Czech-Austrian Spring and Summer School

The relevance and costs of short vs long-term storage

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Structure of the presentation

- Motivation – the relevance of energy storage
- State of art in CZE and AUS
- Long-term and short-term storage
- Examined storage technologies
- Method of aproach
- Results
- Conclution

Motivation – the relevance of storage

- Due to climate change there is a need for deployment of renewable energy resources
- Renewable resources are mostly intermittent – there is a need for energy storage
- Energy storage can be useful in:
  - Stabilization of power grid and ensuring its safe operation
  - Lowering the energy losses in power grid
  - Saving energy in times of surplus generation for later use

State of art

- Both Austria and Czech Republic mainly Pumped Hydro Storage, only starting with the instalations of Li-ion batteries
- Austria – 6358 MW installed in PHS, 2,5 MW in Li-ion batteries
- Czech Republic – 1175 MW installed in PHS, 3 MW in Li-ion batteries

Long-term and short-term energy storage

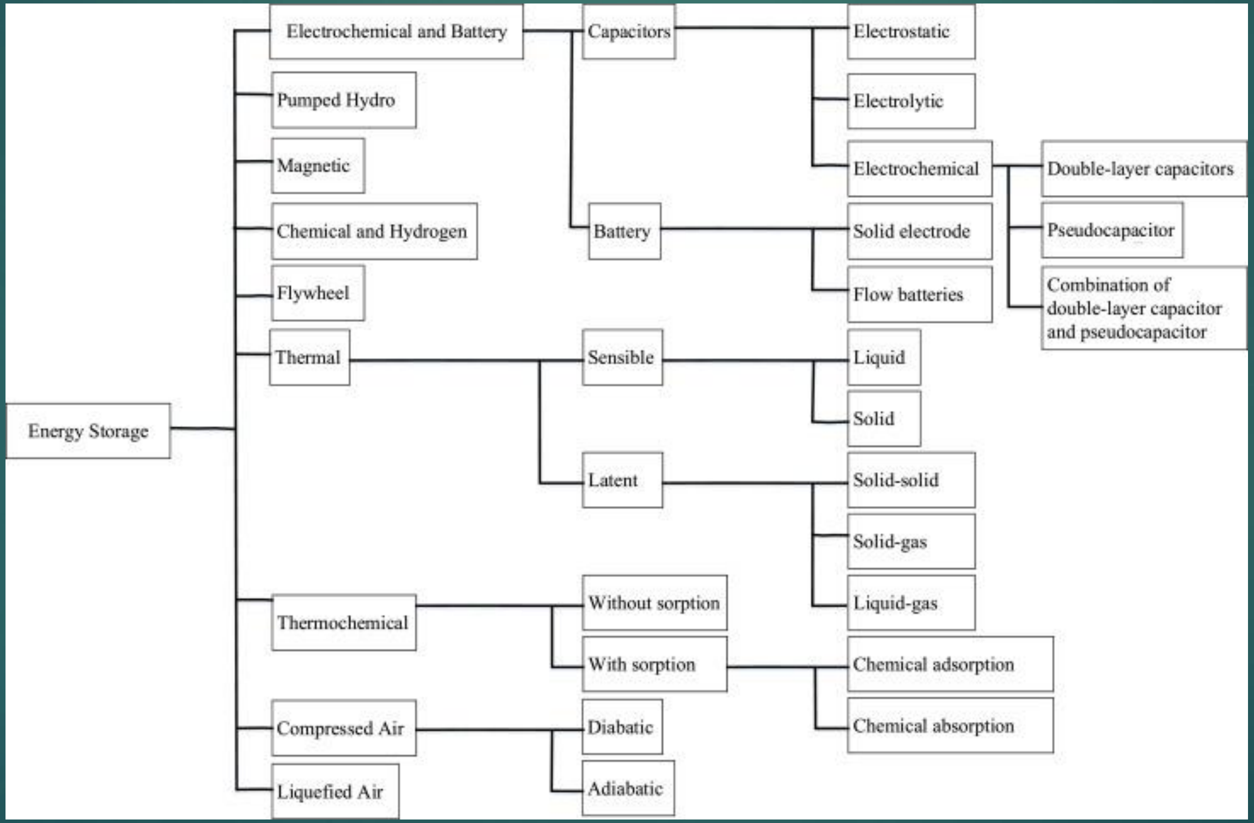
Short-term energy storage

- Used for power grid stabilization
- Ensures power quality (voltage and frequency) is remained
- Very short response time – miliseconds
- Can operate for shorter time than long-term storage (minutes to hours)

