Bauzentrum München

Sektorenkopplung für Mehrfamilienhäuser 2023

30. März 2023, online

Flexible Sektorenkopplung mit Energiespeichern - die Zukunft der Energiewende?

Dr. Christoph Rathgeber

ZAE BAYERN

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- Energy Storage – Definitions
- Energy Storage – Technologies
- Energy Storage – Applications

- Flexible Sector Coupling – Definitions & Assumptions
- Flexible Sector Coupling – Concept
- Flexible Sector Coupling – Applications & Best Practice Examples

- Conclusions

Energy Storage – Definitions

Definition „Energiespeicher“

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Was ist ein Energiespeicher?

Ein Energiespeicher kann Energie aufnehmen und zu einem späteren Zeitpunkt wieder abgeben.

Der Speicherprozess besteht prinzipiell aus drei Schritten:
Dem Laden, dem eigentlichen Speichern und dem Entladen.

Nach dem Entladen kann ein Energiespeicher erneut geladen werden.

BVES

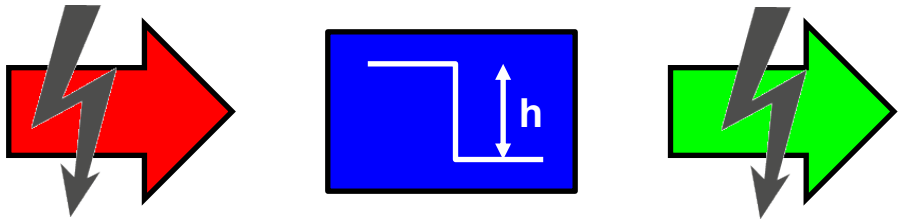
Definition „Energiespeicher“

Was wird gespeichert?

Die Energieform (Elektrizität, Wärme, Kälte, mechanische Energie, chemische Energie), die ein Energiespeicher aufnimmt, wird in der Regel auch wieder abgegeben.

Allerdings wird häufig die geladene Energieform zur Speicherung in eine andere umgewandelt (z. B. Pumpspeicherwerk).

Zum Entladen wird sie dann wieder in der ursprünglichen Form bereitgestellt, oder in manchen Ausprägungen auch in der Form der Speicherung bereitgestellt, z. B. Power-to-Gas oder Power-to-Heat.



