Integration of Renewable Energies by Distributed Energy Storage Systems

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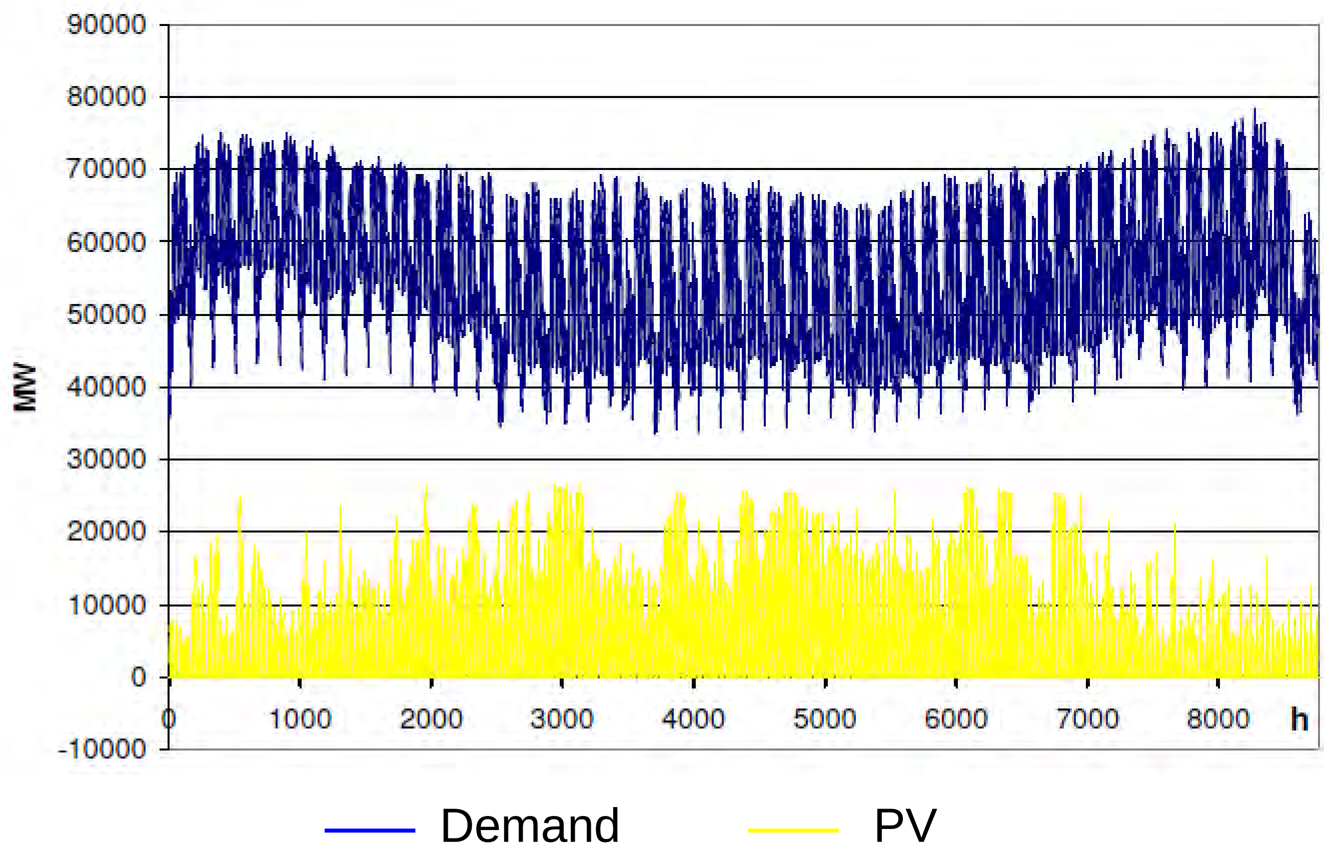
Motivation

More renewable energy has to be integrated!

Fluctuating resources have to be balanced!

Energy Storage!

Motivation



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Motivation

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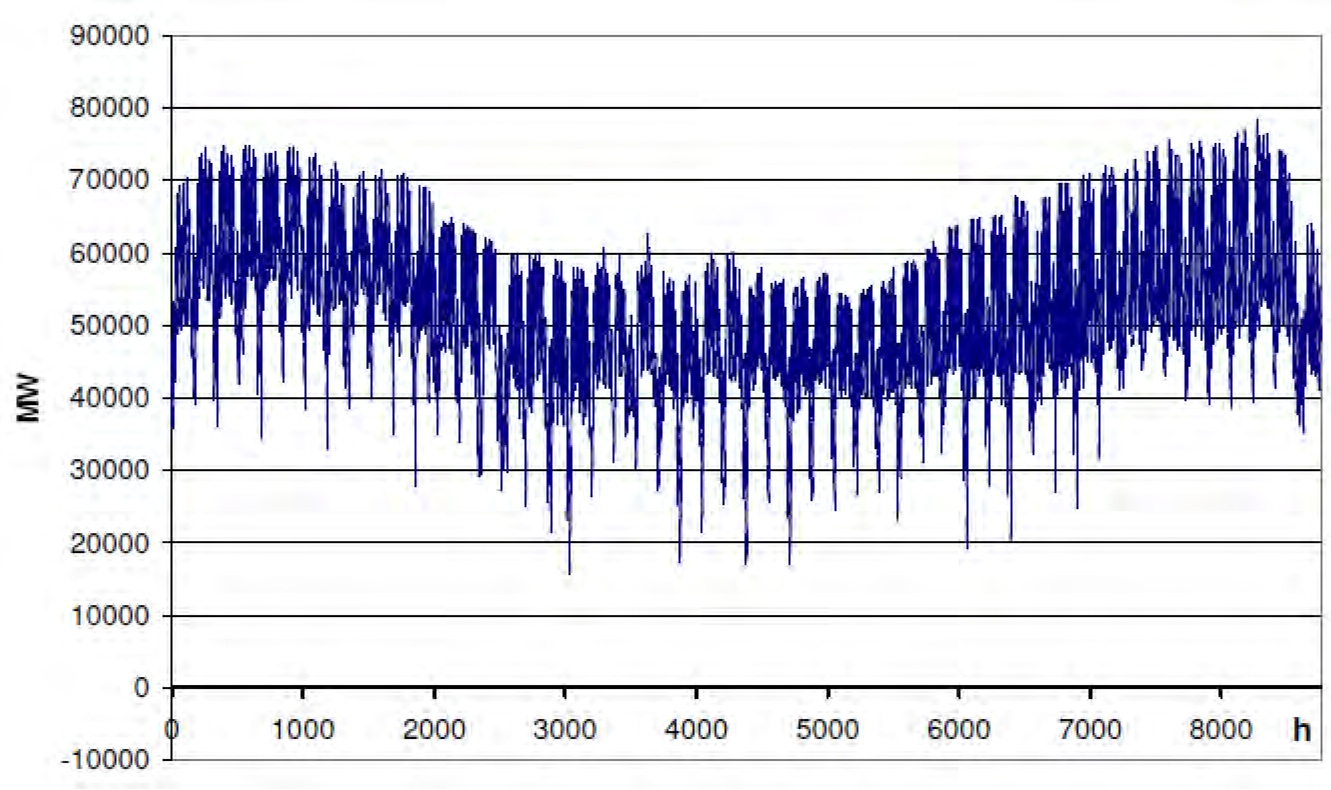

