“FLEXIBLE SECTOR COUPLING” - CONCEPT

Andreas Hauer

World Bank Academy 2021

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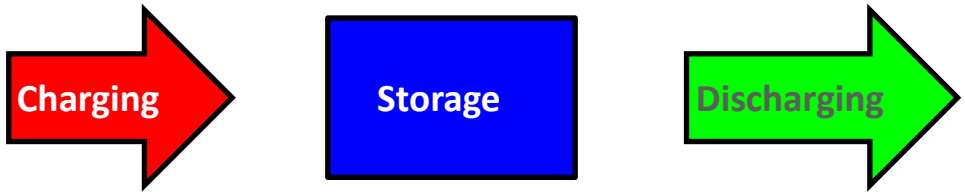
Energy Storage – Basic Definitions

Definitions „Energy Storage“

What is energy storage?

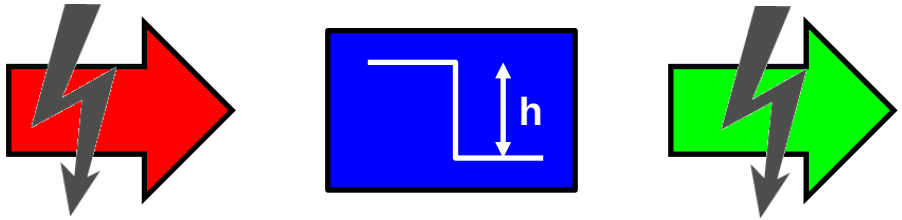
An energy storage system can take up energy and deliver it at a later point in time. The storage process itself consists of three stages: The charging, the storage and the discharging. After the discharging step the storage can be charged again.



Definitions „Energy Storage“

What is actually stored?

The form of energy (electricity, heat, cold, mechanical energy, chemical energy), which is taken up by an energy storage system, is usually the one, which is delivered.
However, in many cases the charged type of energy has to be transformed for the storage (e.g. pumped hydro storage or batteries). It is re-transformed for the discharging. In some energy storage systems the transformed energy type is delivered (e.g. Power-to-Gas or Power-to-Heat).

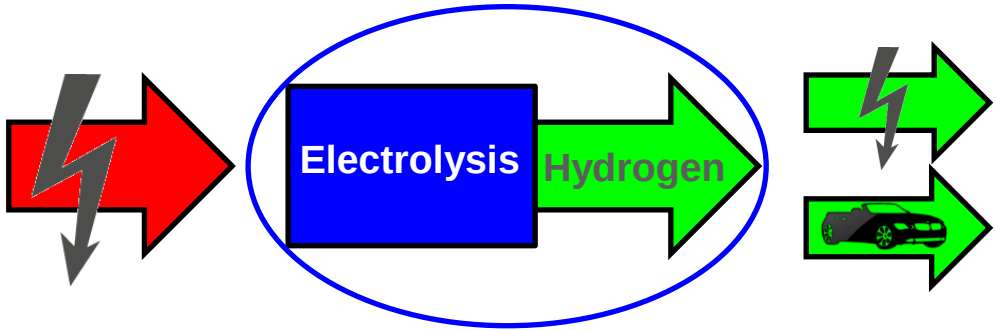


Definitions „Energy Storage“

Relation between energy storage systems and their applications

The technical and economical requirements for an energy storage system are determined by its actual application within the energy system. Therefore any evaluation and comparison of energy storage technologies is only possible with respect to this application.

The application determines the technical requirements (e.g. type of energy, storage capacity, charging/discharging power,…) as well as the economical environment (e.g. expected pay-back time, price for delivered energy,…).



Matching Supply and Demand

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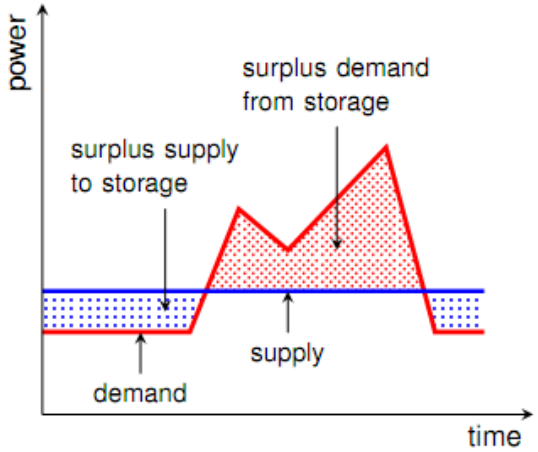
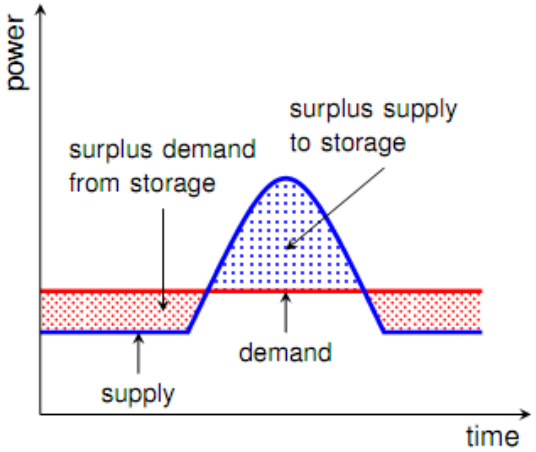
Constant Supply



Fluctuating Supply



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Energy Storage – Technologies

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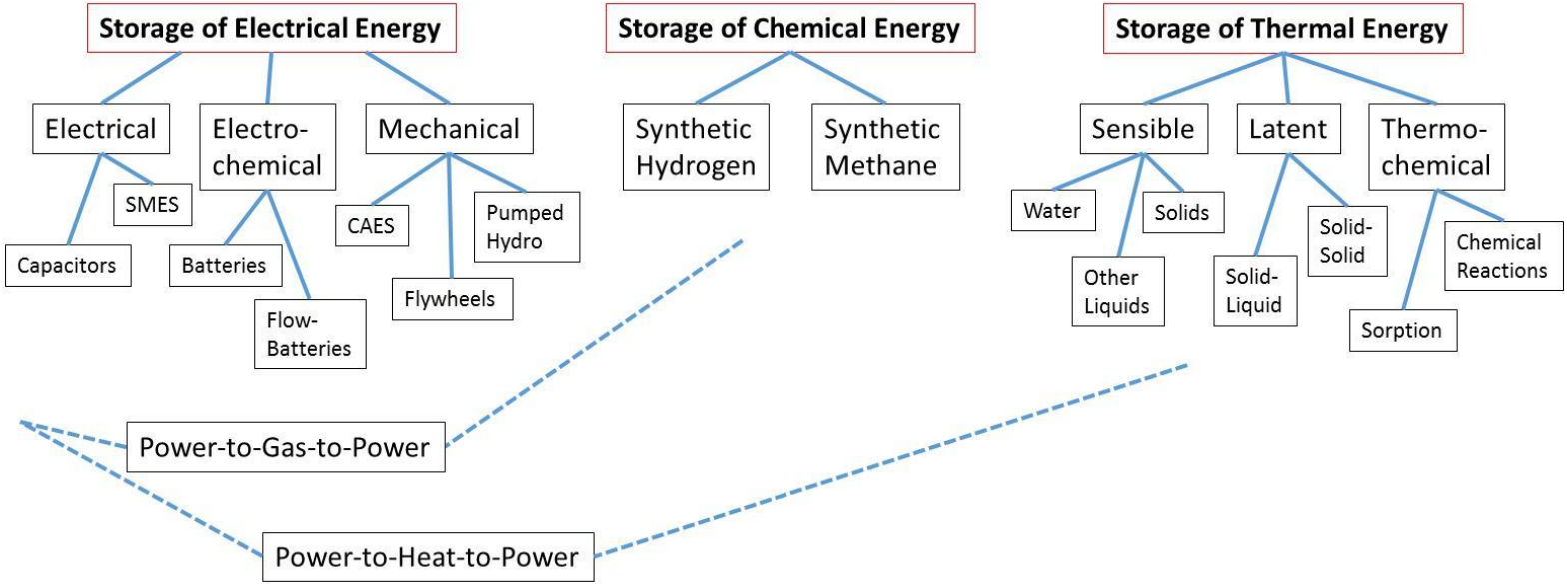
Structure of Energy Storage Technologies following the Physical Storage Effect
(not the relevance of the technologies!)