Difference between Power & Energy

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„Storage of Power“

Picture: ADS-TEC

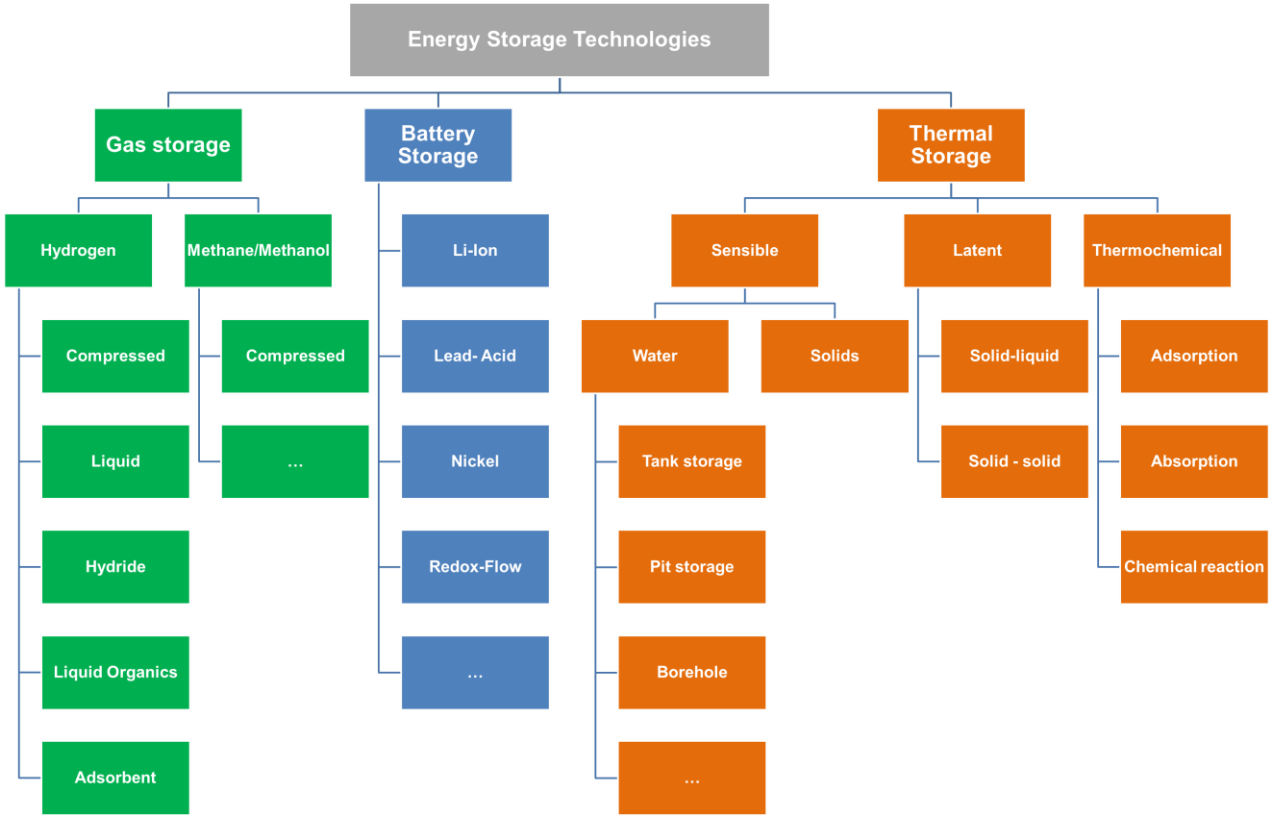
e.g. Power Reserve

„Storage of Energy“

e.g. Peak Shaving / Dispatchable Load

Energy Storage – Technologies

Overview of Energy Storage Technologies (non-exhaustive)



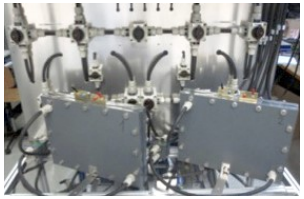
Electrical Storage Technologies

- **Electrical Energy Storage**


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

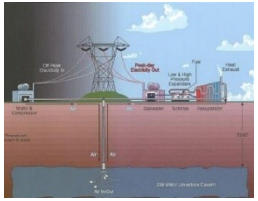
- **Electrochemical Energy Storage**





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

- **Mechanical Energy Storage**


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

Thermal Storage Technologies

- **Sensible heat storage**



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

- **Latent heat storage**




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

- **Thermochemical heat storage**



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

Chemical Energy Storage

Energy Storage by Hydrogen Production and Storage

- Hydrogen: highest energy density per mass
- Loss-free long-term storage possible
- Electricity production by fuel cells

- From Hydrogen a number of energy carriers can be developed, e.g. Methane
- Methane storage with existing Infrastructure (natural gas)

Energy Storage – Applications

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
- …

Transport

- Propulsion
- Heating / Air Conditioning

Energy Storage Applications

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Renewable Energies

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- …

Transport

- Propulsion
- Heating / Air Conditioning

EES – Electrical Energy Storage

TES – Thermal Energy Storage

CES – Chemical Energy storage

EES/TES/CES – All Storage Technologies

„Flexible Sector Coupling“ – Definitions and Assumptions

Definitions of Energy Sectors

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In this context **Sectors = Demand Sectors**

„The energy form needed“ → **Electricity**, **Transport**, **Thermal**

Electricity Sector: (= electric energy)
- „Everything that consumes electricity“
- Obvious = lighting, ICT, controlling,…but also electric motors in industry, appliances in householdes etc.