Residual Demand (PV)

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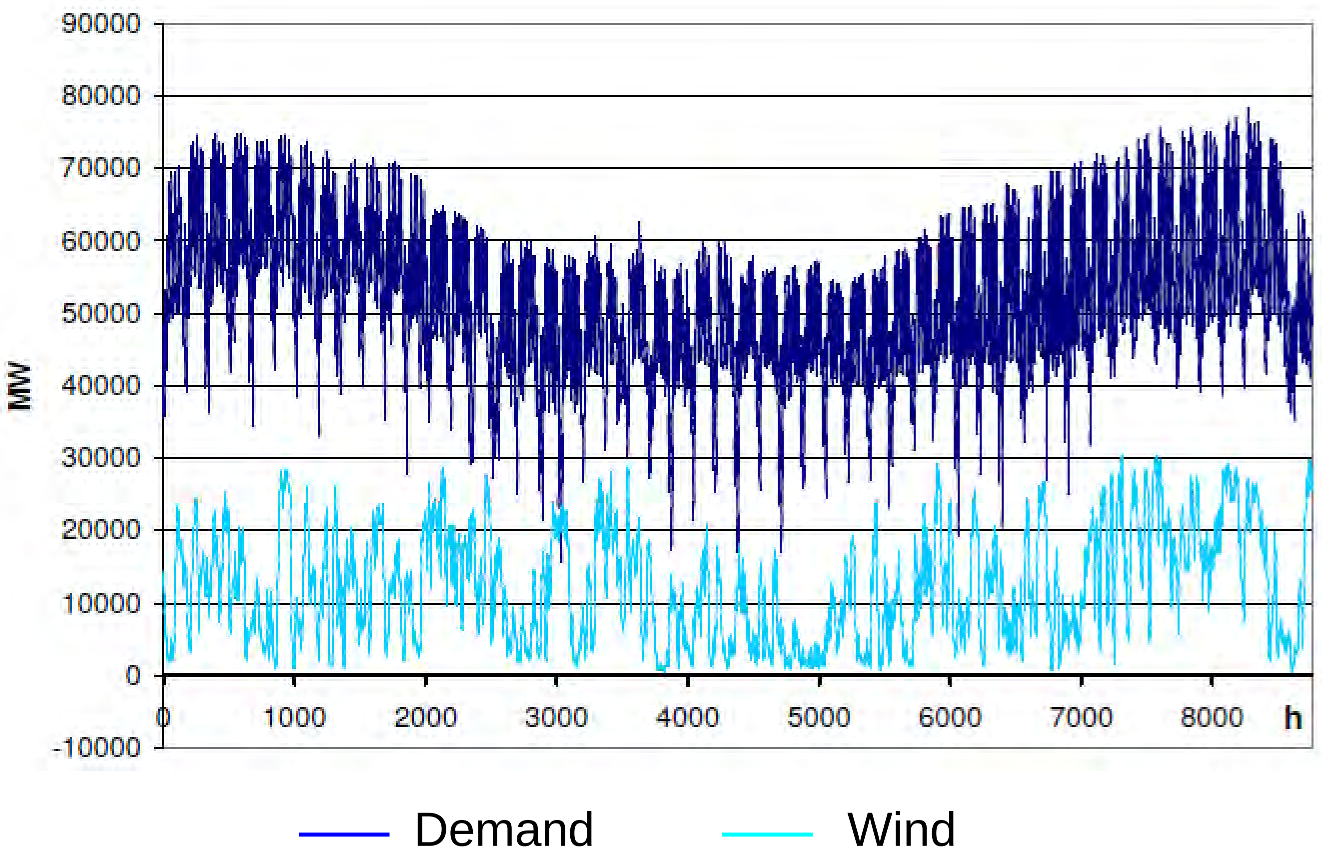

