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Storage Technology Issues and Opportunities

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CERT Energy Storage Workshop, February 15 2011, Paris

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„Forum on Energy Storage“ Workshops 2009 & 2010

- Solar Heating and Cooling (SHC)
- Buildings and Community Systems (ECBCS)
- Energy Conservation through Energy Storage (ECES)
- Electricity Networks Analysis, R&D (ENARD)
- Heat Pump Programme
- High Temperature Superconductors (HTS)
- Hydrogen (HIA)
- Solar Power and Chemical Energy Systems (SolarPACES)
- Advanced Fuel Cells (AFC)
- ETSAP

- Ocean Energy Systems (OES)
- District Heating and Cooling (DHC)
- Greenhouse Gas (GHG)
- Solar Heating and Cooling (SHC)
- Photovoltaic Power Systems Programme (PVPS)
- Demand Side Management (DSM)
- Industrial Energy-Related Technology and Systems (IETS)
- Energy Technology Systems Analysis Programme (ETSAP)
- Energy Conservation through Energy Storage (ECES)
- Solar Power and Chemical Energy Systems (SolarPACES)
- Heat Pump Programme (HPP)
- Electricity Networks Analysis, R&D (ENARD)

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Content

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- **Motivation**
- **Energy Storage Technologies**
  - *electrical*
  - *thermal*
  - *chemical*
- **Comparison – A Complex Matter**
- **Thermal Energy Storage for Electricity Storage?**
- **Economical Constraints**
- **R&D Demand**
- **Conclusion**

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Motivation

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More renewable energy has to be integrated!

Fluctuating resources have to be balanced!

Energy efficiency has to be improved!

Unused energy has to be utilized!

Energy Storage!

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Energy Storage Technologies

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Properties of an Energy Storage System

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- Storage Capacity (kWh/kg, kWh/m³)

  Phys. / Chem. Effect, Storage Material, Boundary Conditions
- Charging / Discharging Power (W/kg, W/m³)

  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
- Competing Technologies

  Transmission System, Smart Grids, Demand Side Management, Electricity Production

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Electrical Energy Storages

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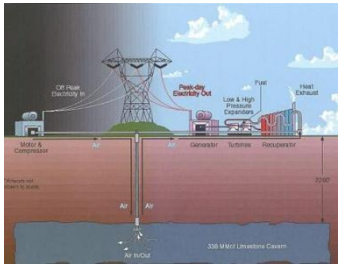
- **Storage of Electrical Energy**