Energy Storage Technologies

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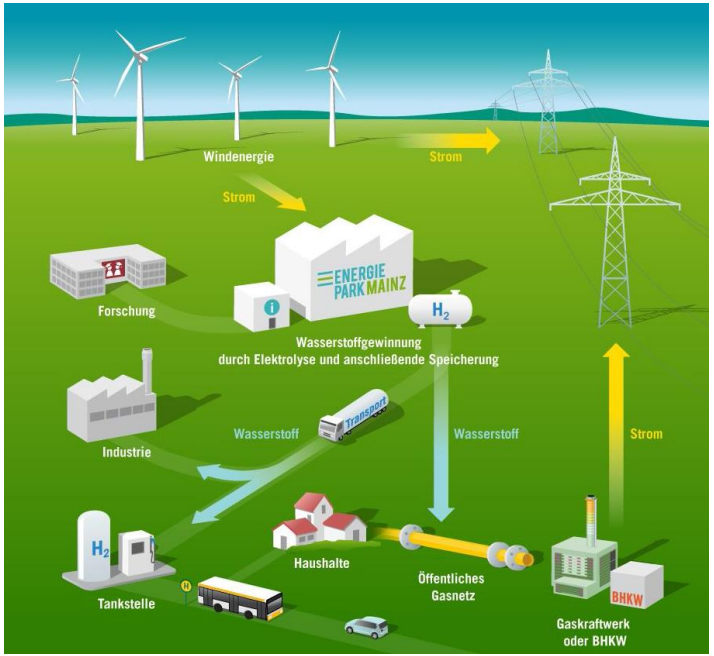
Electrical Energy Storage

Thermal Energy Storage

Chemical Energy Storage



Electrical Energy Storages

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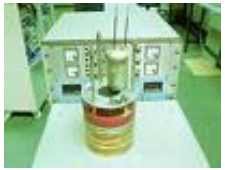
- **Storage as Electrical Energy**



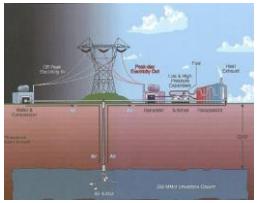

- Super-conducting Magnetic Energy Storage (SMES)
- Super-Capacitor

- **Storage as Electro-chemical Energy**



- Lithium-Ion Battery
- Sodium-Sulfate Battery (NaS-Cells)
- Lead-Acid Battery
- Redox-Flow Battery

- **Storage as Mechanical Energy**


- Pumped Hydro Storage
- Compressed Air Energy Storage (CAES)
- Flywheel

Electrical Energy Storages

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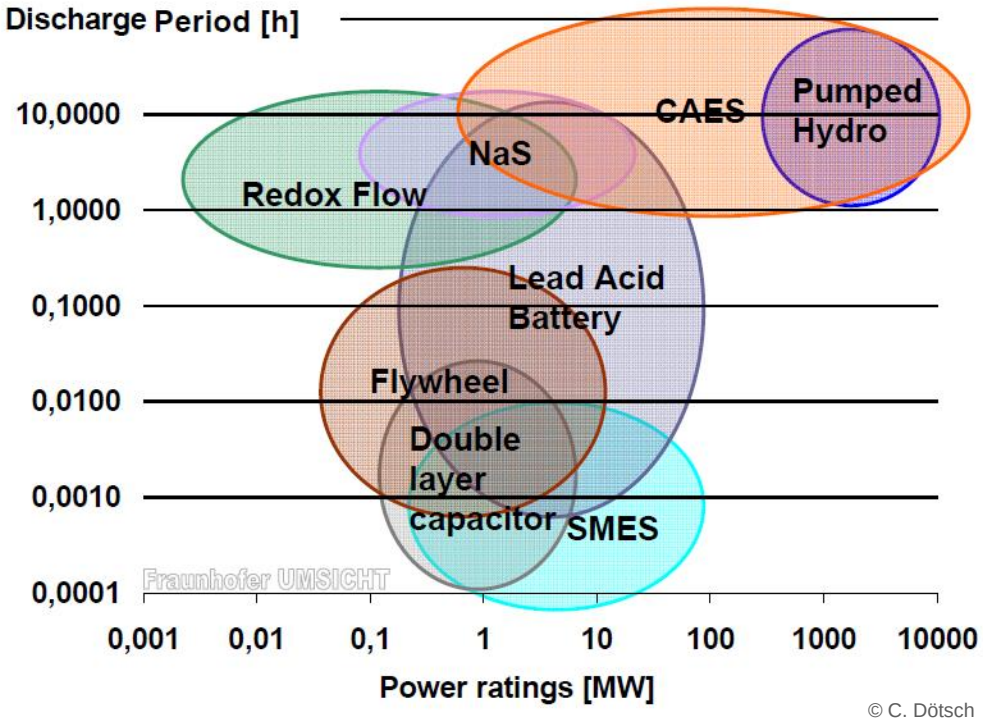
Storage Period and Discharging Power

Energy Management

Bridging Power

Power Quality



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Thermal Energy Storages

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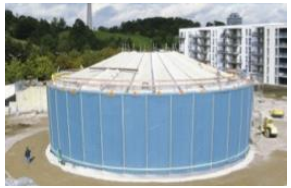
- **Thermal Energy can be stored as sensible heat**



  - Hot Water Tank
  - Underground Thermal Energy Storage (UTES)

- **Thermal Energy can be stored as latent heat**




  - Macro- / Micro-encapsulated Phase Change Materials (PCM)

- **Thermal Energy can be stored thermo-chemically**



  - Adsorption (Zeolite) and Absorption (LiCl) Storage
  - ThermoChemical Materials (TCM)

