Electricity Transmission and Distribution 2: Thermal and electrical energy storage

IEA-RSA Bilateral Event

Electricity Transmission and Distribution, Smart Cities

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Energy Storage Implementing Agreement

Introduction

- Properties of and Energy Storage System
  - Storage Capacity (kWh/kg, kWh, m^3)
    - **Phys. / Chem. Effect, Storage Material, Boundary Conditions**
  - Charging / Discharging Power (W/kg, W/m^3)
    - **Mass and Heat Transfer, Storage Engineering**
  - Storage Efficiency
    - **Losses (Storage Period, Transformations)**
  - Storage Period (Time)
    - **Hours, Days, Months, Year**
  - Cost (€/kWh, €/W)
    - **Investment, Number of Storage Cycles**

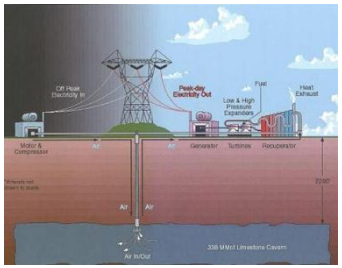
Electrical energy storage technologies

- Storage of Electrical Energy


- Storage of Electro-chemical Energy

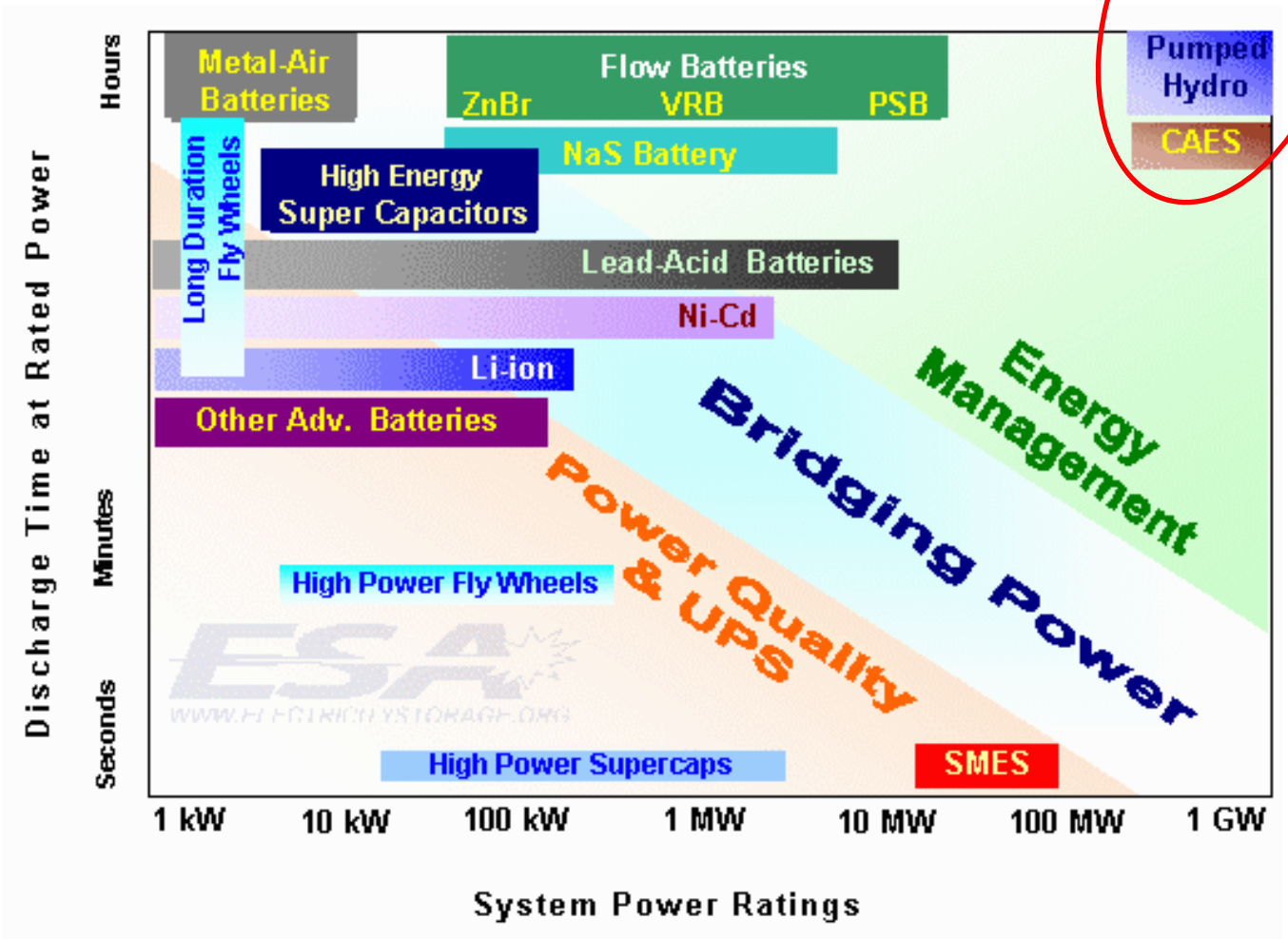


- Storage of Mechanical Energy

Electrical energy storage technologies

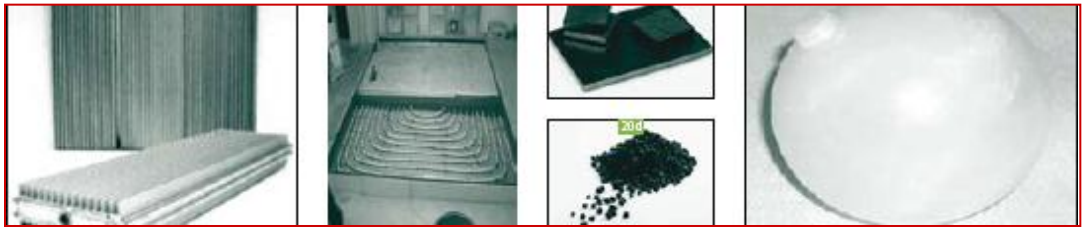
- Storage Period and Discharging Power



Thermal energy storage technologies

- Thermal energy can be stored as sensible heat

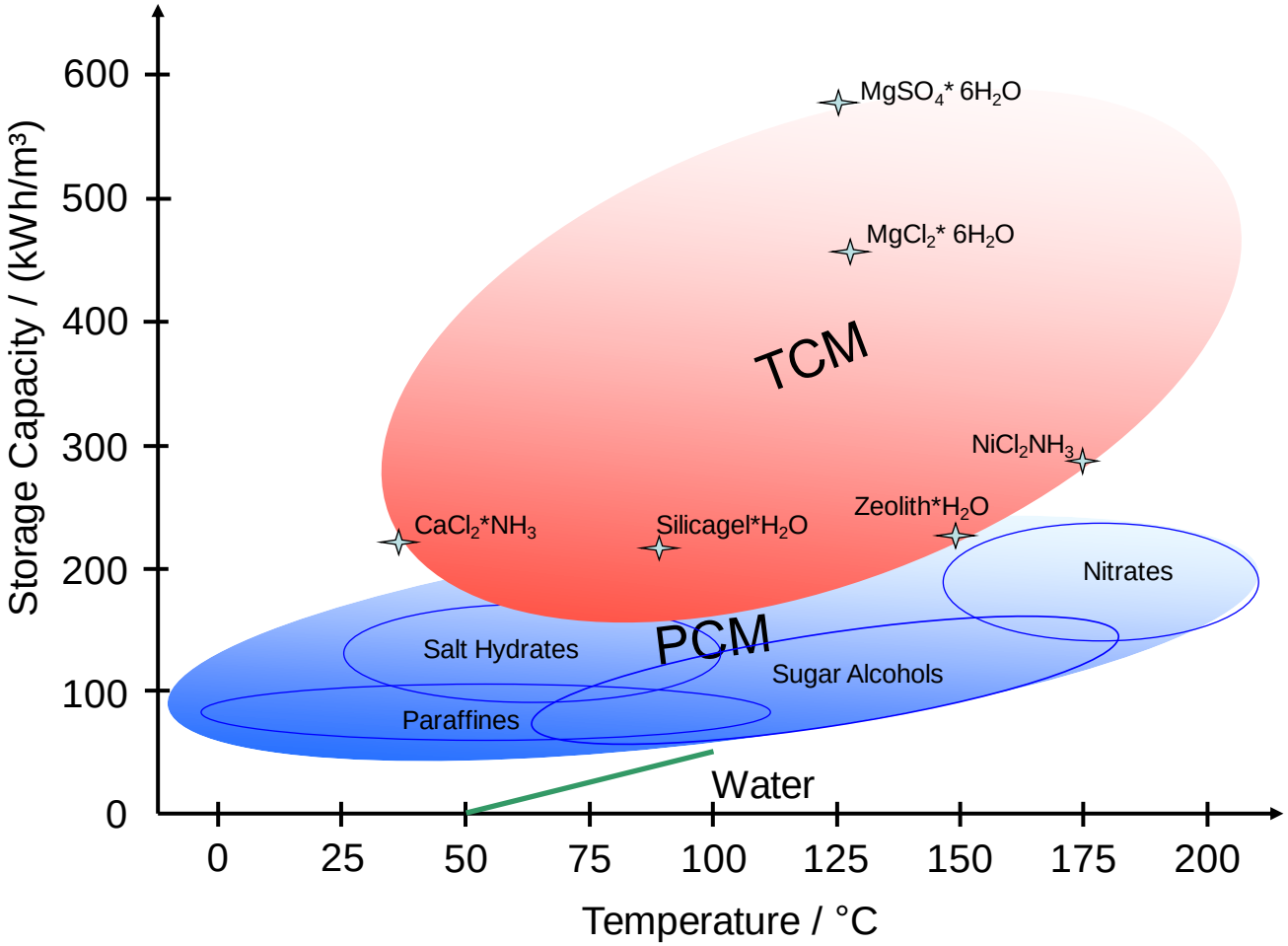
- Thermal energy can be stored as latent heat