- **Storage of Electro-chemical Energy**



- **Storage of Mechanical Energy**

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Electrical Energy Storages

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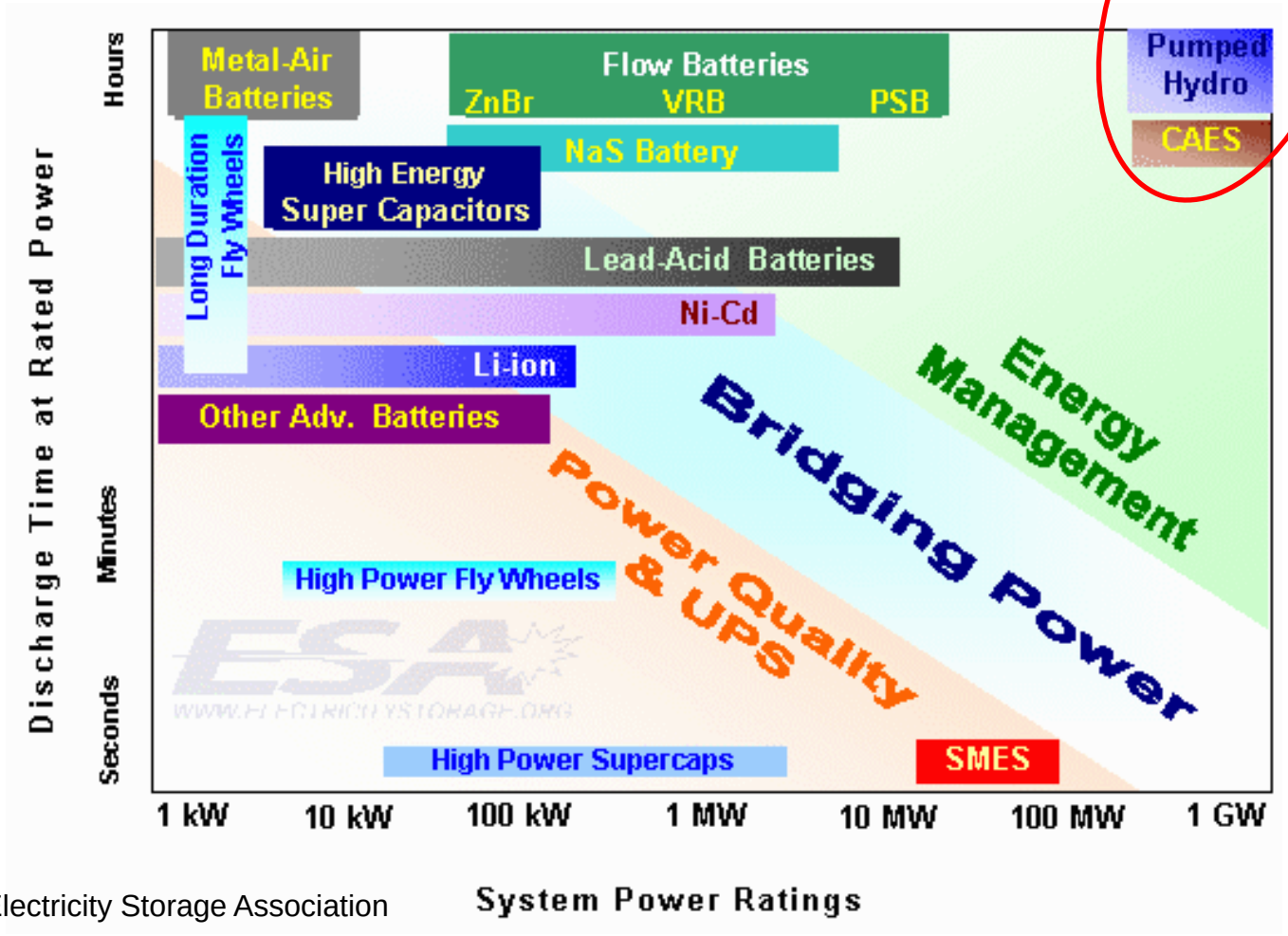
Storage Period and Discharging Power

Grid Balance



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Thermal Energy Storages

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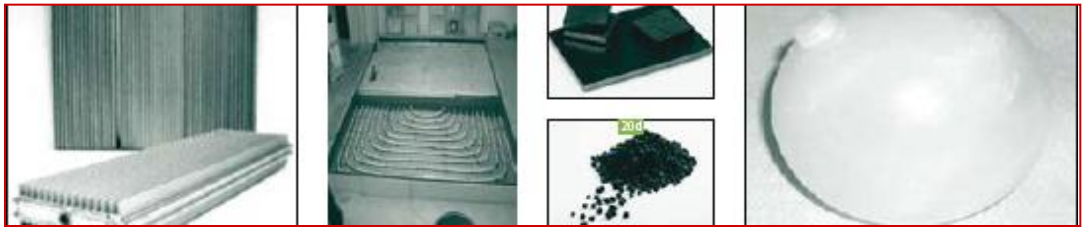
- Thermal Energy can be stored as sensible heat

- Thermal Energy can be stored as latent heat



- Thermal Energy can be stored thermo-chemically

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Storage Capacity vs. Temperature