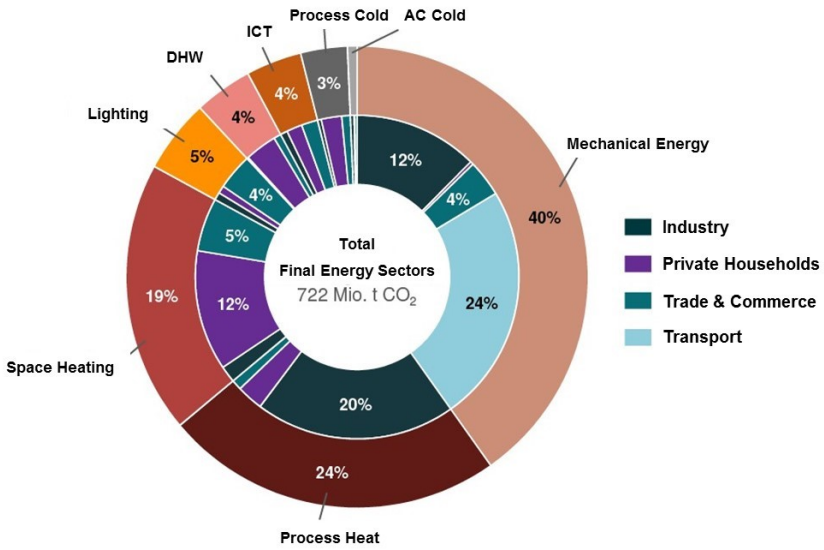
Transport Sector: (= kinetic energy)
- Transportation of goods and people in general
- Vehicles: cars, buses, trucks, trains, ships, planes,…

Thermal Sector: (= thermal energy)
- Heating & cooling in buildings and industry
- Process heat &cold, space heating, domestic hot water,…

Example Germany: Energy Demand Sectors and CO2 Emissions

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 %
- **Transport** **24 %**



The thermal and the transport sector cause about 75 % CO_2 emissions in developed countries.

Source of figure: 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

Assumptions for Sector Coupling

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1. Main energy source in the future has to be **Renewable Energy**
2. Renewable Energy will come mainly from **Wind and PV → input to the electricity sector**
3. The **relevance of the sectors** (concerning final energy demand and CO_2 emissions): Electricity ≈ 25 %, Transport ≈ 25 %, Thermal ≈ 50 % in developed countries, globally as per figure below
4. **Share of Renewable Energy** already integrated in the different sectors: Highest in the electricity sector but low in transport and heat sectors

Sector Coupling is key to decarbonization of all sectors.

„Flexible Sector Coupling“ – Concept

First Conclusions

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1. **Decarbonizing the transport and thermal sector** is crucial → intergration of renewable electricity by **sector coupling**
2. Higher shares of renewable energy only possible by **matching supply and demand in time** → **flexibility** of fluctuating sources (Wind and PV)
3. This **flexibility** can be delivered by the implementation of **energy storage**
4. The **installed storage capacity** can provide the **final energy needed** e.g. heat/cold, green fuels,…
5. Higher shares of renewables → **Higher degree of utilization of** (already) **installed renewable sources** → **Economic benefits!**