Storage Capacity vs. Temperature

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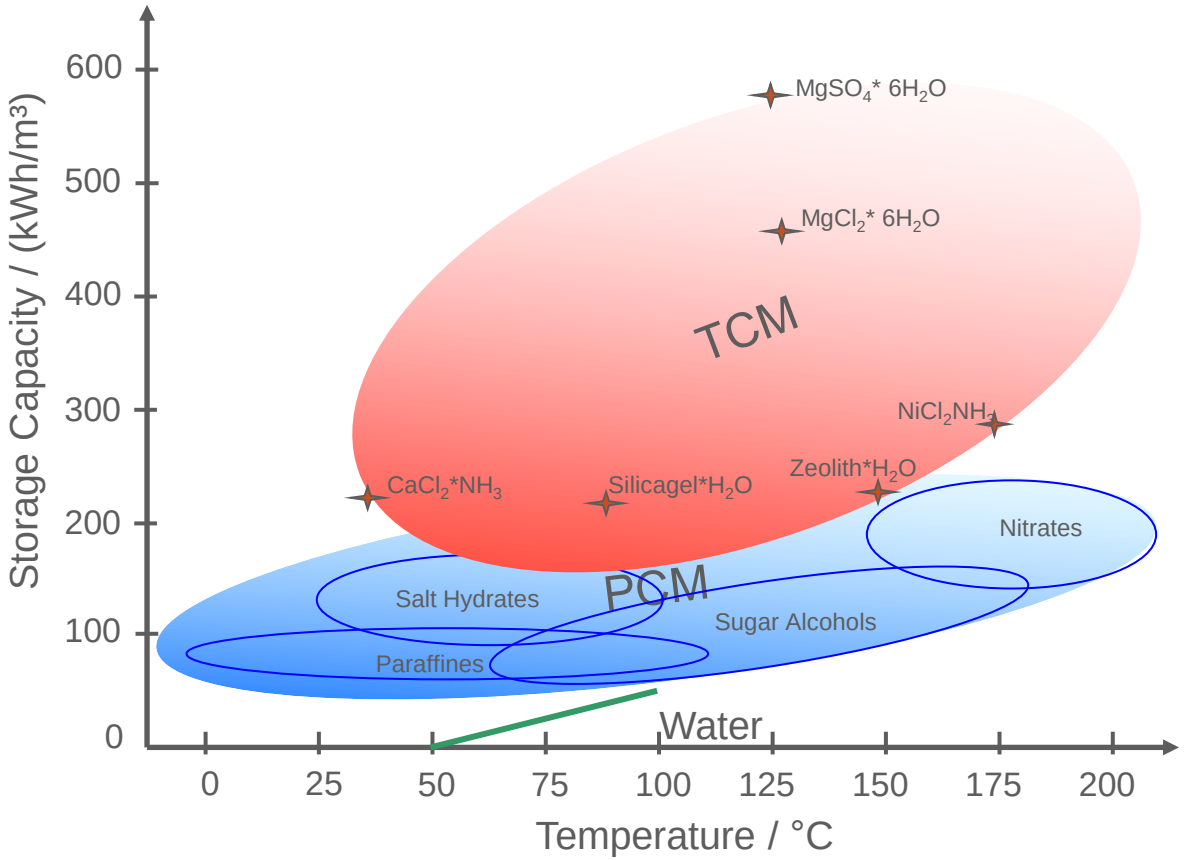

Chemical Energy Storage

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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 / H_2 turbines

Chemical Energy Storage

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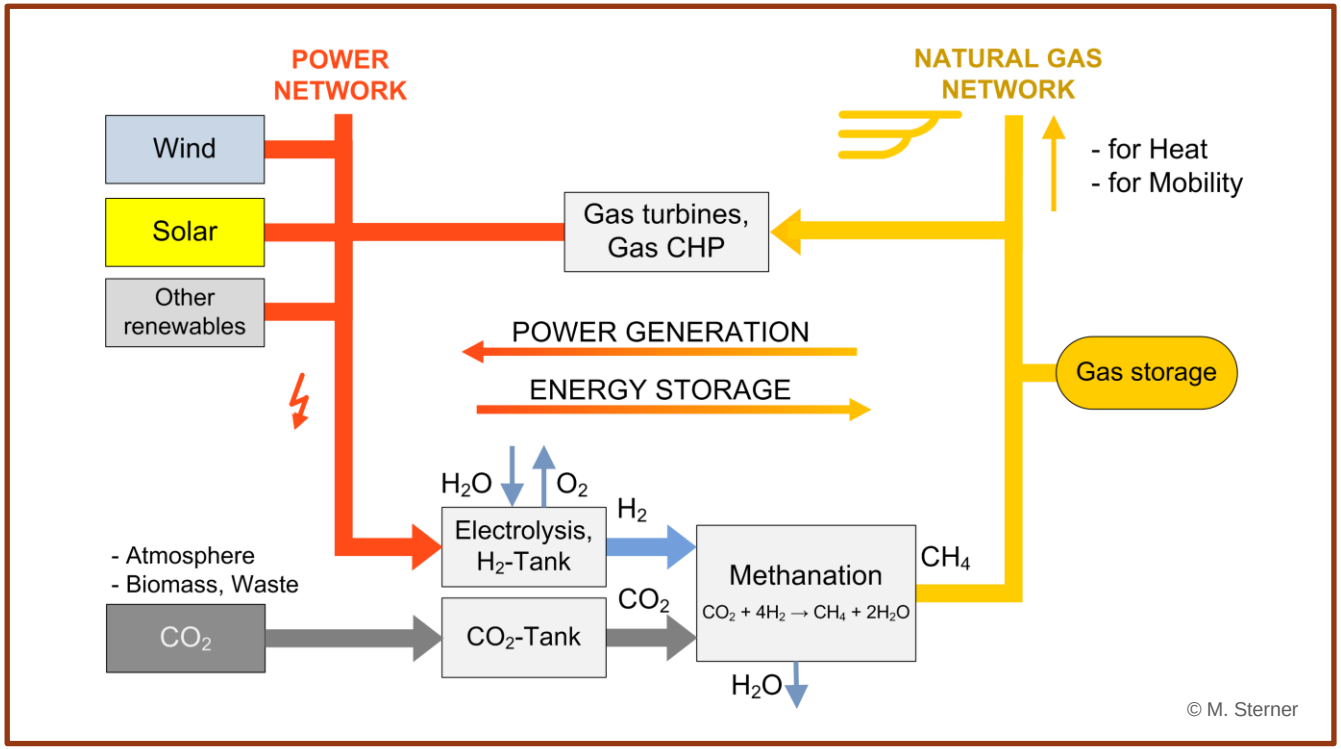

Energy Storage – Applications

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Renewable Energies

Integration of Renewable Electricity

- Grid Stability
  - Frequency regulation
  - Voltage support
  - T&D congestion relief
  - Black start
- Grid balancing
  - Fast power reserve
  - Peak shaving
  - Self-consumption, Off-grid
- Demand Side Integration
  - Dispatchable Load
  - Power-to-Gas
  - Power-to-Heat

Integration of Renewable Thermal Energy

- Concentrated Solar Power
- Solar-thermal Process Heat
- Solar-thermal Heating & Cooling

Energy Efficiency

Industrial Processes

- Waste Heat Utlization
- Recuperation of Mech. Energy

Buildings

- Heating & Cooling
  - Day/Night-Balancing
  - Summer/Winter-Balancing

Electricity Production

- Fossil Thermal Power Plants
- Heat Utilization of CHP
- …

Mobility

- Propulsion
- Heating / Air Conditioning

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EES – TES – EES/TES/CES

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„Flexible Sector Coupling“ – Definition and Concept

Energy Demand Sectors and CO_2 Emissions

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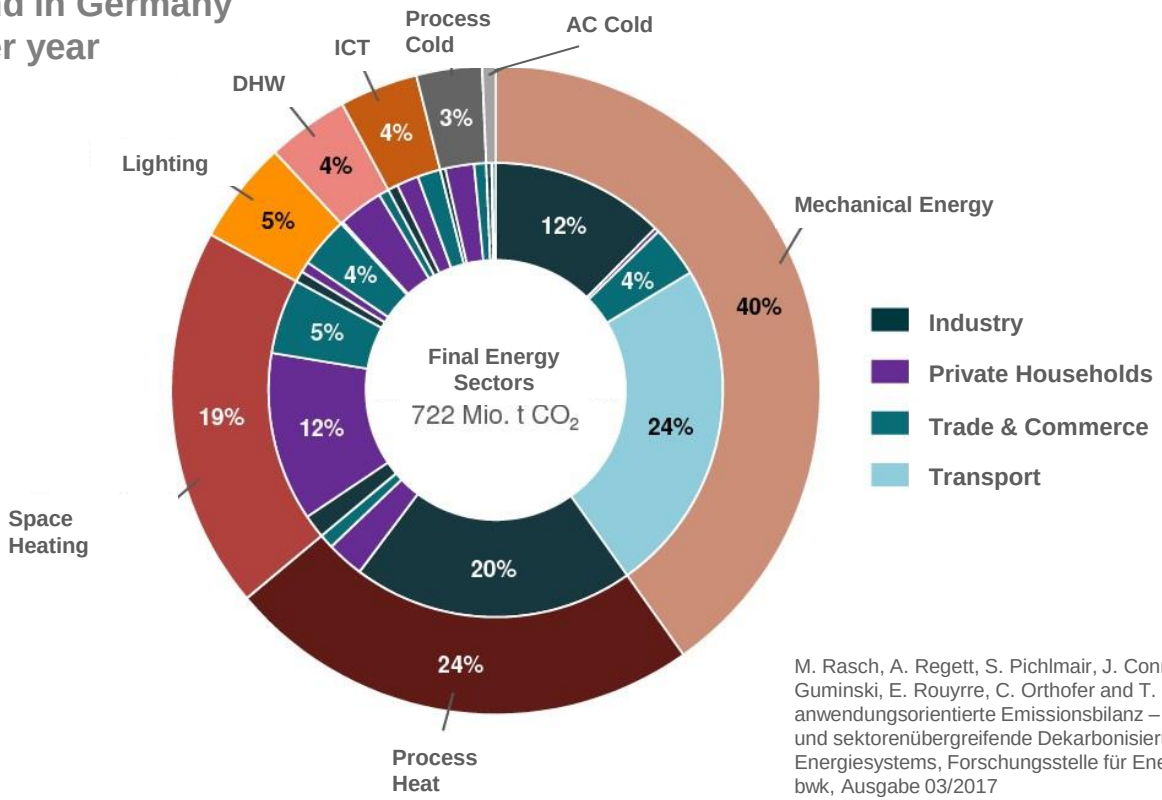
Final energy demand in Germany about 2,600 TWh per year