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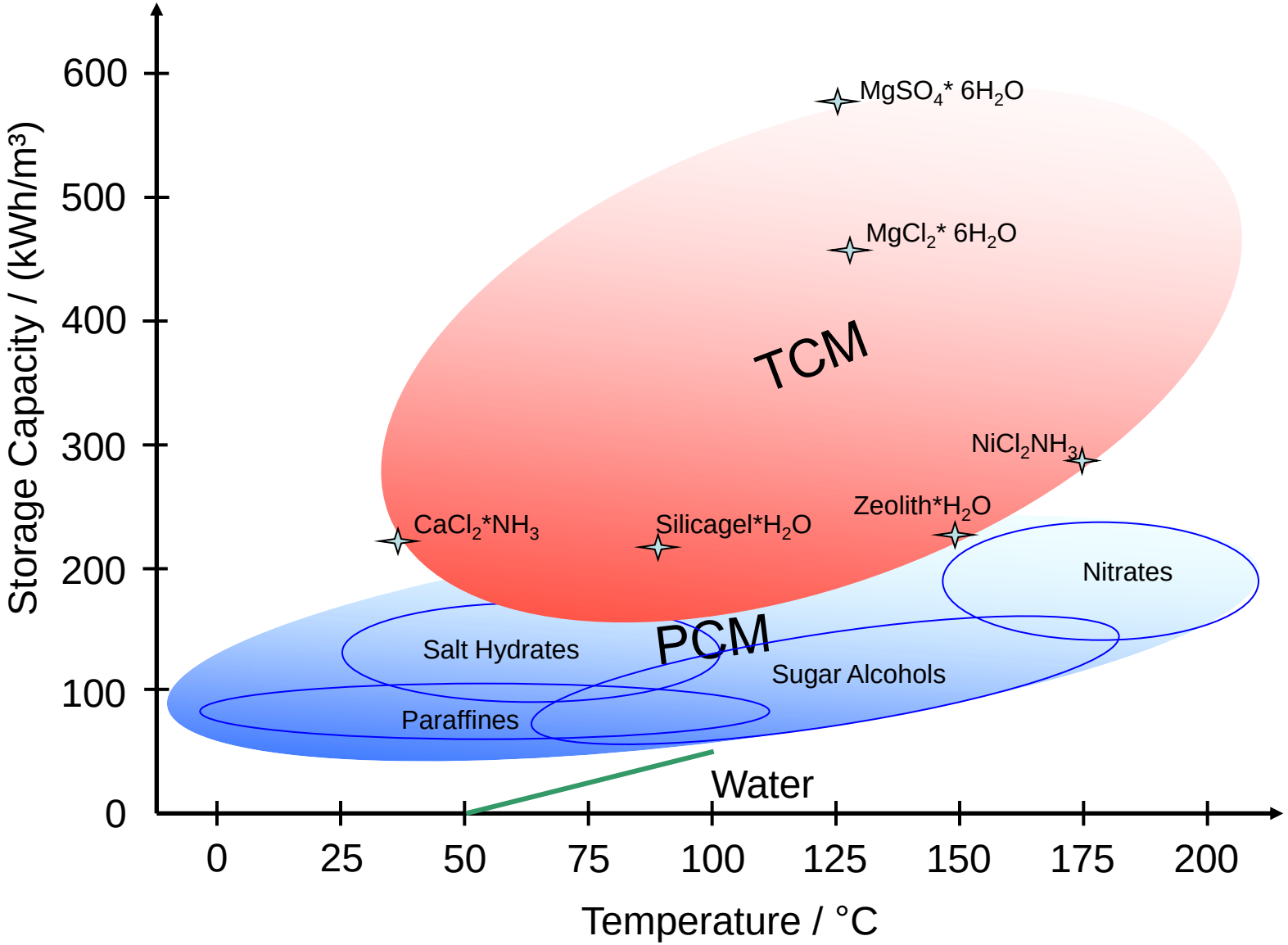

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Chemical Energy Storage

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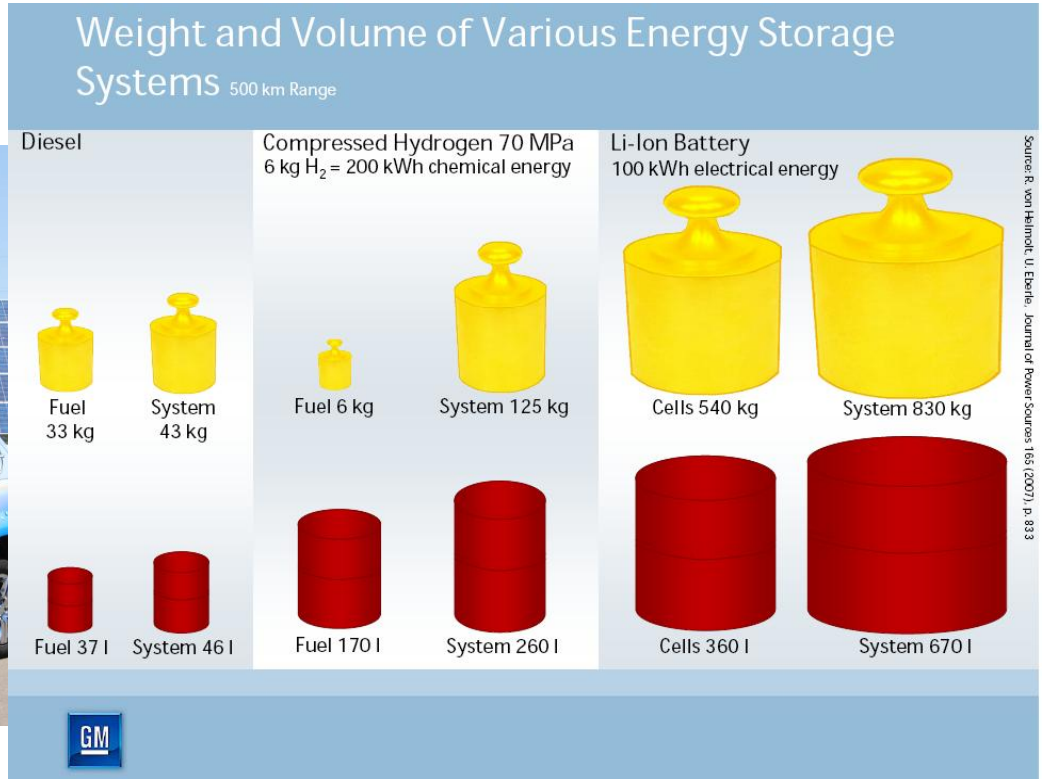
Energy Storage by Hydrogen Production and Storage

