

Energy storage in the OEO

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OEO DEV meeting 46

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The issues, the problems

Issues dealing with energy storage

- **energy storage** brakes monohierarchy [#1170](#)
- Relations of **hydro storage power plant** and **pumped hydro storage power plant** [#1174](#)
- Add thermal energy storages [#1261](#)
- Restructure energy storage and energy storage object [#1262](#)
- Add **tank** [#1301](#)

Relations of **hydro storage power plant** and **pumped hydro storage power plant #1174**

- **pump storage**: *A pumped storage (pumped-storage hydroelectricity) is an energy storage that uses water from a higher reservoir to generate energy.*
 - Label could be improved
 - The definition would also fit to **hydro storage power plant** (currently: *A hydro storage power plant is a hydro power plant that uses the available hydro energy of a stationary water storage.*)
- Why do we need the subclasses of **energy storage**? Do we need to replicate the technical details that are already covered by the objects?

energy storage brakes monohierarchy #1170

Definition: *Energy storage is a function of an artificial object that has been engineered to contain energy for conversion as usable energy later.*

- Problems:
 - Subclass of both **energy carrier disposition** and **function**
 - Unused: no class has an axiom **'has function' some 'energy storage'**
- Option 1: Leave as it is, but add an editor note
- Option 2: Create mono-hierarchy with a general class axiom:
'material entity' and ('bearer of' some 'energy storage') SubClassOf 'has disposition' some 'energy carrier disposition'
- Option 3: Add axiom: **'energy storage object' 'has disposition' some 'energy carrier disposition'** (depends on #1262)

Restructure energy storage and energy storage object #1262 (part 1)

- Problem: No clear distinction between subclasses of **energy storage** and subclasses of **energy storage object**
 - Proposals in #1262: Include conversion processes in the definition
 - **electrochemical energy storage**: *An electrochemical storage is an energy storage that uses an electrochemical reaction to store energy.*
 - **chemical conversion storage**: *A chemical conversion storage is an energy storage that uses chemical conversion to convert one matter that is hard to store to another that is easier to store.*
 - **thermo-chemical heat storage**: *A thermo-chemical heat storage is an energy storage that uses reversible chemical reactions with thermo-chemical materials (TCM) to store thermal energy.*
 - ...
 - OEO dev meeting 43: Structure **energy storage** by type of energy
 - **chemical energy storage**: *A chemical energy storage is an energy storage with chemical energy as input and output.*
 - **electrical energy storage**: *An electrical energy storage is an energy storage with electrical energy as input and output.*
 - **kinetical energy storage**: *A kinetical energy storage is an energy storage with kinetical energy as input and output.*
 - **potential energy storage**: *A potential energy storage is an energy storage with potential energy as input and output.*
 - Align **thermal energy storage**: *A thermal energy storage is an energy storage with thermal energy as input and output.*

Restructure energy storage and energy storage object #1262 (part 2)

- Improve definition of **energy storage**: *Energy storage is a function of an artificial object that has been engineered to contain energy for later usage whereby input energy and usable output energy are of the same type.*



- Energy storage (function) shows what energy goes in and out
- Artificial object defines what happens inside (=> black box for the energy storage function)
- This makes a nice distinction to **energy carrier disposition**: *An energy carrier disposition is a disposition of an material entity that contains energy for conversion as usable energy.*
- How to do describe, in which form the energy is stored in the energy storage object?
 - Proposal: use **'bearer of' some energy** axioms

Add thermal energy storages #1261

- A **thermo-chemical heat storage** is a thermal energy storage object that stores thermal energy through reversible exotherm/endothrm chemical reaction with thermo-chemical materials (TCM).
 - A **chemical heat storage** is a thermo-chemical heat storage that stores thermal energy by using the chemical binding energy in an endotherm reaction
 - A **sorption heat storage** is a thermo-chemical heat storage that stores thermal energy by using desorption.
- A **sensible heat storage** is a thermal energy storage object that stores thermal energy through temperature changes in some medium.
 - A **sensible fluid heat storage** is a sensible heat storage that uses fluids (like water, oil, ...) to store thermal energy.
 - A **sensible solid heat storage** is a sensible heat storage that uses solid materials (like bulk goods, powder, ...) to store thermal energy.
- A **latent heat storage** is a thermal energy storage object that stores thermal energy through phase transitions in phase-change materials (PCM).
 - A **latent solid-fluid heat storage** is a latent heat storage that stores thermal energy by converting solid materials to their liquid equivalent i.e. melting the material.
 - A **latent fluid-gaseous heat storage** is a latent heat storage that stores thermal energy by converting liquid materials to their gaseous equivalent i.e. evaporating the material.