M. Rasch, A. Regett, S. Pichlmair, J. Conrad, S. Greif, A. Guminski, E. Rouyrre, C. Orthofer and T. Zipperle, Eine anwendungsorientierte Emissionsbilanz – Kosteneffiziente und sektorenübergreifende Dekarbonisierung des Energiesystems, Forschungsstelle für Energiewirtschaft FfE, bwk, Ausgabe 03/2017

Energy Demand Sectors and CO_2 Emissions

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Sectors = Demand Sectors

Electricity-Sector: (= electric energy)
- Main input from renewable sources (PV/Wind)
- „Everything that consumes electricity“?
- obvious = lighting, ICT, controlling,…but also electric motors in industry, appliances in householdes etc.

Mobility-Sector: (= kinetic energy)
- Transportation of goods and poeple
- cars, trucks, trains, ships, planes,…

Thermal-Sector: (= thermal energy)
- Heating & cooling in buildings and industry
- process heat &cold, space heating, DHW,…

„Energy Sectors“ and CO_2 Emissions

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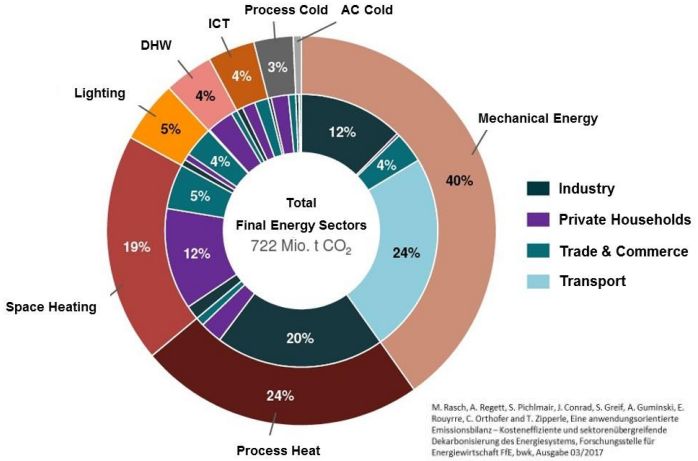
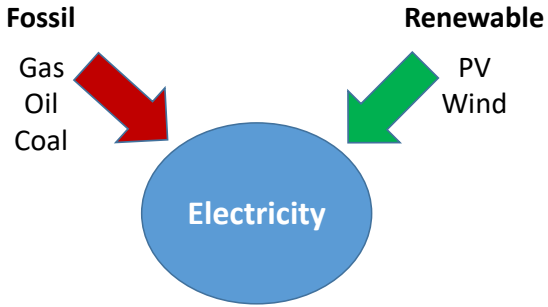
Distribution of CO_2 emissions among the „Sectors“:

- **Electricity** **24%**
  - Lighting 5 %
  - ICT 4 %
  - Mech. Energy in Ind./T&C 16 %
- **Thermal** **> 50 %**
  - DHW 4 %
  - Process Cold 3 %
  - Process Heat 24 %
  - Space Heating 19 %
  - AC <1 %
- **Mobility** **24 %**

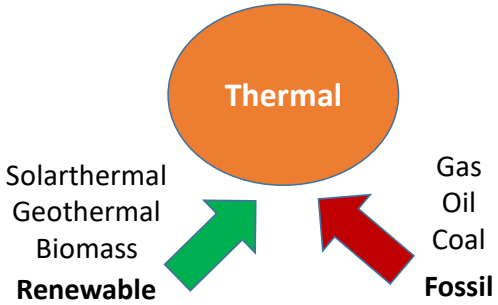


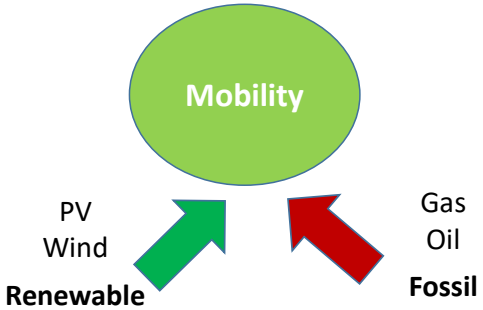
The thermal and the mobility sector cause about 75 % CO_2 emissions in developed countries!

„Sectors“



Energy Supply
for different Sectors

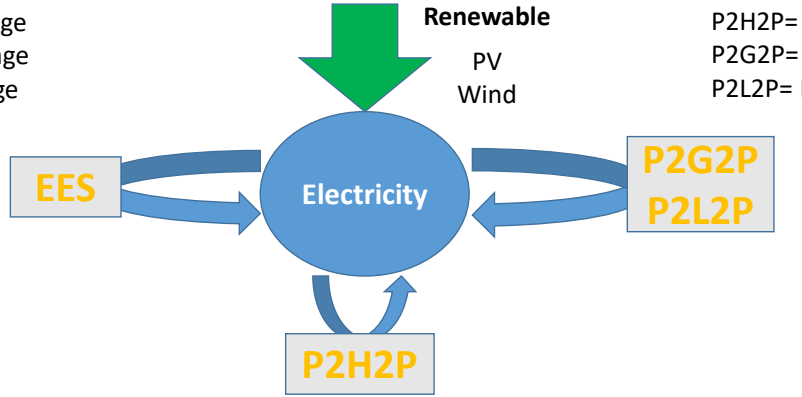




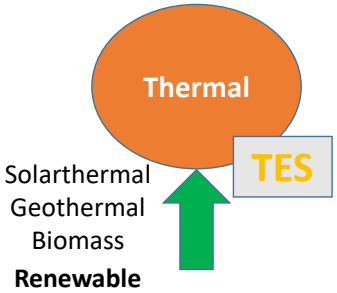
Storage within „Sectors“

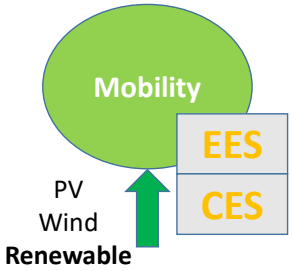
EES = Electrical Energy Storage
CES = Chemical Energy Storage
TES = Thermal Energy Storage

P2H2P= Power-to-Heat-to-Power
P2G2P= Power-to-Gas-to-Power
P2L2P= Power-to-Liquid-to-Power