- Thermal energy can be stored thermo-chemically

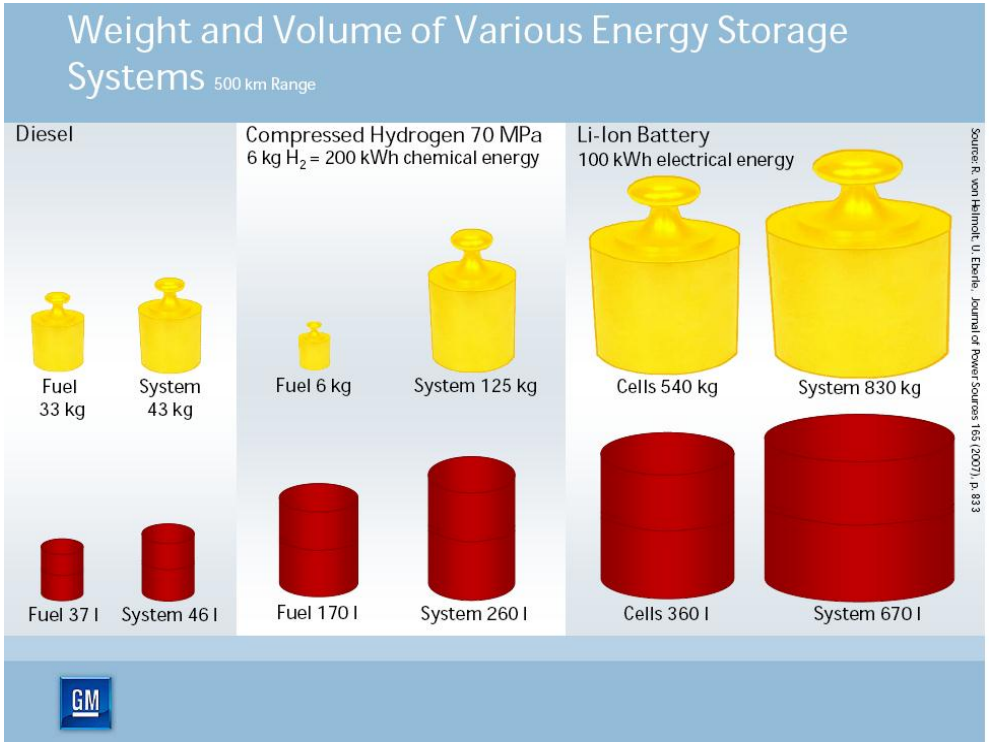
Thermal energy storage technologies

- Storage capacity vs. Temperature



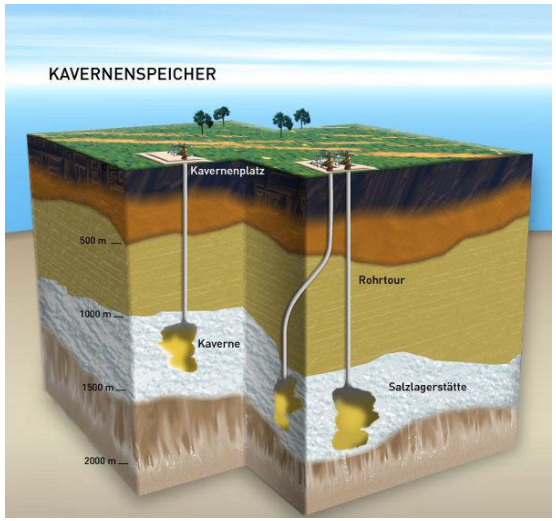
Chemical energy storage

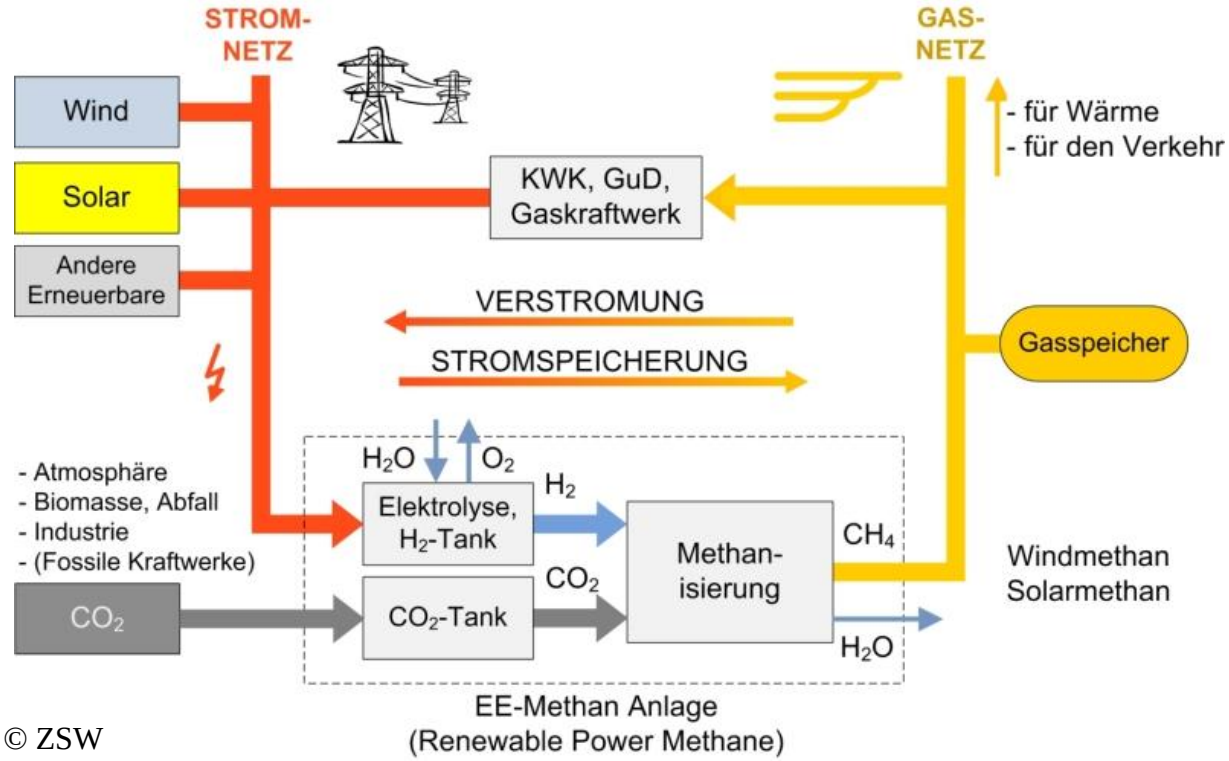
- Energy Storage by Hydrogen Production and Storage
  - Hydrogen is the most powerful fuel with regard to its mass
  - Loss-free long-term storage is possible
  - Electricity production by fuel cells



Chemical energy storage

- Energy Storage by Methane Production and Storage
  - Methane from Hydrogen (and CO2)
  - Efficiency >80 % (Sabatier-Process)
  - Existing Infrastructure (natural gas)





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Comparison: Energy Storage Technologies