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Motivation

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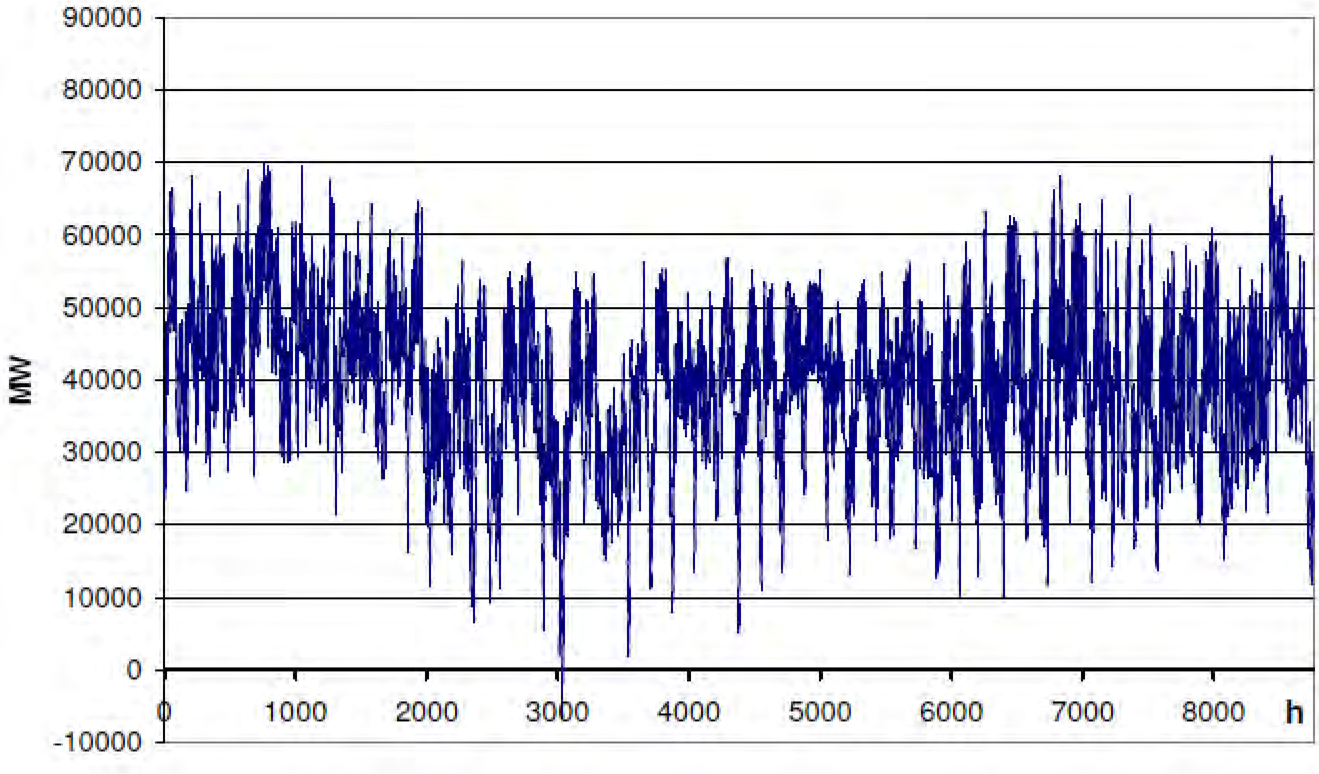

Residual Demand (PV + Wind)

Overview of Storage Technologies

Properties of an Energy Storage System

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- Storage Capacity (kWh/kg, kWh/m³)

  Phys. / Chem. Effect, Storage Material, Operating 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

Electrical Energy Storages

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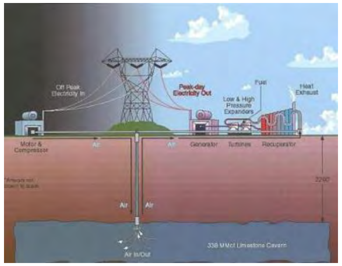
- **Storage of Electrical Energy**


- **Storage of Electro-chemical Energy**



- **Storage of Mechanical Energy**

Electrical Energy Storages

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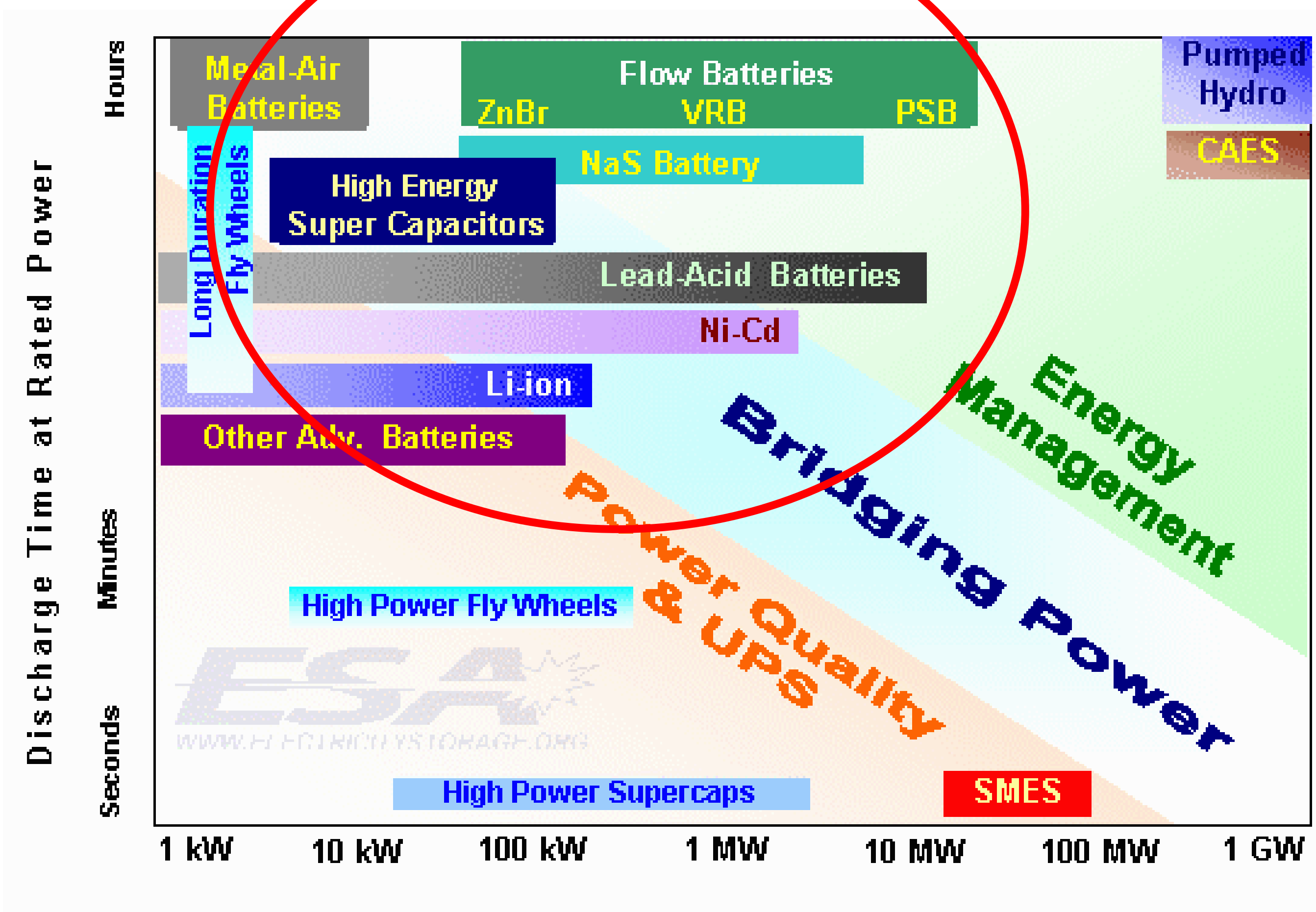
Storage Period and Discharging Power