Energy Storage within the Sectors





„Sector Coupling“

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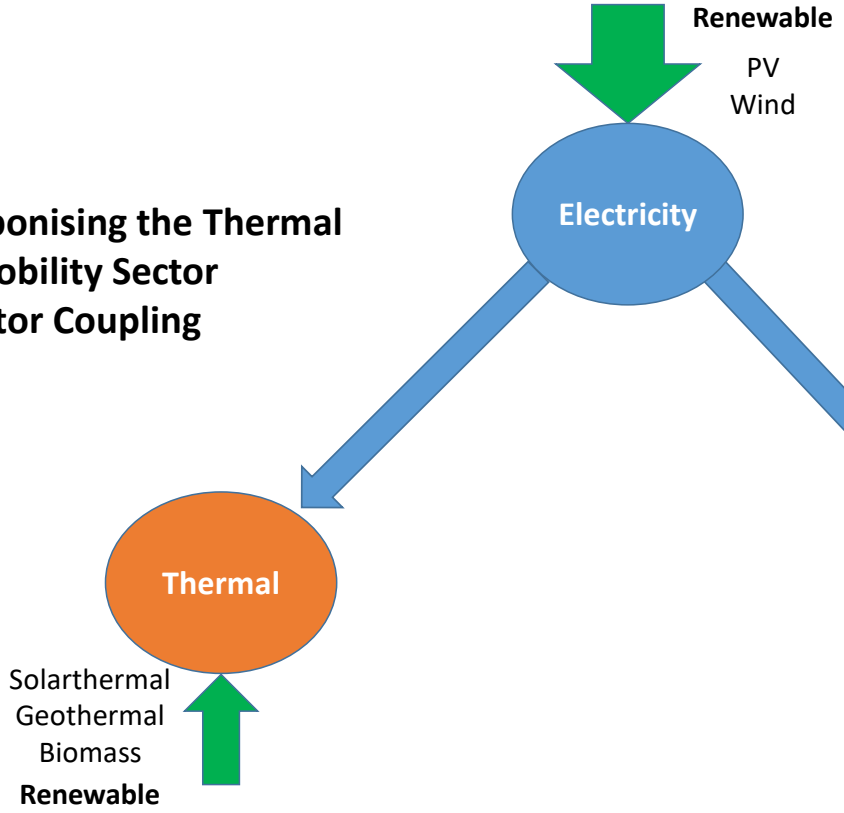
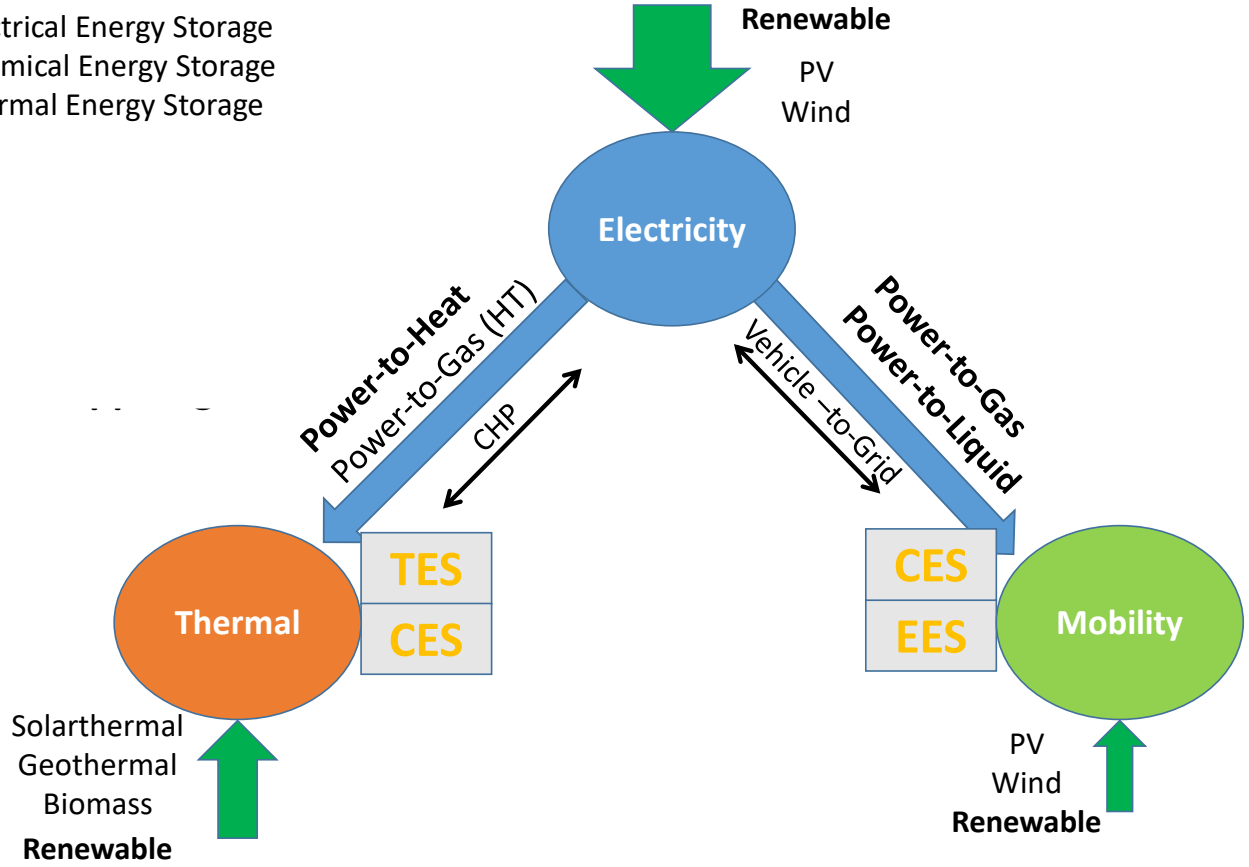
Decarbonising the Thermal and Mobility Sector by Sector Coupling



Mismatch in Supply and Demand!

„Flexible Sector Coupling“

EES = Electrical Energy Storage
CES = Chemical Energy Storage
TES = Thermal Energy Storage



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…better keep it simple!