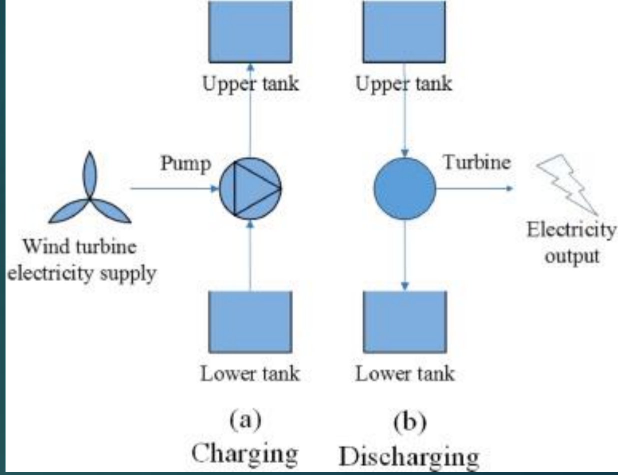
Long-term energy storage

- Used in times of peak demand, when there is not enough energy supply
- Can opperate for few hours and supply electrical energy to the grid

Energy storage technology



Examined storage technologies



Short-term energy storage

- **Flywheel** – transfers kinetic energy in and out with electric machine, efficient but expensive
- **Ultracapacitor** – „big“ capacitors storing energy, longer life cycle than batteries but again very costly
- **Li-ion batteries** – store electrical energy electrochemically, high energy density and efficiency among the batteries

Long-term energy storage

- **Pumped Hydro Storage** – uses hydraulic potential energy of water, high investment cost, it is difficult to make them commercially and socially acceptable
- **Compressed Air Energy Storage -** stores compressed air in an abandoned mine, a drilled cavern or a steel tank, efficieny is variable and there are safety issues

Method of approach

- $C_{total} = Cpcs + Cbop + Csto \times t$
- $Clcc = Ccap, a + CO\&M, a + Cr, a + Cdr, a$
- Ccap, a= $Ctotal * \alpha$
- $\alpha = \frac{i(1+i)^T}{(1+i)^T - 1}$
- $CO\&M, a = Cf, a + Cv, a * t$
- $Cr, a = \alpha * \sum_{k=1}^{r} (1+i)^{-kp} * \frac{Cr * t}{\eta s}$
- $Cdr, a = Cdr * \frac{i}{(1+i)^T - 1}$

Levelized costs of storage

- $$Cs = \frac{\frac{C_{total}{}_{*}\alpha + CO\&M}{T} + Ce}{\eta s} = \frac{\frac{Ccap,a + CO\&M,a}{T} + Ce}{\eta s} = \frac{Clcc}{T\eta s} + \frac{Ce}{\eta s} = Clcoe + \frac{Ce}{\eta s} = Clcos$$
- *Cs = storage costs*
- *Ce=energy costs, electricity price*
- *Clcoe=levelized cost of electricity*
- *Clcos= levelized cost of storage*
- *T= full load hours*
- *ηs= efficiency of storage*

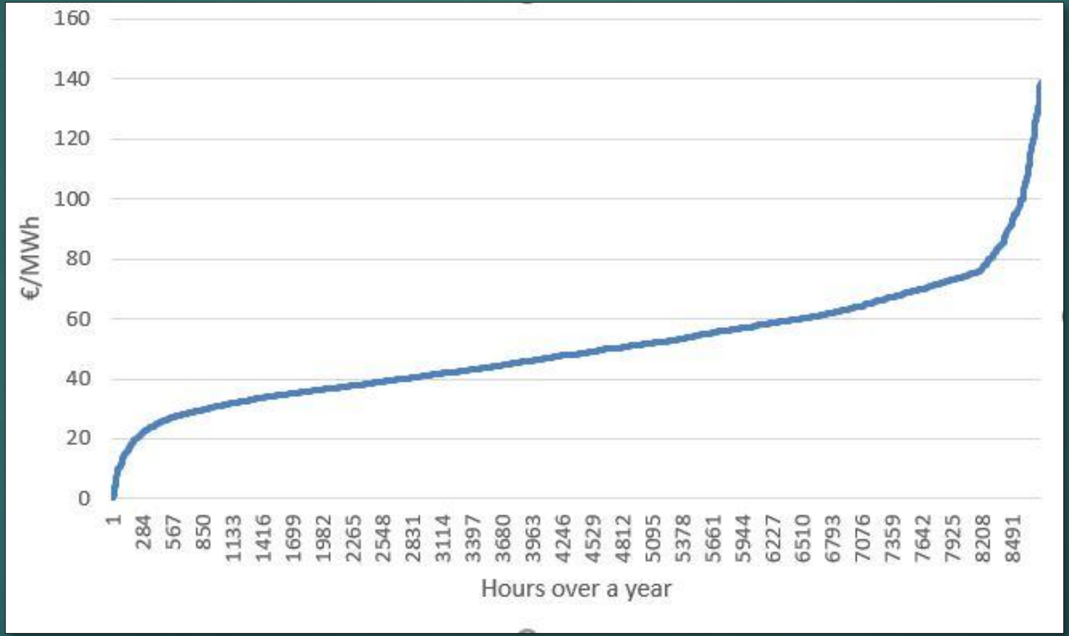
Input parameters for different short and long- term storage technologies

