One possible Annex structure could therefore be as follows:



The **scope** of the Annex will be restricted to the conversion and storage of electricity in the form of thermal energy. Other technologies such as electrochemical and mechanical storage technologies are excluded.