This leads to the concept of

→ **„Flexible Sector Coupling“**

Flexible Sector Coupling (FSC) Concept Development

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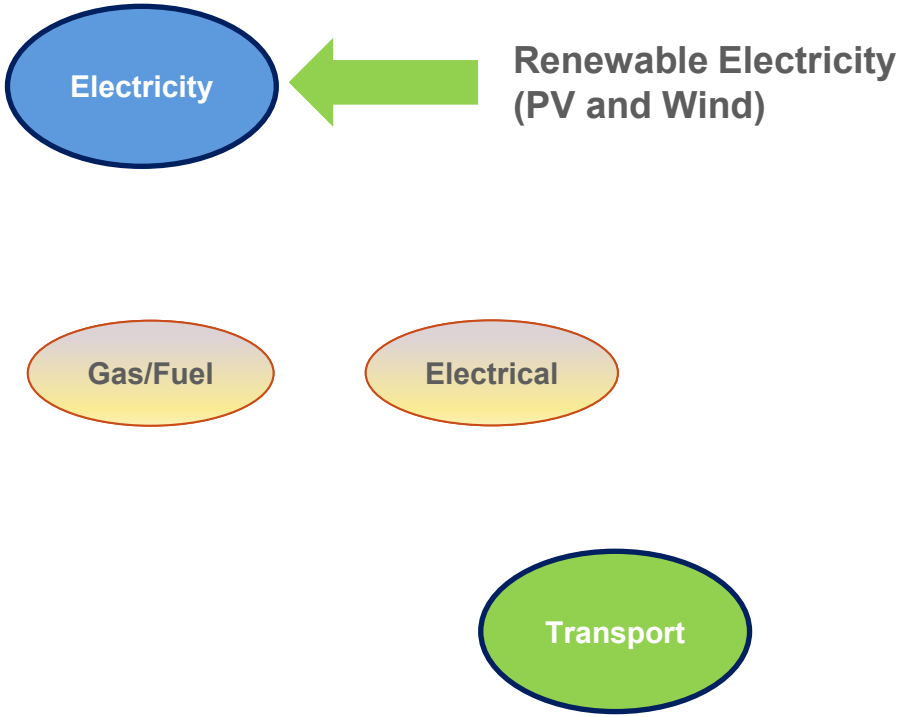

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Flexible Sector Coupling (FSC) Concept Development

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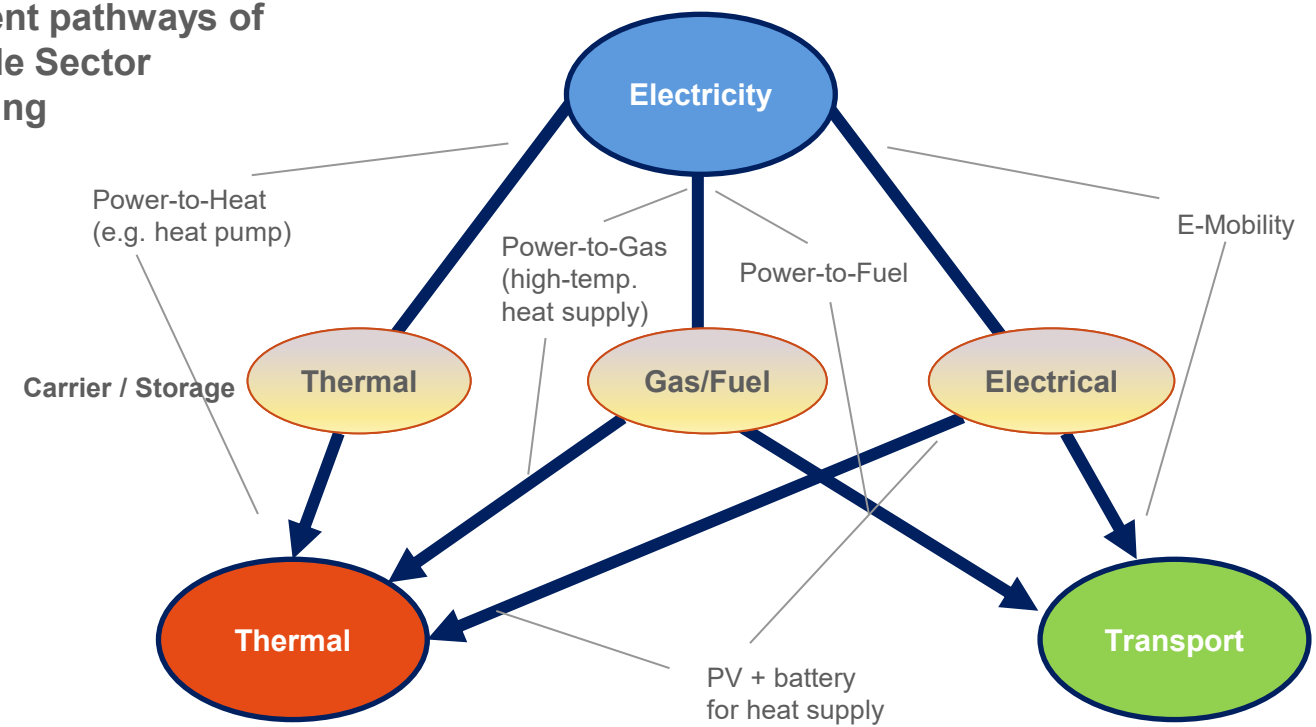
Different pathways of Flexible Sector Coupling