	PHS	CAES	Flywheel	Ultracapcitor	Lithium- ion battery
Capital costs €/kWh	2,190	1,385	1,992	332	225
Power conversion system PCS €/kW	included in Capital Costs		included in Capital Costs	290.5	239.04
Balance of Plant BOP €/kW				83	83
Construct and Commissionig €/kWh			398.4	66.4	83.83
Total Costs €/kW	2,190	1,385	2,390	772	1,557
Total Costs €/kWh	137	87	9,562	61,818	389
O&M Fixed €/kW-year	13.20	13.86	4.65	0.83	0.0249
O&M Variable (cents/kWh)	0.0002075	0.1743	0.0249	0.0249	0.0249
Round- Trip efficiency %	0.8	0.52	0.86	0.92	0.86
Cycles at 80% DoD	15,000	10,000	200,000	1,000,000	3,500
Calendar Life	50	25	>20	16	10
Energy/power ration	16	16	0.25	0.0125	4

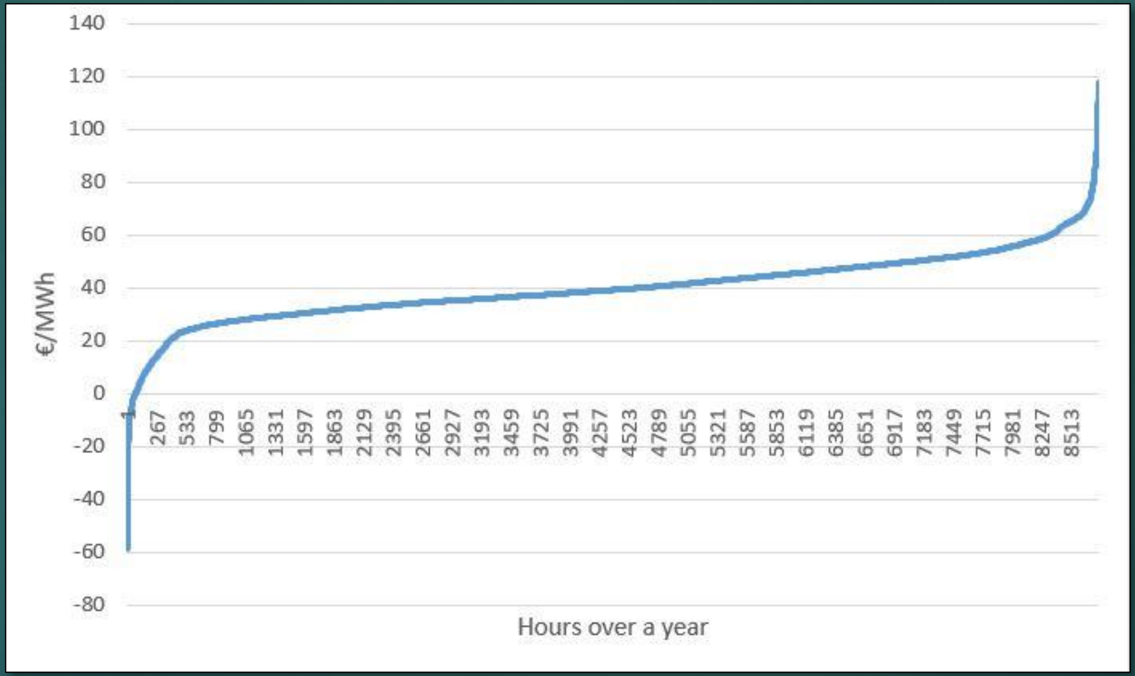
Results

	PHS	CAES	Flywheel	Ultracapcitor	Lithium- ion battery
Capital recovery factor	0.1009	0.1102	0.1175	0.1278	0.1627
Capital costs €/kW	220.84	152.61	280.78	98.66	253.41
Capital costs €/kWh	13.81	9.60	1123.10	7901.42	63.35
Life cycle costs €/kW	234.03	166.50	285.42	99.49	253.43
FULL load hours	5,840	5,840	91	5	1,460
Levelized cost of electricity €/MWh	40.07	28.51	3127.93	21806.39	173.58
Electricity market price €/MWh Hudex 2019.			50.36		
Electricity market price €/MWh Epex 2019.			40.06		
Levelized cost of storage for Czech Republic market €/MWh	113.04	151.67	3695.69	23757.34	260.40
Levelized cost of storage for Austria market €/MWh	100.17	131.87	3683.71	23746.14	248.42