Grid
Balance



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Thermal Energy Storage Technologies:

- **Storage of Sensible Heat**

- **Storage of Latent Heat**

- **Thermochemical Heat Storage**

Storage Capacity vs. Temperature

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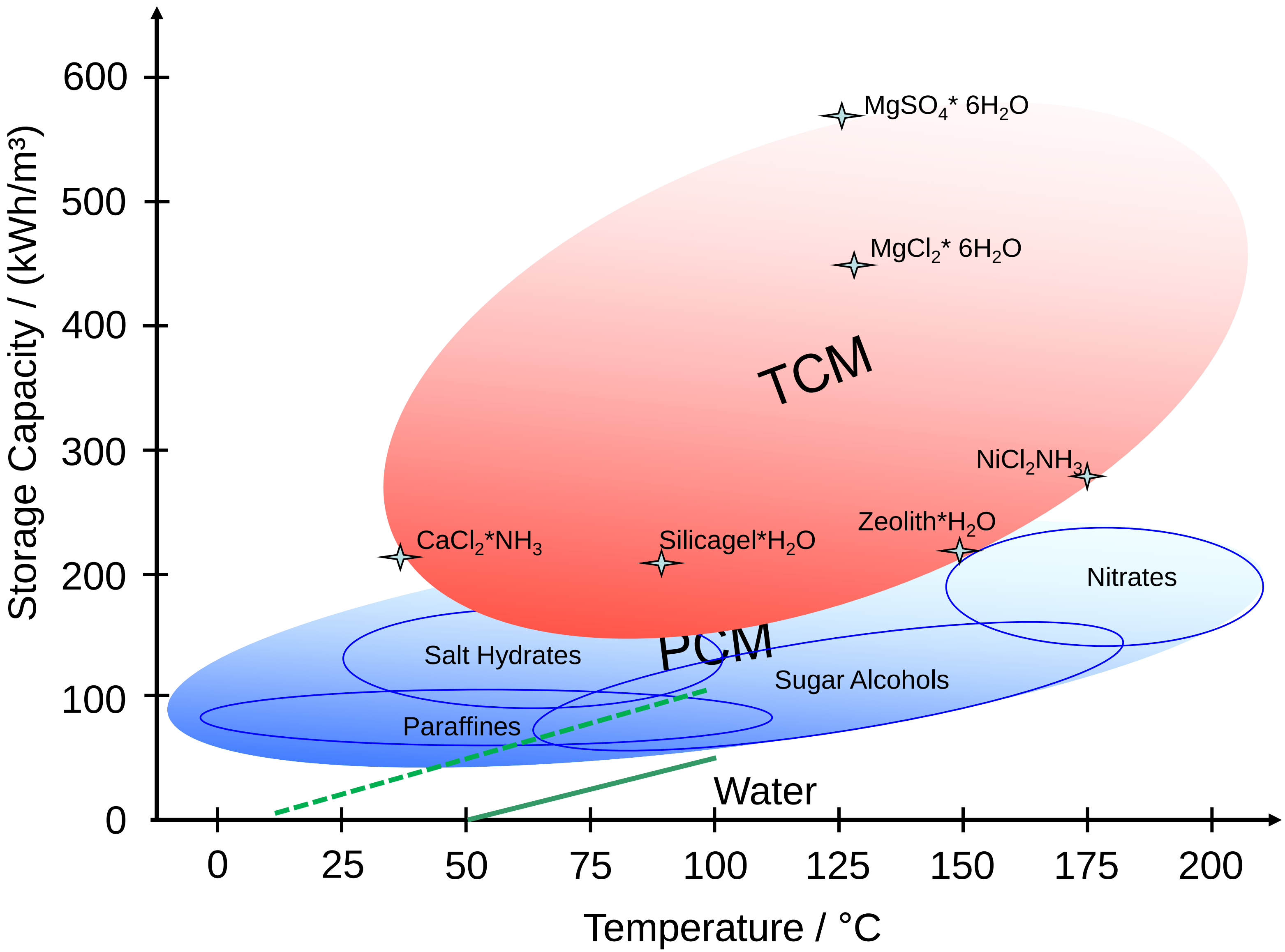
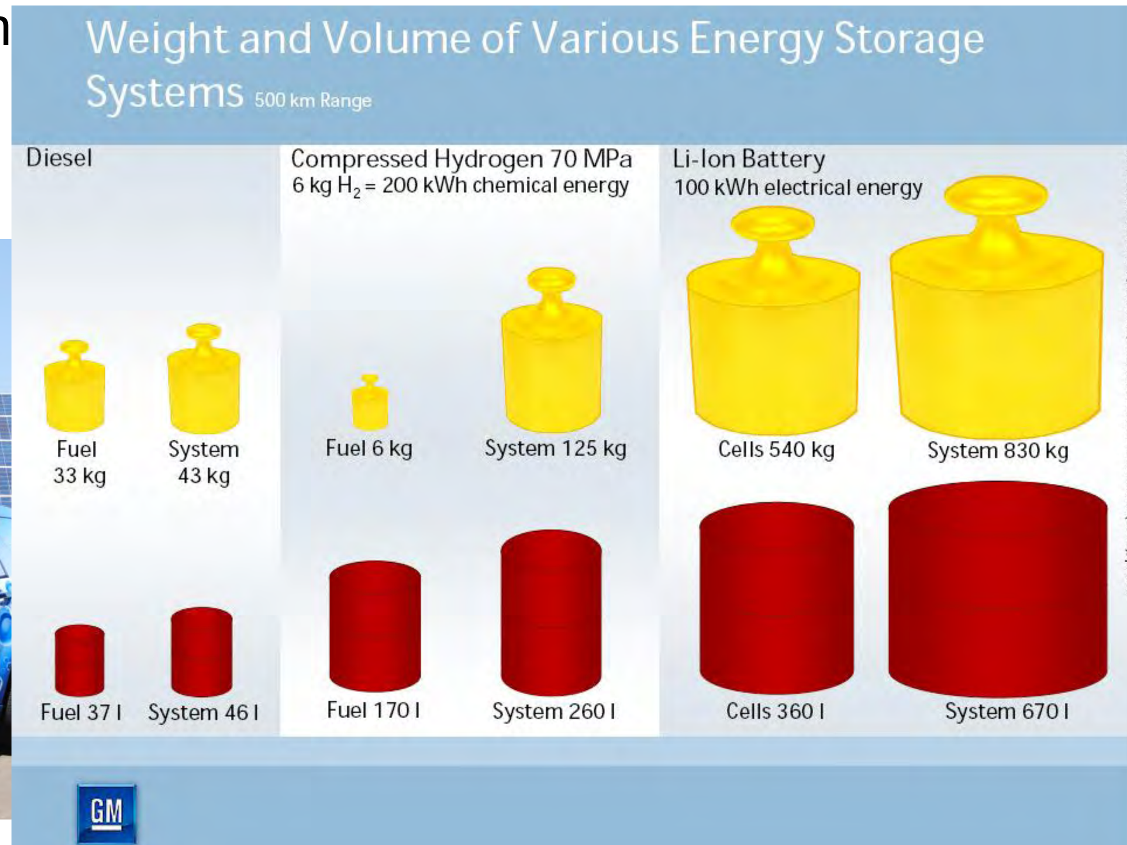