Storage Technologies	Capacity kWh/t	Power MW	Efficiency	Storage Time	Cost €-cent/kWh
Mechanical					
Pumped Hydro	1	1-1500	70-80%	day - month	8-14
Flywheel	5-100	1-100	90%	hour	300-500
CAES	2 kWh/m³	300	40-70%	day	13-27
Electro-chemical					
Lead-Acid	40		85%	day - month	28-37
Li-ion bat.	130	0.02 - ?	90%	day - month	57-140
NaS bat.	110	0.05	85%	day	31-43
Redox-Flow bat.	25	0 10	75%	day - month	20-30
SMES	3	10	95%	hour - day	~10000
Supercaps	5	0. - 1	95%	hour - day	~10000
Thermal					
Hot Water	10-50	0.001 - 10	50-90%	day - year	0.01
PCM	50-150	0.001 - 1	75-90%	hour - week	1-5
Chemical Reactions	120-250	0.01 - 1	100%	hour - day	0.8-4
Chemical					
Hydrogen	2,8 kWh/m³	0.001 - 1	28-50%	day - year	19-50
Methane	10,2 kWh/m³	0.01 -200	24-42%	day - year	12-34

Comparison: Energy Storage Technologies

- A complex matter:
  - Seasonal storage – Long-term Storage of PV (Summer to Winter)

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Pumped Hydro	1	1-1500	70-80%	day - month	8-14
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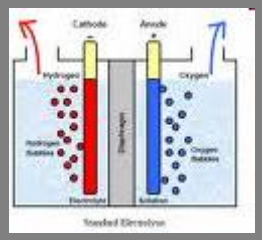
Comparison: Energy Storage Technologies

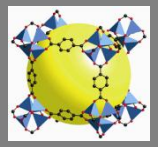
- A complex matter:
  - Seasonal storage

Hydrogen:

Fuel: **Overall Efficiency 50%**
Electricity (Fuel Cell): **Overall Efficiency 30 %**
Heating: **Overall Efficiency 50 %**





Total

~ 51%

Efficiency:	**Electrolysis**	**Compression**	**Transport**	**Storage**
	~ 70 %	**~ 90 %**	**~ 90 %**	**~ 90 %**

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Comparison: Energy Storage Technologies

- A complex matter:
  - Seasonal storage

Fuel: **not possible!**
Electricity: **not possible!**
Heating: **Overall Efficiency 225 %**

Hot Water:

Efficiency: **Heat Pump** **Storage**

~ 300 % **~ 75 %**

Total

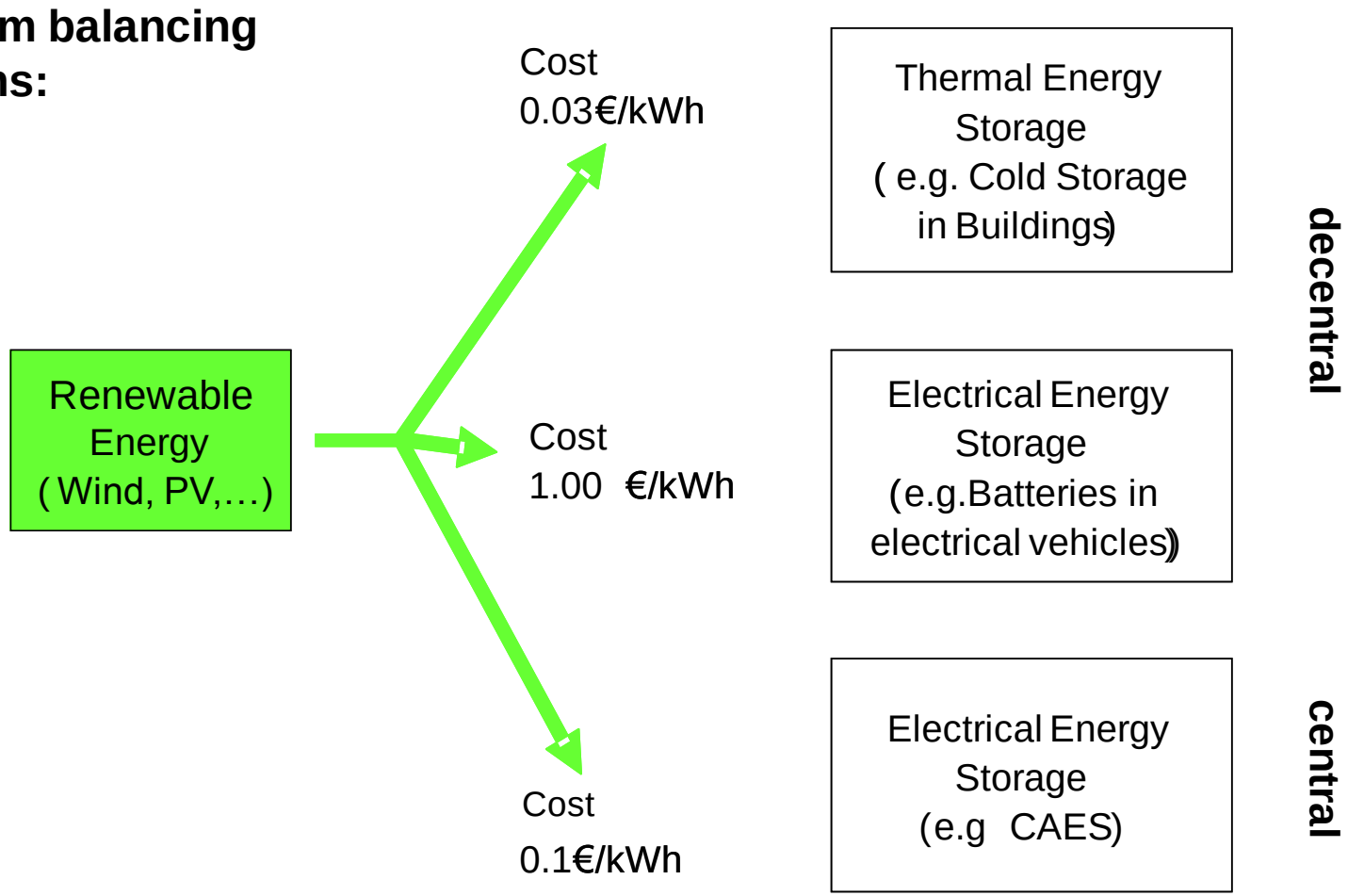
~ 225%

Comparison: Energy Storage Technologies

- A complex matter:
  - Important:
    - Look at the whole efficiency chain
    - Take the final energy demand into account
    - Try to identify the most suitable technology for the application

Thermal Energy Storage for Electricity Storage?

- Application: Integration of Wind Energy



Thermal Energy Storage for Electricity Storage?

- Application: Integration of Wind Energy
  - Storing Wing Electricity in Fridges
    - 20 Million Fridges (<50% of German Households)
    - PCM Cold Storage for 12 hours
    - Charging Time 3 hours
    - Cost 5 €

Electric Power **1.15 GW**
Storage Capacity **3.5 GWh**
Economics **> 120 Cycles/Year**

Economical Limits

- Example: Thermal Energy Storage
  - Storage capacity = 100 kWh
  - Price for thermal energy = 0.05 €/kWh
  - Return on invest = 5 years

Storage Technologies	Capacity kWh/t
Thermal	
Hot Water	10-50
PCM	50-150
Chemical Reactions	120-250

Economy Depending on the Number of Storage cycles

	Cycles per Year	Cycles 5 Years	Total Energy Savings kWh	Savings €	Specific Invest Cost €/kWh	Simplified Cost Model (Capital + Operation) €/kWh
Seasonal Storage	1	5	500	25	**0,25**	**0,18**
Daily Storage	300	1.500	150.000	7.500	**75**	**54**
Short Term Storage 3 Cycles per Day	900	4.500	450.000	22.500	**225**	**160**
Buffer Storage 10 Cycles per Day	3.000	15.000	1.500.000	75.000	**750**	**540**

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Commercial Issues and Barriers

- Absence of (defined) market/competitive product
- Limited presence of corporate vendors
- Limited understanding of applications & benefits
- Position/competitiveness, relative to conventional network solutions
- Financing/resourcing RD&D programmes

Conclusions

- The optimal energy storage technology has to be identified for the actual application:
  - Energy storage provides the energy form needed
    - Electricity – Heat/Cold – Fuel
  - Efficiency has to be evaluated over the complete storage process (from charging to utilization
  - Economical boundary conditions have to be taken into account

The diversity of possible energy storage solutions enables a high stability of future energy systems

Thank you for your attention

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