BVES
BUNDESVERBAND
ENERGIESPEICHER

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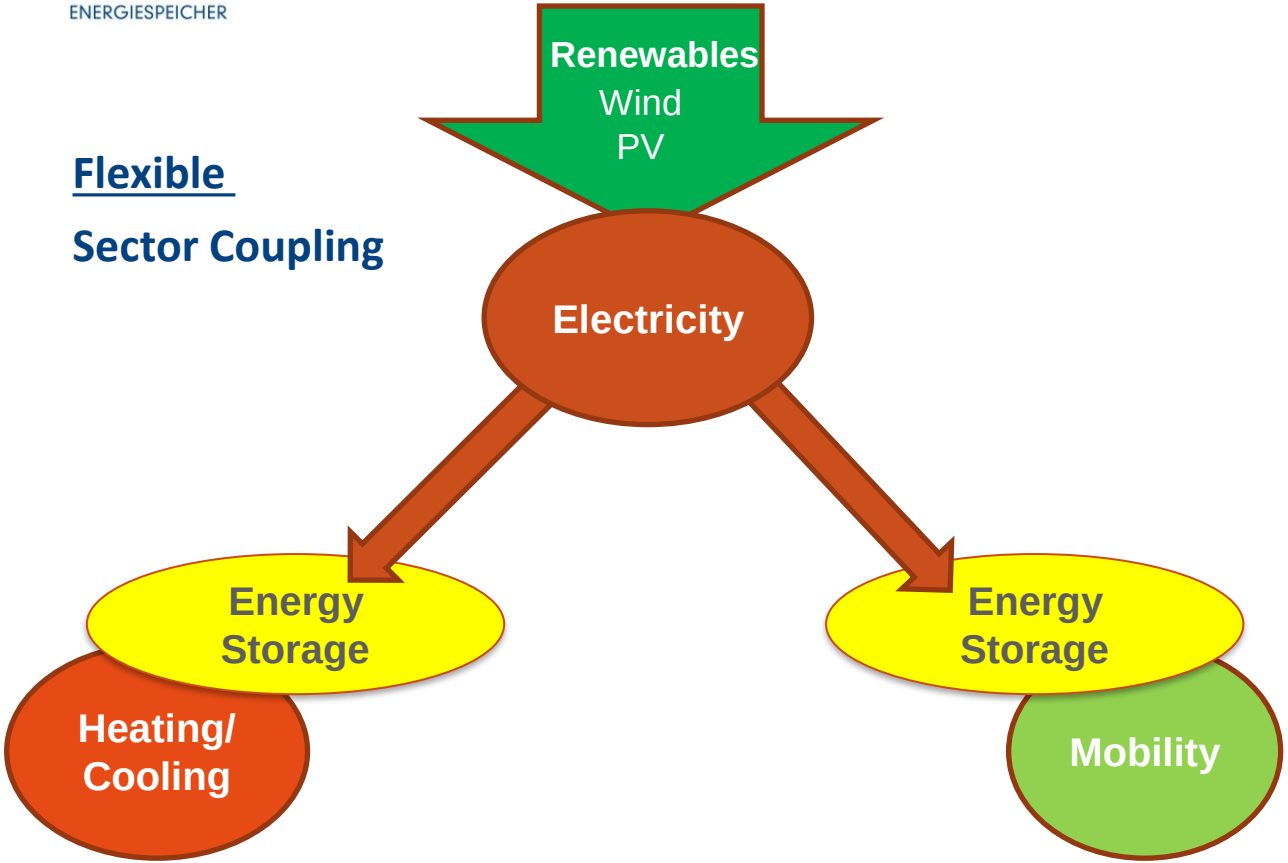
Flexible

Sector Coupling



BVES
BUNDESVERBAND
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Flexible

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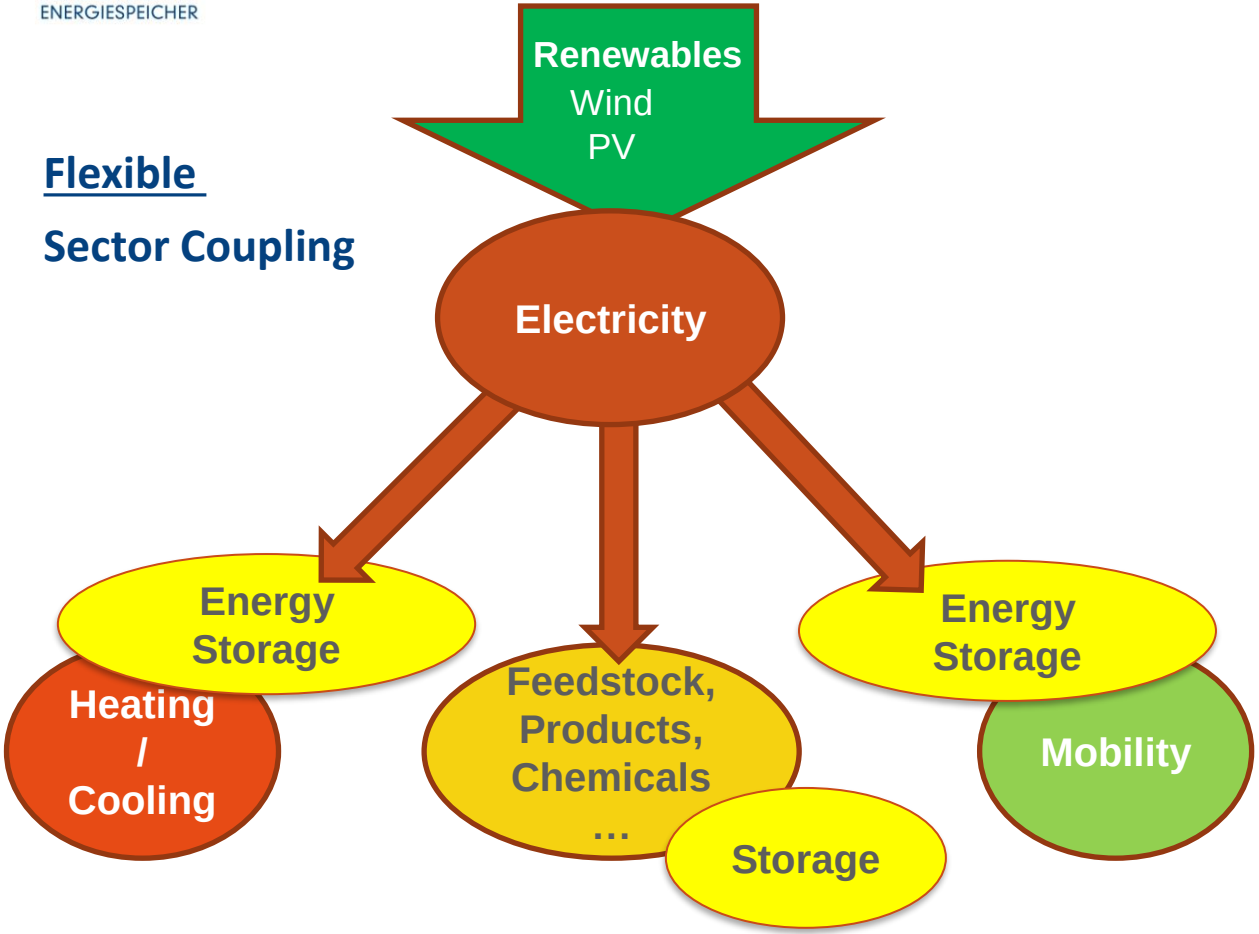
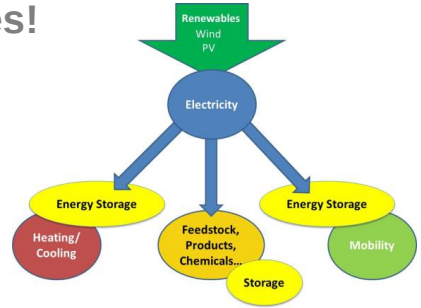
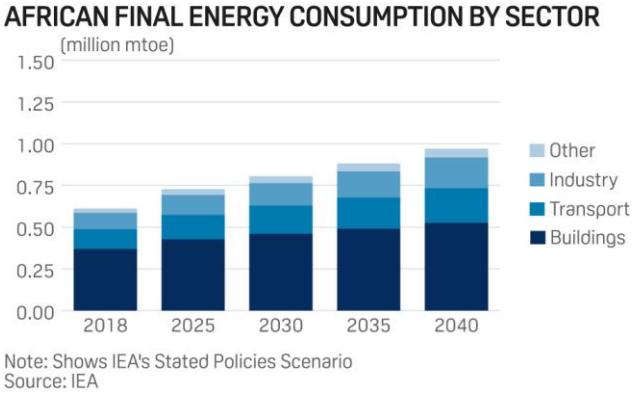


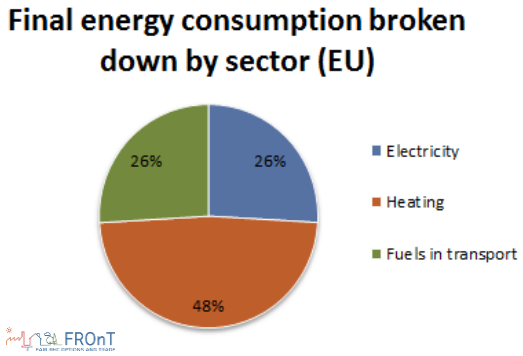
Why Flexible Sector Coupling?

Important: Higher degree of utilization of renewable sources!
Economic justification!

Sector Coupling is key to decarbonization of all sectors!