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



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Chemical Energy Storage

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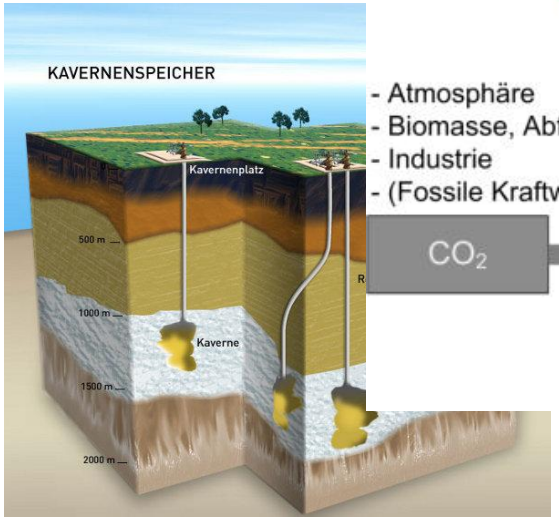
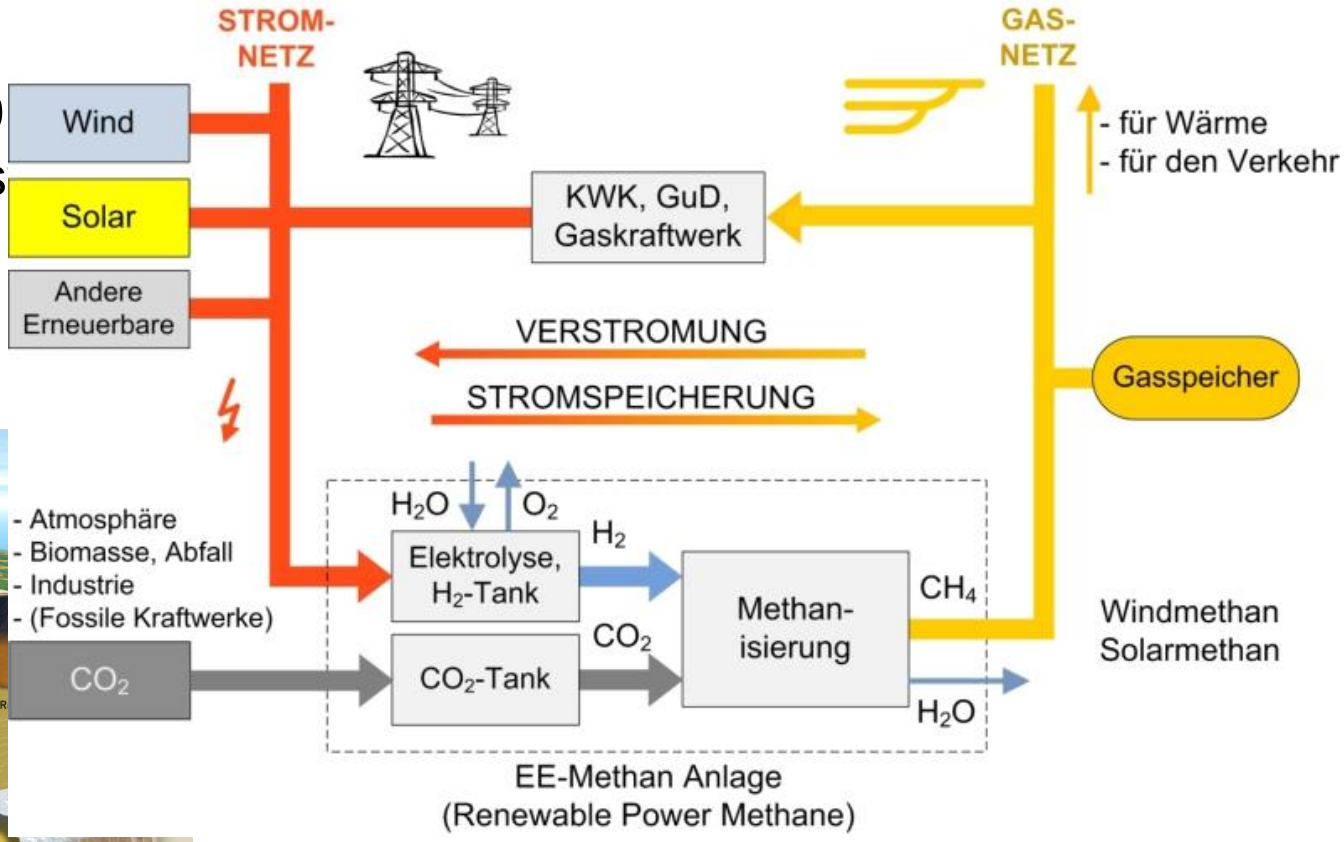
Energy Storage by Methane Production and Storage