Chemical Energy Storage

Energy Storage by Hydrogen Production and Storage

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



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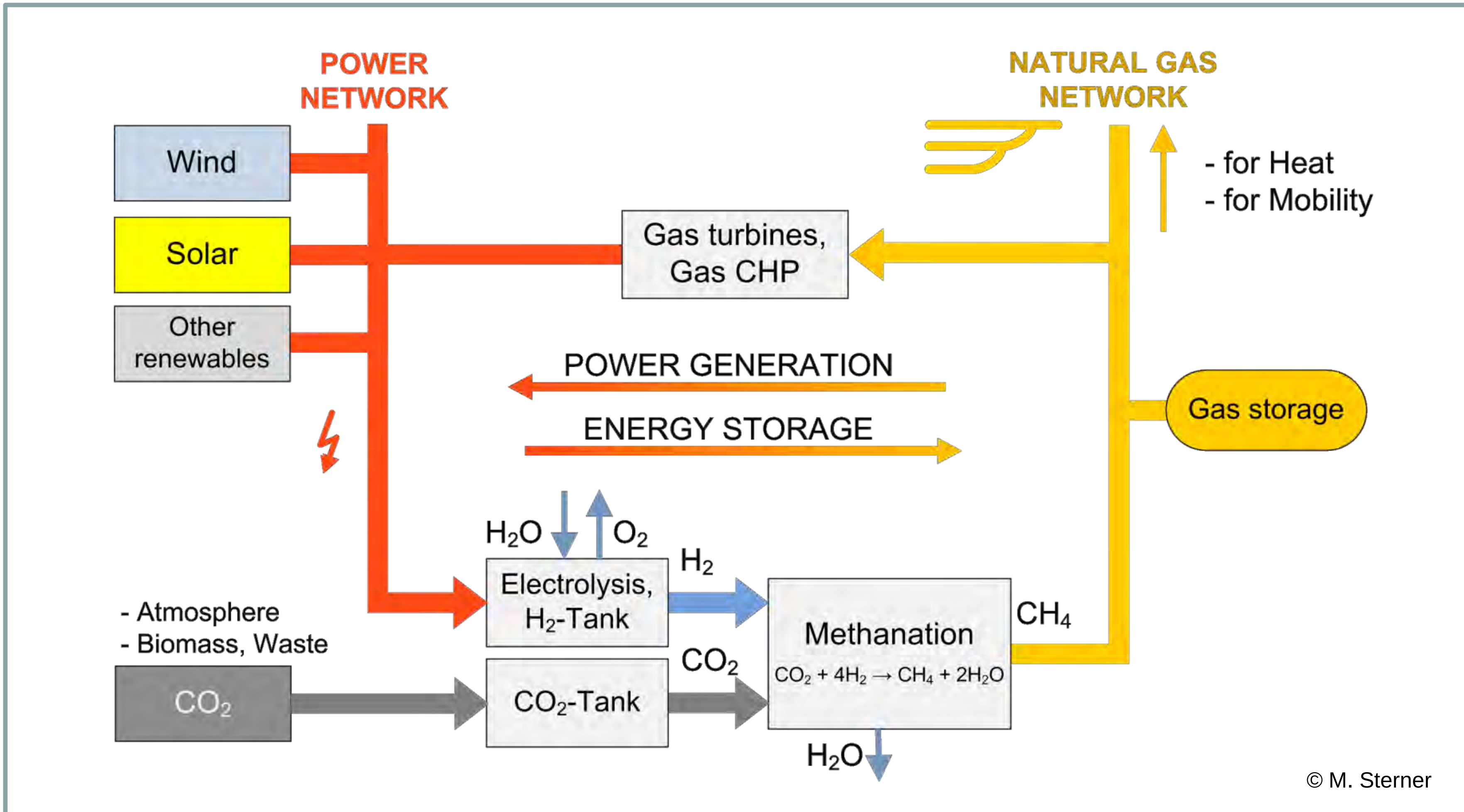
Energy Storage by Methane Production and Storage