Possible Pathways from renewable electricity (from PV or Wind)

- Power-to-Heat
- Power-to- Cold

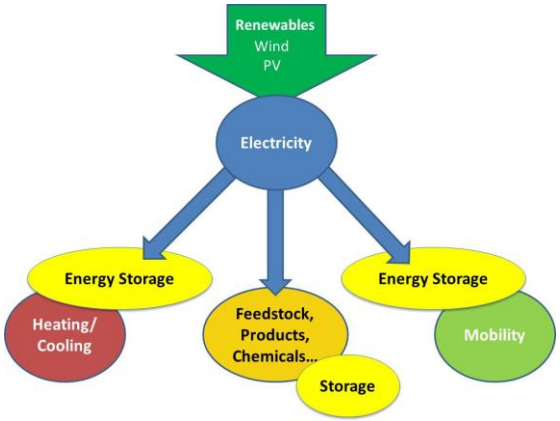
} Thermal Sector

- Power-to-Hydrogen
- Power-to-Water
- Power-to-Chemicals

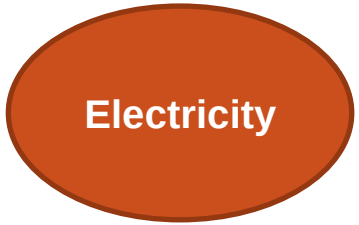
} Industry/Agriculture Sector

- Power-to-E-Mobility
- Power-to-Hydrogen
- Power-to-Fuel

} Mobility Sector



Latest Way of Visualizing the Concept



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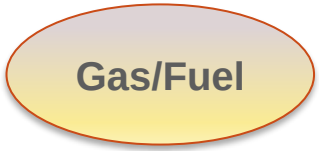
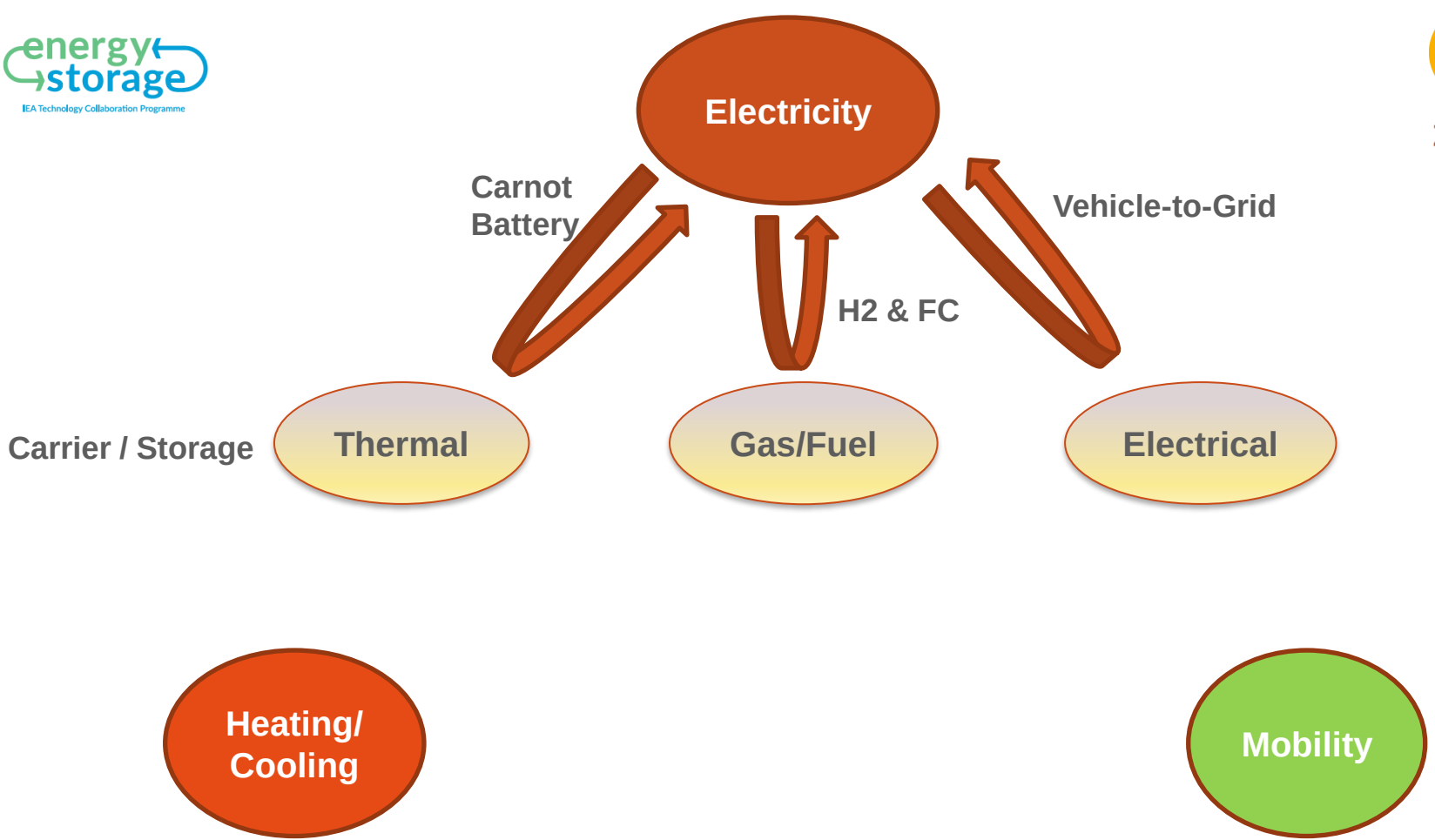
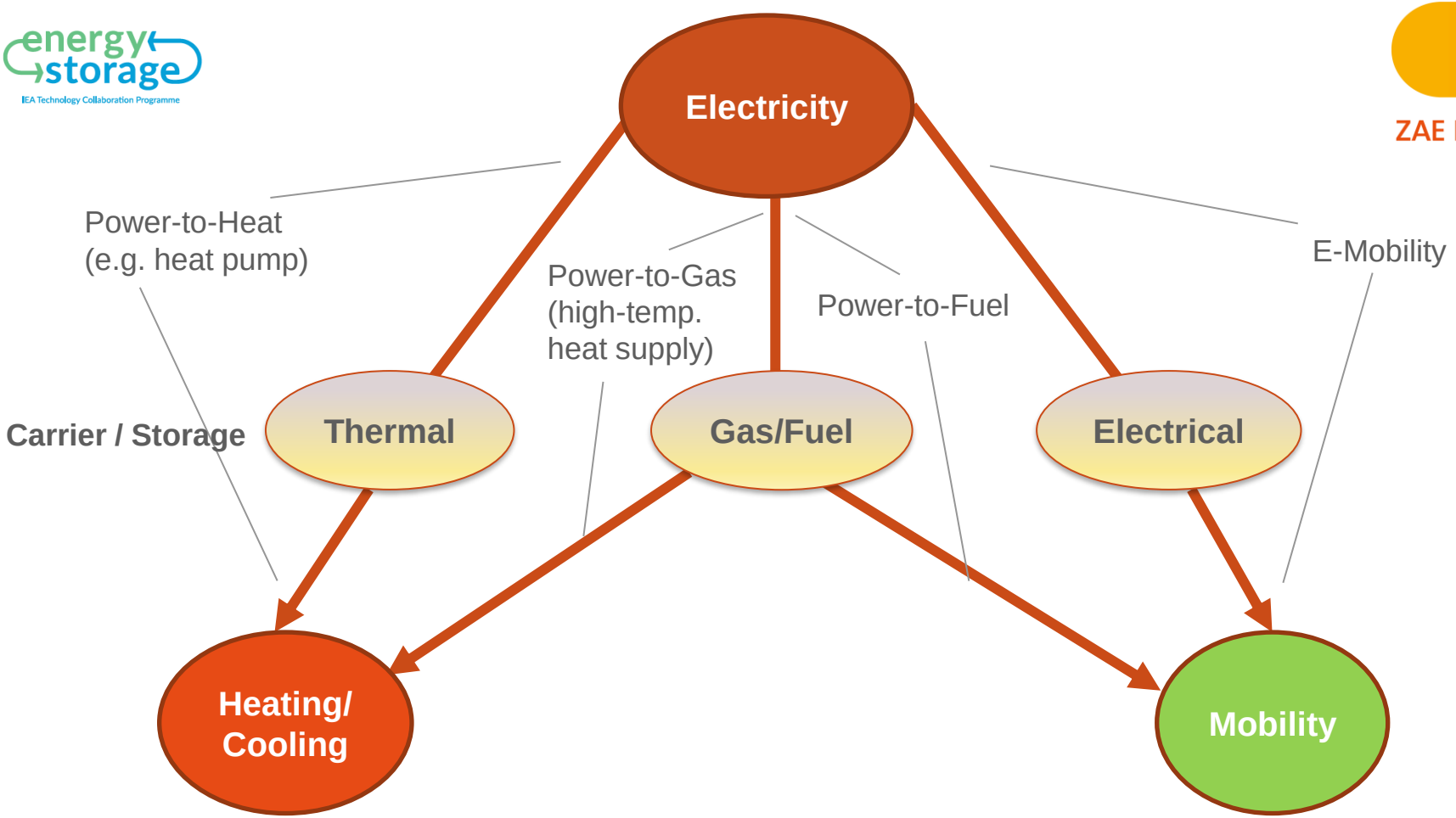
Carrier / Storage