Add tank #1301

- **tank**: *A tank is an artificial object that stores a liquid or gaseous portion of matter.*
- **fuel tank**: *A fuel tank is a tank that stores a fuel.*
- Axiom: **'fuel tank' 'has function' some 'energy storage'**

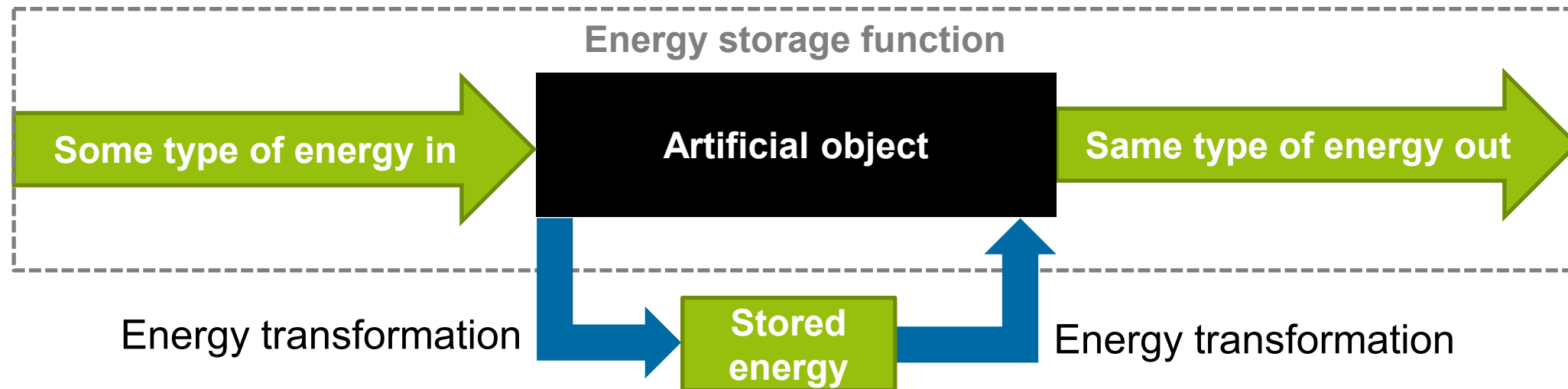
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Some proposals

- partly from the issue discussion
- partly from ideas I got, reading all relevant issues together

Definition energy storage

- Improve definition of **energy storage**: *Energy storage is a function of an artificial object that has been engineered to contain energy for later usage whereby input energy and usable output energy are of the same type.*



- The artificial object participates in one or more energy transformation
 → The energy transformations describe, how the energy is stored.
- Add axiom: **‘energy storage’ ‘has bearer’ some ‘artificial object’**

Subclasses of energy storage and labels

- Problem: No clear distinction between subclasses of **energy storage** and subclasses of **energy storage object**
 - Proposal: Clarify distinction by re-labeling **energy storage** including subclasses:
 - **energy storage function**: *An energy storage function is a function of an artificial object that has been engineered to contain energy for conversion as usable energy later.*
 - **chemical energy storage function**: *A chemical energy storage function is an energy storage function with chemical energy as input and output.*
 - **electrical energy storage function**: *An electrical energy storage function is an energy storage function with electrical energy as input and output.*
 - **kinetical energy storage function**: *A kinetical energy storage function is an energy storage function with kinetical energy as input and output.*
 - **potential energy storage function**: *A potential energy storage function is an energy storage function with potential energy as input and output.*
 - **thermal energy storage function**: *A thermal energy storage function is an energy storage function with thermal energy as input and output.*

Energy storage and energy storage object

- Monohierarchy problem:
 - ~~Option 1: Leave as it is, but add an editor note => worst option~~
 - Option 2: Create mono-hierarchy with a general class axiom:
'material entity' and ('bearer of' some 'energy storage function') SubClassOf 'has disposition' some 'energy carrier disposition'
 - Option 3: Add axiom: **'energy storage object' 'has disposition' some 'energy carrier disposition'**

- In all cases: Make **energy storage object** an equivalent class:
'energy storage object' EquivalentTo: 'artificial object' and ('has function' some 'energy storage function')