Comparison: Energy Storage Technologies

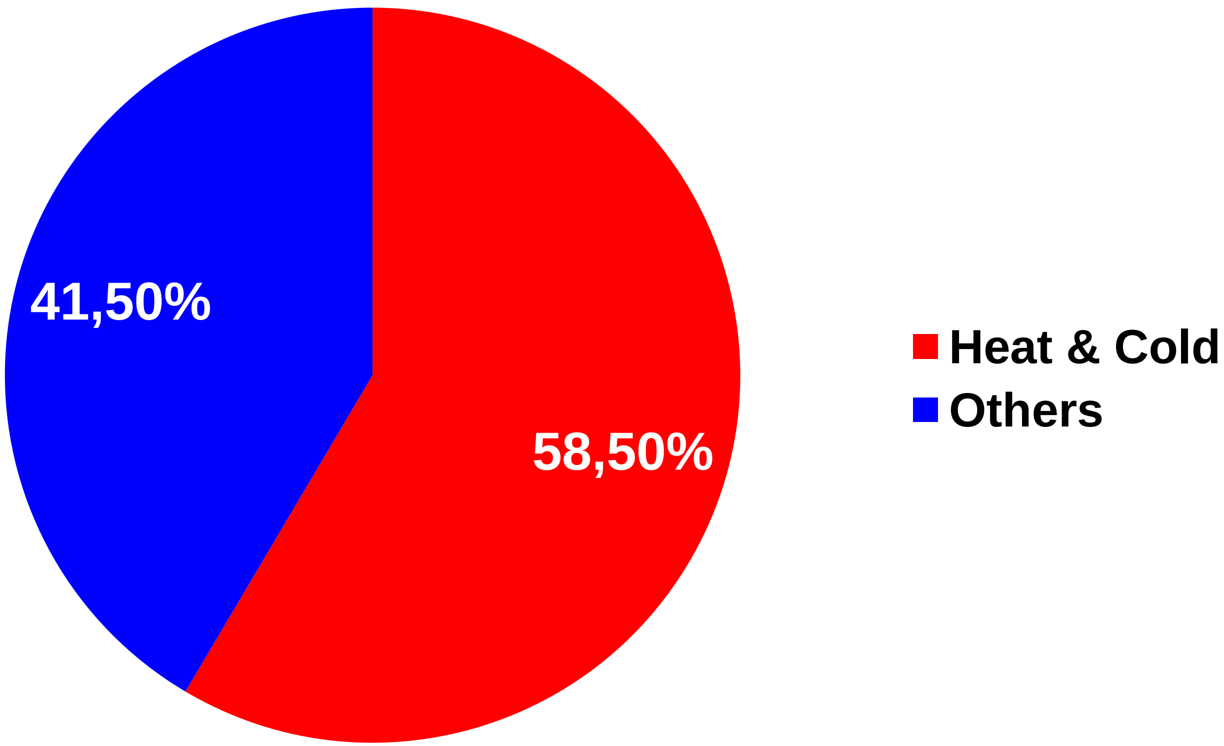
Storage Technologies	Capacity kWh/t	Power MW	Efficiency	Storage Time	Cost €-cent/kWh
Mechanical					
Pumped Hydro	1	1-1500	70-80%	day - month	8-14
Flywheel	5-100	1-100	90%	hour	300-500
CAES	2 kWh/m³	300	40-70%	day	13-27
Electro-chemical					
Lead-Acid	40	[illegible]	85%	day - month	28-37
Li-ion bat.	130	[illegible].02 - ?	90%	day - month	57-140
NaS bat.	110	0.05 [illegible]	85%	day	31-43
Redox-Flow bat.	25	0[illegible]0	75%	day - month	20-30
SMES	3	[illegible] 10	95%	hour - day	~10000
Supercaps	5	0.[illegible] - 1	95%	hour - day	~10000
Therm[illegible]					
Hot W[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PCM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chem[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chem[illegible]					
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

What are suitable Technologies for distributed energy storages?

What are „Distributed Energy Storages“?

- Distributed energy storages (DES) are located at the consumer side.
- Facing a growing impact of distributed renewable energy generation by PV, solarthermal or biomass (via Combined-Heat & Power) only DES are able balance the storage demand at this level.
- DES could contribute to the storage demand given by the fluctuations of larger Wind and PV installations, provided that the grid is able to transport the energy to the DES location. In this case DES are connected to a “virtual” central energy storage.

Final Energy Demand (Germany)



Renewables & Distributed Storages: Where and how?

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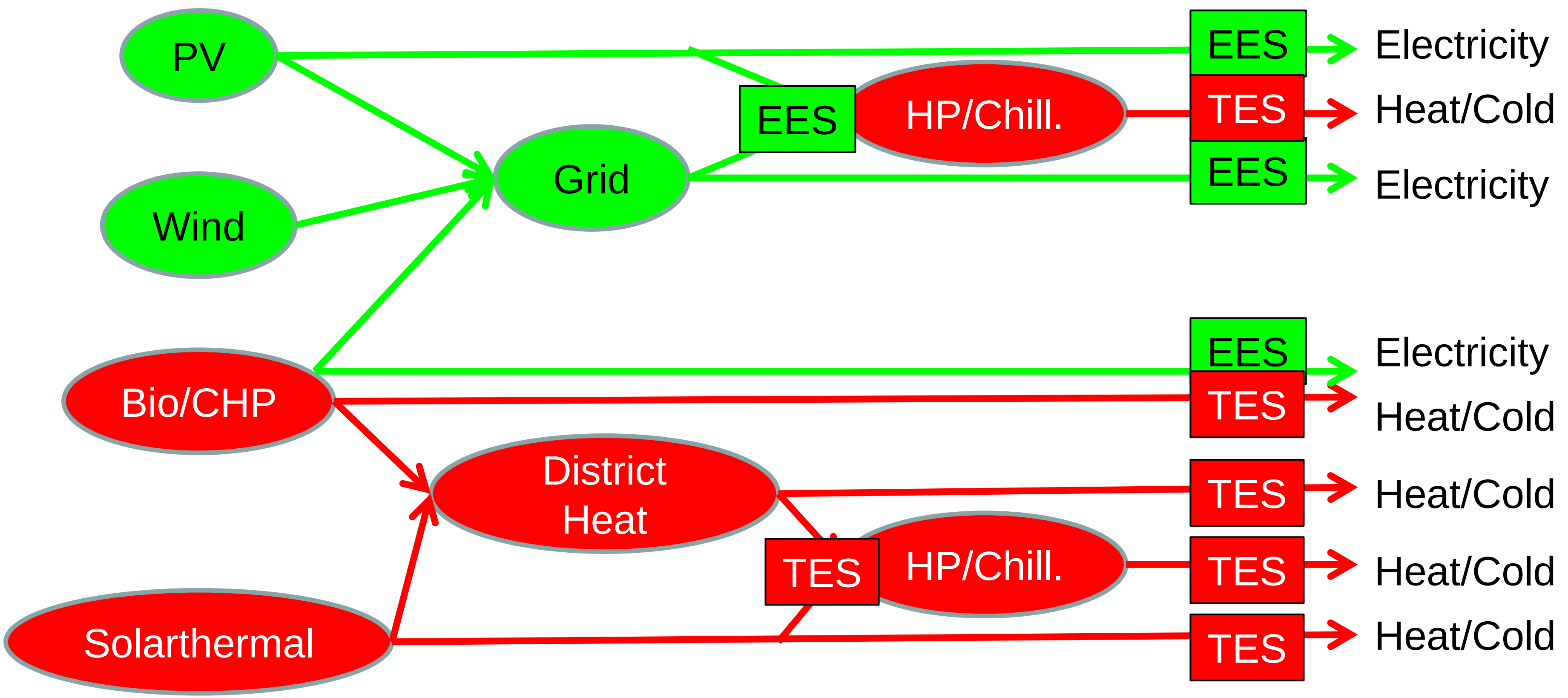
Renewable Energy **Distribution** **Transformation** **Consumer**