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„Flexible Sector Coupling“ – Applications and Best Practice Examples

Flexible Sector Coupling (FSC) Best Practice Examples

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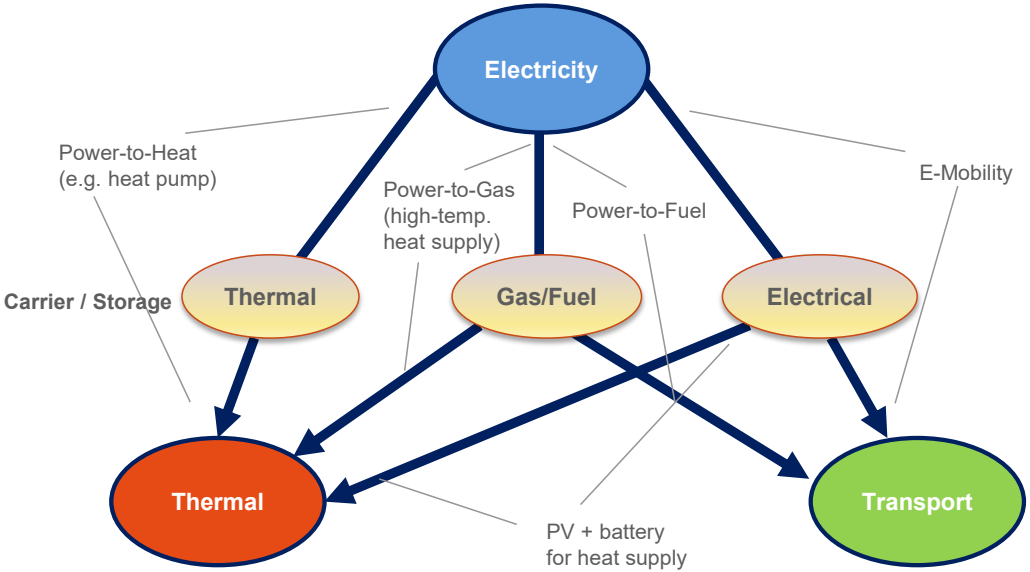
The examples represent possible pathways from the Electricity sector to the Thermal and Mobility sector