- Methane from
- Efficiency >80
- Existing Infras





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Comparison: Energy Storage Technologies

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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

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Energy Storage Technologies: Comparison – A Complex Matter

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Seasonal Storage

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Longterm Storage of PV (Summer to Winter)

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
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Seasonal Storage

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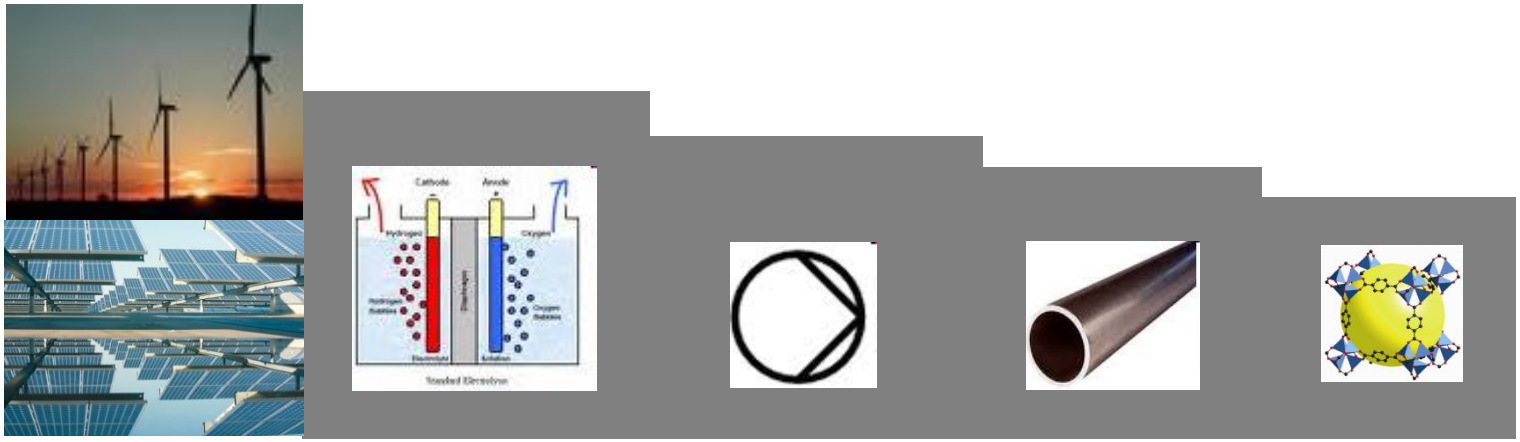
Hydrogen:



Total

~ 51%

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

Fuel: **Overall Efficiency 50%**

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

Heating: **Overall Efficiency 50 %**

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Seasonal Storage

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Hot Water:

Total

~ 225%

Efficiency:	**Heat Pump**	**Storage**
	~ 300 %	**~ 75 %**

Fuel: **not possible!**

Electricity: **not possible!**

Heating: **Overall Efficiency 225 %**

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Important:

- **Look at the whole efficiency chain!**
- **Take the final energy demand into account!**
- **Try to identify the most suitable technology for the application!**

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Thermal Energy Storage for Electricity Storage?