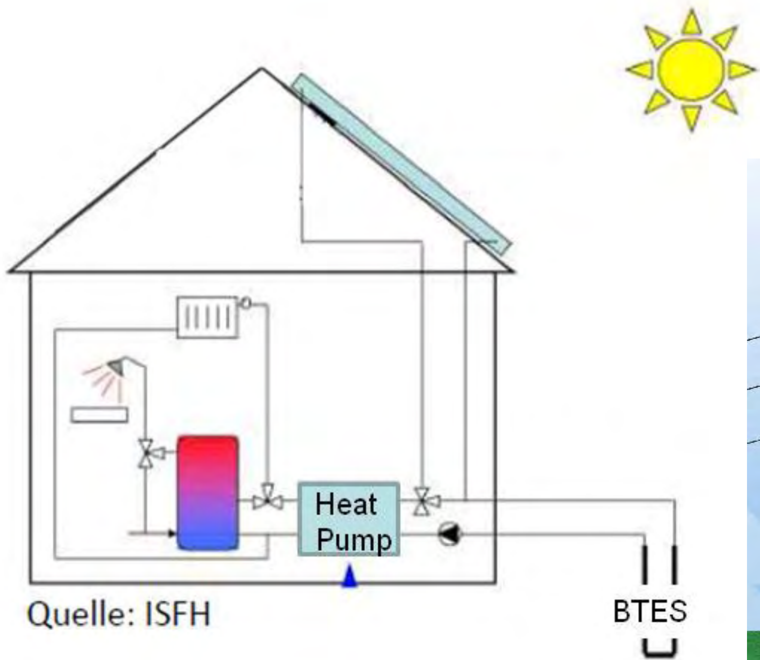


TES Thermal Energy Storage

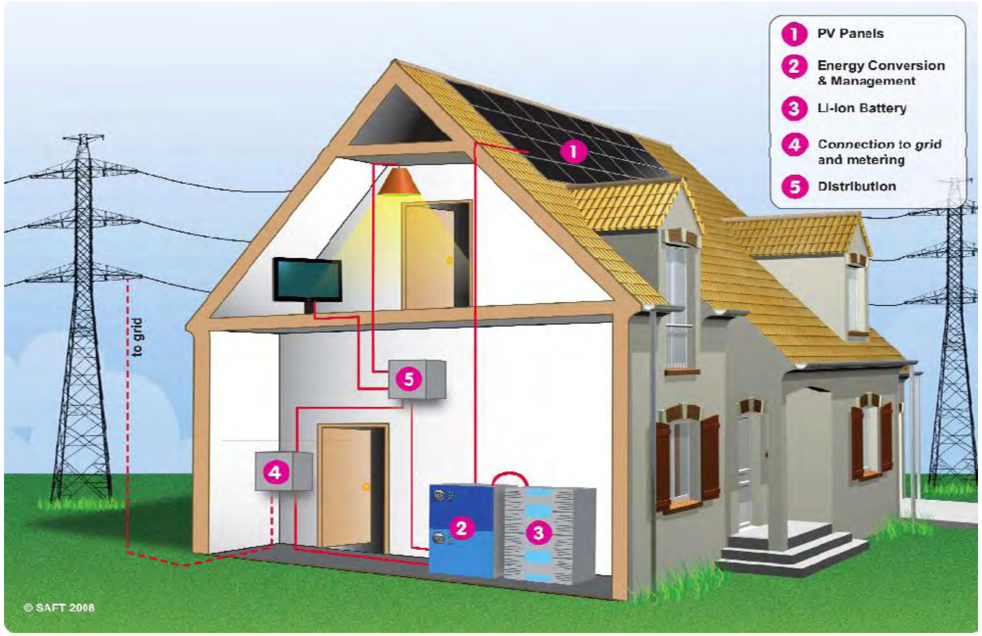
EES Electrical Energy Storage

Examples: Distributed storage systems

Solar-thermal – distributed UTES for heat pump application



PV – Li-ion Battery - Grid



Examples: „In/Out“ and „One-Way“

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„In/Out“ Energy storage

e.g. electricity in and electricity out
or heat in and heat out

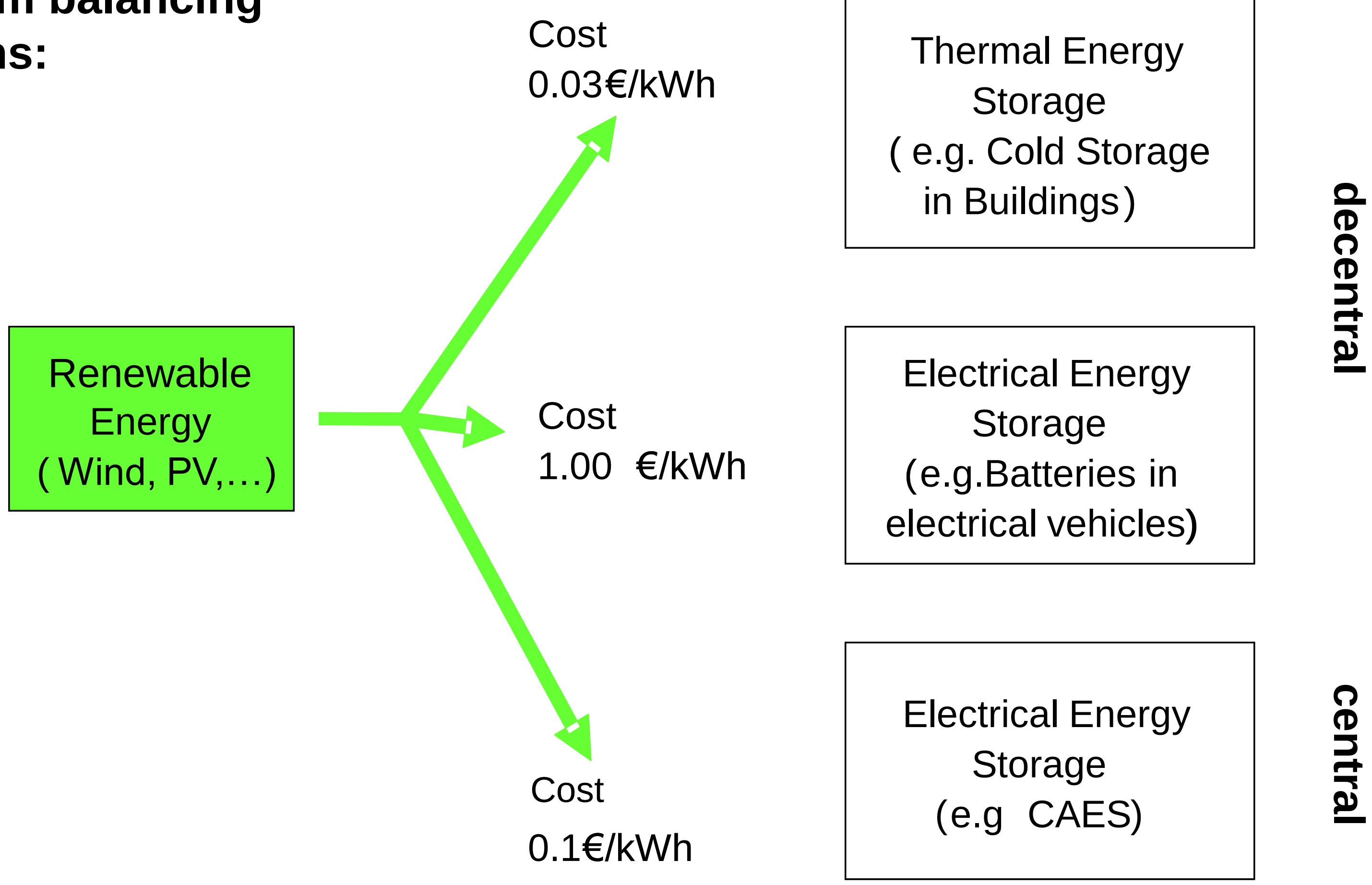
„One-Way“ energy storage
(demand side management)

e.g. electricity in and heat out

Storage Technologies might be the same!

Example: distributed / central

System balancing actions:



Example: „One-Way“ Cold Storage

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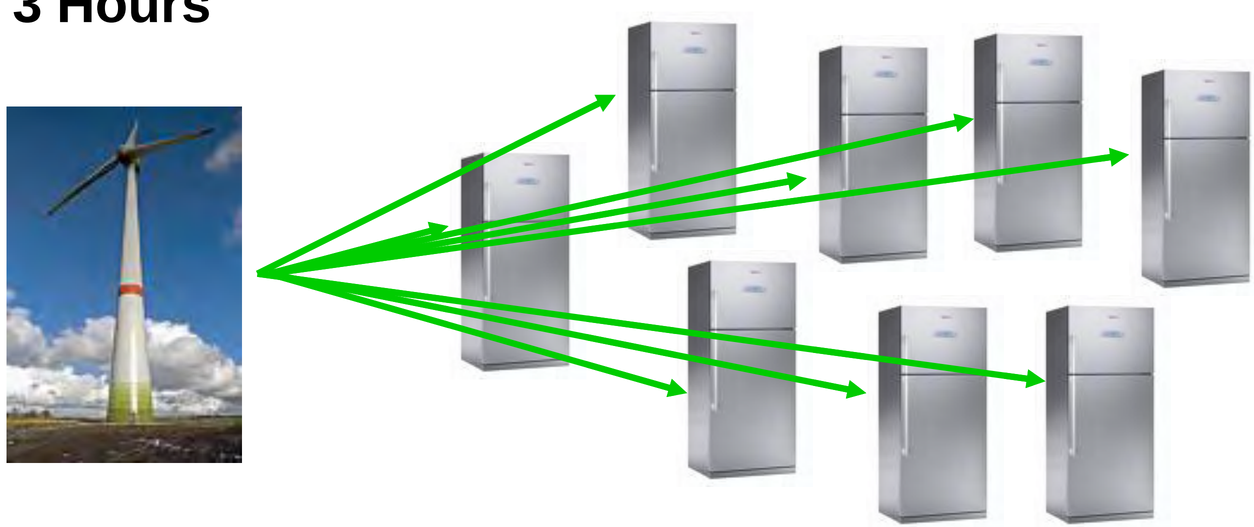
„Storing Wind Electricity in Fridges“

- 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**

Communication / Smart Grid

- **Storage has know its state!**

- **Grid has to know its demand!**

- **Both have to communicate!**
  - For balancing the grid
  - To maximize financial benefits
  - …

Distributed Energy Storage Systems

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Central Energy Storages are more „popular“ because…

- The potential can be estimated easily
- „One big solution“, like Hydrogen, Methane, CAES

Distributed Energy Storages are not taken into consideration, because…

- The potential is difficult to be estimated
- A number of different technologies are possible
- The controlling strategies might be complex

But they could be:

- **Economical interesting (low invest, low operation)**
- **Best storage technology for the actual application**
- **Most stable system**

Outlook

I believe we need in any future energy system

- **Distributed <u>and</u> central energy storage technologies**
- **<u>All</u> storage technologies (electrical, thermal and chemical)**

Thank you very much for your attention!