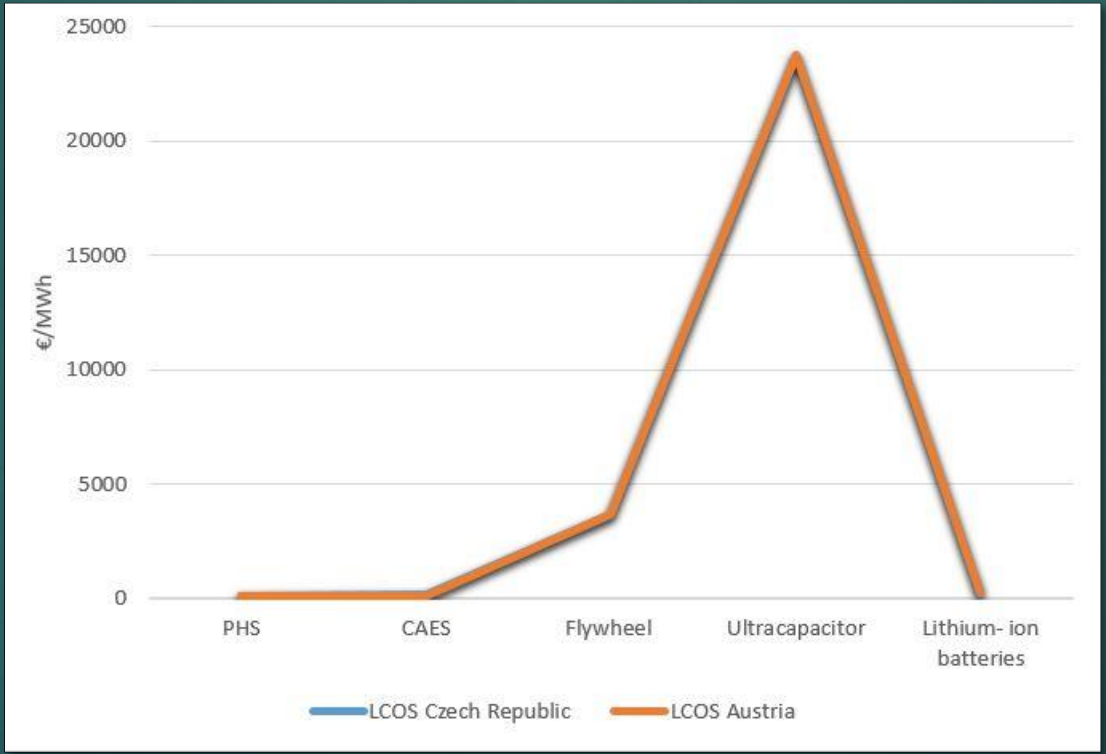
Electricity market Hudex hourly prices



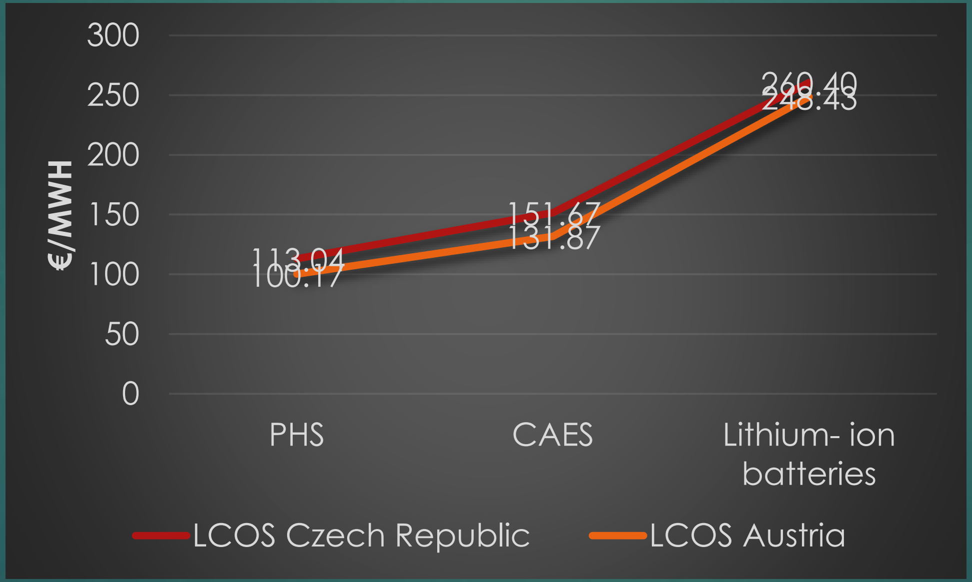
Electricity market Epex hourly prices



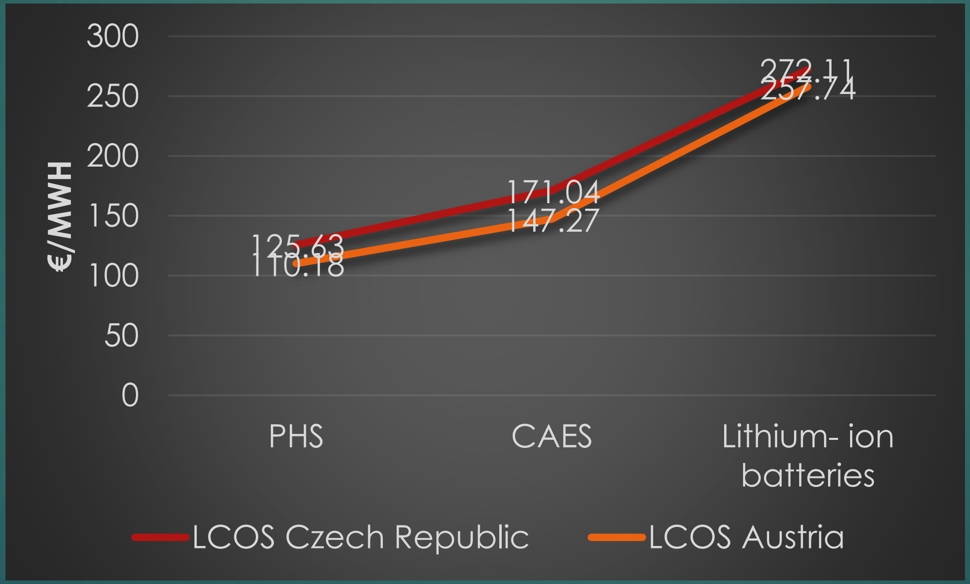
Levelized costs of storage for Hudex and EPEX market price



Levelized cost of storage for most cost-effective short and long-term technologies



Sensitivity analysis of levelized cost of storage for different short and long-term technologies



Conclusion I.

- Investments in energy storage systems are going to increase
- Advantages: stability and safe operation of the interconnected electricity grids
- Usage for RES integration : load levelling, frequency regulation, voltage support and black start.
- Optimisation of the transmission and distribution of electricity, lower grid losses.
- Challenge: enough energy according to demand.
- Long-term energy storage systems supply electrical energy in the time of peak demand or when demand overcomes supply.
- Why: achieving carbon-neutral EU and other goals for the years 2030 and 2050

Conclusion II.

- PHS the most cost- effective technology with 113 €/MWh levelized cost of storage, followed by compressed air storage with 152 €/MWh.
- Short- term energy storage : Lithium- ion batteries are leading with costs of 260 €/MWh
- If market prices increase, levelized cost of energy storage would increase as well.
- Austria has desirable geographical position, has pumped hydro storage installed, should invest more in batteries.
- Czech Republic, should invest more in energy storage
- Firstly, investments will be in the most cost-efficient short and long-term energy storage technologies, but others will follow as well.
- Future work would likely cover other calculation for other energy storage technologies.

Thank you for your attention!