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Application: Integration of Wind Energy

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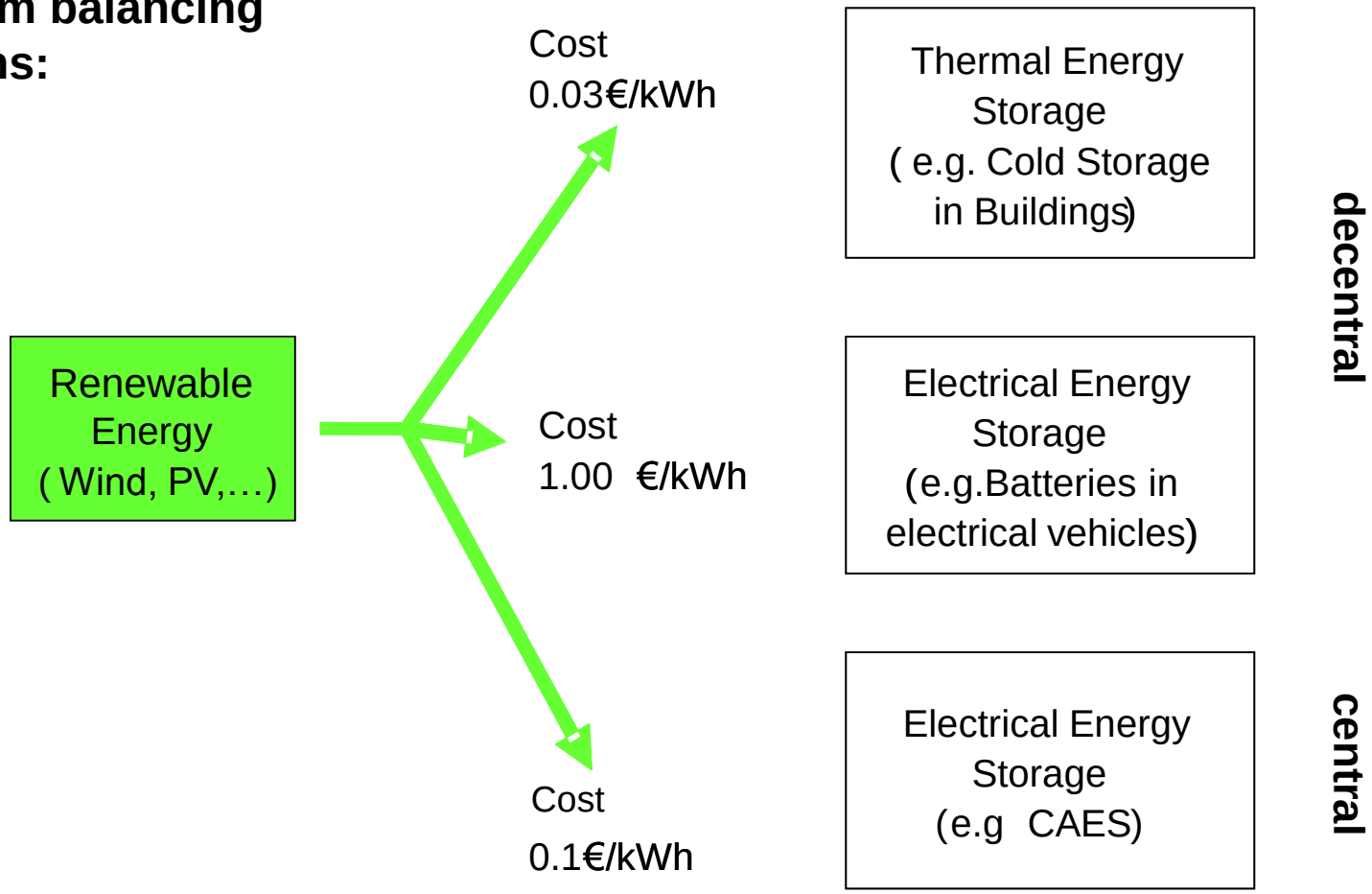
System balancing actions:



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Application:
Integration of Wind Energy

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„Storing Wind 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

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Economical and Commercial Constraints

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Economical Limits

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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 Barriers

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Commercial Issues & 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

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R&D Demand

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R&D Demand

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- **Development and optimisation of different energy storage technologies (new materials & processes)**
  - **electrical**
  - **thermal**
  - **chemical**
- **Detailed and quantitative estimation of the storage demand for**
  - **integration of renewable energies**
  - **increase of energy efficiency**
- **Development of methods for the comparison of storage technologies and the identification of the most suitable technology for the actual application**

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Conclusions

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Conclusions

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- **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**

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

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Thank you very much for your attention!

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