Proposals: battery

- **battery storage**: *A battery storage is a energy storage that uses batteries to store energy.*
- **battery**: *A battery is an energy storage object using different chemical or physical reactions to store energy.*
- Proposal:
 - Delete **battery storage**
 - Add axioms:
 - **battery ‘bearer of’ some ‘chemical energy’**
 - **battery ‘has energy input’ some ‘electrical energy’**
 - **battery ‘has energy input’ some ‘electrical energy’**
 - **battery ‘has function’ some ‘electrical energy storage’**
 - **battery ‘participates in’ some ‘electrochemical reaction’**

Proposals: power-to-gas and power-to-liquid (1/2)

- **methanation gas storage:** *A methanation gas storage is a energy storage that uses carbon dioxide and hydrogen from electrolysis to produce methan and store this. The methan can then be used to produce electricity or heat in a gas generator.*
 - Problems: a) describes more the object and the process than the function; b) too many things in the definition;
 - Proposal: Make subclass of **power to gas system** (*A power-to-gas system is an energy transformation unit that implements a power-to-gas process. A water electrolyser is participating in the power-to-gas process.*)
 - New definition: *A power-to-methane system is a power-to-gas system that implements the power-to-methane process.*
 - **Power-to-methane process:** *A power-to-methane process is a power-to-gas process that has water and carbon dioxide as physical input and synthetic methane carrying chemical energy as physical output. It consists of two sub processes: an electrolysis process and a methanation.*

Proposals: power-to-gas and power-to-liquid (2/2)

- **power-to-liquid system:** *A power-to-liquid (often abbreviated P2L or PtL) system is an energy storage object that converts electrical power to a liquid fuel.*
 - Proposal: align with **power-to-gas system**
 - New definition: *A power-to-liquid system is an energy transformation unit that implements a power-to-liquid process. A water electrolyser is participating in the power-to-liquid process.*

Proposals: power-to-gas and power-to-liquid (2/2)

- **underground hydrogen storage**: *An underground hydrogen storage is an energy storage object that stores hydrogen underground. Examples are underground caverns, salt domes and depleted oil/gas fields.*
 - Proposal add intermediary class **underground fuel storage (object?)**: *An underground fuel storage (object?) is an energy storage object that stores chemical energy in form of fuels underground.*
 - Add axiom: ‘**underground storage (object?)**’ ‘has function’ some ‘**chemical energy storage**’
 - Proposal: *An underground hydrogen storage (object?) is an underground fuel storage object that stores hydrogen. Examples are underground caverns, salt domes and depleted oil/gas field.*
 - This allows further underground fuel storage objects like underground oil storage objects or underground natural gas / methane storage objects.

Proposals: pumped hydro

- Related classes:
 - **pumped hydro storage power plant**: *A pumped hydro storage power plant is a hydro storage power plant which has some pumps as parts.*
 - **pumped water**: *Pumped water is liquid water which was pumped into an upper reservoir and thus contains potential energy.*
 - **pumped storage**: *A pumped storage (pumped-storage hdyroelectricity) is an energy storage that uses water from a higher reservoir to generate energy.*
- Proposal:
 - Delete **pumped storage**
 - Extend definition of pumped hydro storage power plant: *A pumped hydro storage power plant is a hydro storage power plant which has some pumps **and some reservoirs** as parts.*
 - Add axiom: **‘pumped hydro storage power plant’ ‘has function’ some ‘electrical energy storage function’**
 - Add axiom: **‘pumped water’ ‘bearer of’ some ‘potential energy’**

Proposals: SMES

- **SMES**: *Superconducting magnetic energy storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature. A typical smes system includes three parts: superconducting coil, power conditioning system and cryogenically cooled refrigerator. Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely.*
 - Proposal:
 - Add axiom **SMES ‘has function’ some ‘electrical energy storage function’**
 - Can stay an energy storage object, but open separate issue for improving this class
 - » Potentially something like **‘magnetic field’ bearer of’ some energy ...**

Proposals: thermal energy storage objects

- Current pattern: *A X heat storage is a thermal energy storage object that Y...*
- Add axioms like **'chemical heat storage object'** **'bearer of some'** **'chemical energy'**
- Related to [#1303](#) that defines the processes like **adsorption** or **phase transition**
- Discuss details in the issue or in one of the next OEO DEV meetings

Proposals: tank

- **tank:** *A tank is an artificial object that stores a liquid or gaseous portion of matter.*
- **fuel tank:** *A fuel tank is a tank that stores a fuel.*
- Axiom: **'fuel tank' 'has function' some 'chemical energy storage function'**
- Proposal: No further problems, move forward in the issue

Let's discuss!