All Carrier = 100 % energy to store and to provide (thermal, electrical, chemical)


Electricity
Carnot
Battery
H2 & FC
Vehicle-to-Grid
Carrier / Storage
Thermal
Gas/Fuel
Electrical
Heating/
Cooling
Mobility


Electricity
Power-to-Heat
(e.g. heat pump)
Power-to-Gas
(high-temp.
heat supply)
Power-to-Fuel
E-Mobility
Carrier / Storage
Thermal
Gas/Fuel
Electrical
Heating/
Cooling
Mobility

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Further Structuring
the Energy Storage Solutions
For Flexible Sector Coupling

Configuration Related Storage Technology Specifications

Energy storage solutions have to be adapted to their actual application!

	Autarcic Systems/ Island Solutions	Rural Structures/ Districts/Mini Grids	Central Structures/ Cities/Grid
Renewable Energy Source	PV / Wind Biomass Solarthermal	PV / Wind CSP / Biomass Solarthermal Geothermal	PV / Wind CSP / Geothermal
Energy Storage Technologies	EES / TES P2G P2F	EES / TES P2G P2F	EES
Demand/ Energy Consumption	Heating/ Cooling Mobility	Heating/ Cooling Mobility	All (supply from grid)

EES = Electrical Energy Storage, TES = Thermal Energy Storage, P2G = Power-to-Gas; P2F = Power-to-Fuel, CSP = Concentrated Solar Power

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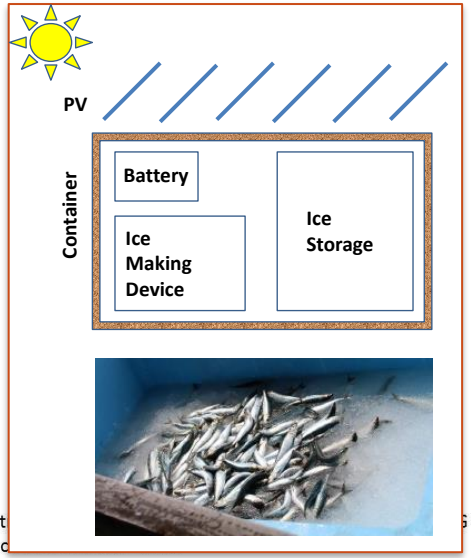
Renewable Energy Source			PV / Wind CSP / Geothermal
Energy Storage Technologies			EES
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EES = Elect … = Power-to-Gas; P2F = Power-to-Fuel,
CSP = Conc…

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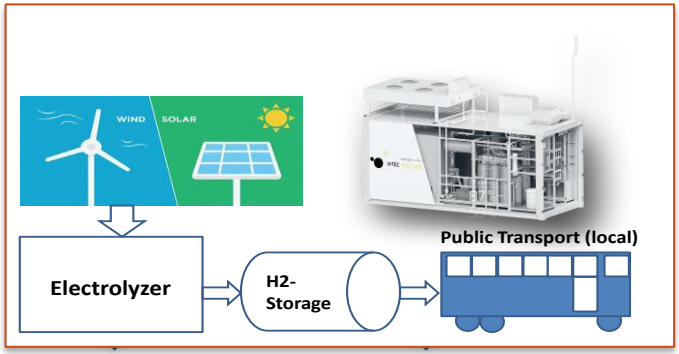

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Concentrated Solar Power

Power -to- Fuel

Synthetic Fuel Storage

Synthetic („Green“) Fuel Export

EES = Electrical Energy Storage, TES = Thermal Energy Storage, P2G = Power
CSP = Concentrated Solar Power

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Conclusions

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- The electricity sector will have the highest share of renewable energy input
- Thermal and the mobility sector are responsible for 75 % of CO_2 emissions
- Sector coupling is crucial for decarbonizing all sectors
- Only „Flexible Sector Coupling“ allows to match supply and demand!
- A number of energy storage technologies is available to address this approach

Thank you very much for your attention!

ZUSE-GEMEINSCHAFT

FVEE ForschungsVerbund Erneuerbare Energien
Renewable Energy Research Association

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Difference between Power & Energy

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„Storage of Power“

„Storage of Energy“

Dispatchable Load

„Energy Sectors“ and CO_2 Emissions

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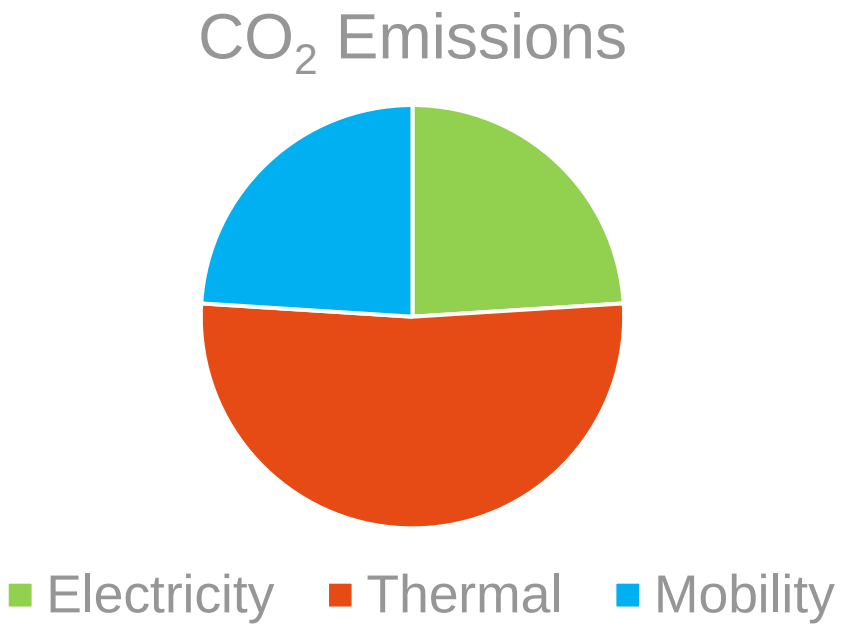
Distribution of CO_2 emissions among the „Sectors“:

• Electricity	21 %
• Thermal	50 %
• Mobility	24 %
	100 %



„Sector Coupling“

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