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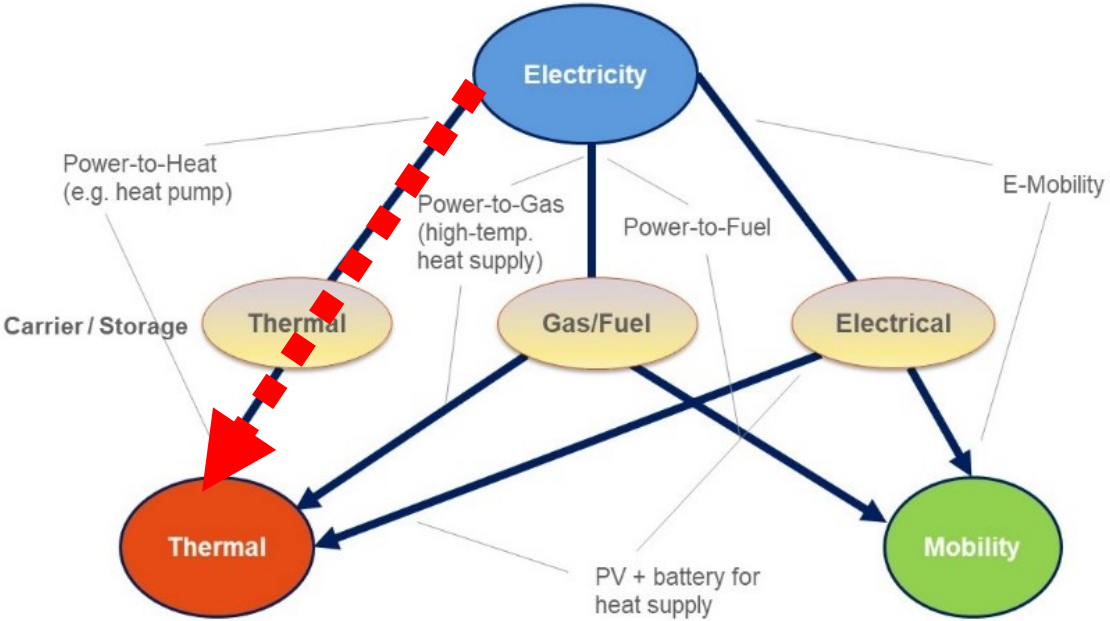
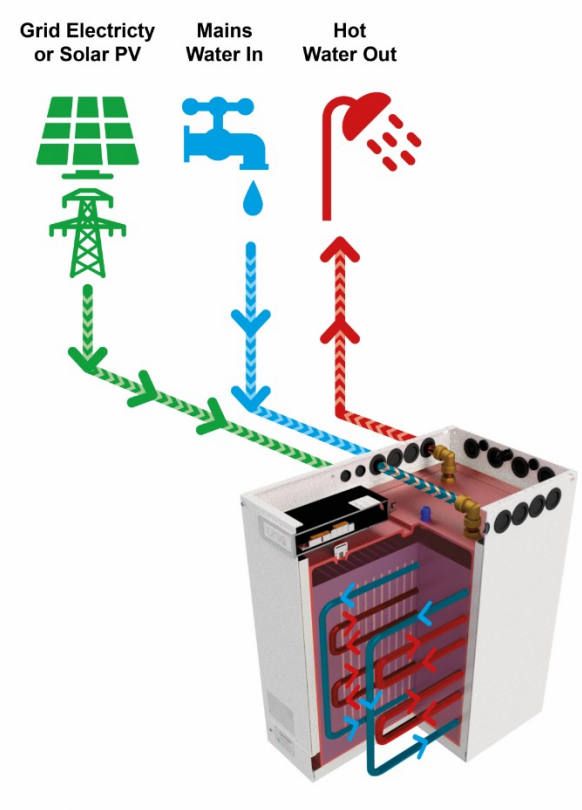
Power-to-Heat with Thermal Energy Storage



„Heat battery“, e.g. by Sunamp



Traditional hot water cylinder

Sunamp heat battery

Pictures: Sunamp Ltd

Integrated PV-Ground source

Ankara, Turkey

TRL	*10*
Storage tech.	*LiIon/sensible heat*
Capacity	*0,0075 Mwh*
Power	*0,024 Mw*
Storage Period	*Minutes/Days*
Sector	*Heat*
Application	*Building*

Describtion:

The PV system installed on the roof meets the electricity demand of the house, excess power is either stored in Li-ion batteries or converted to heat and stored in 3000 L hot water tank for short term. Stored power/heat is used when solar power is not available. The building is heated by the ground source heat pump and natural ground cooling is provided in summer.

Integrated PV-heat pump flexibilisation

Yozgat, Turkey

TRL	*10*
Storage tech.	*LiIon/sensible heat*
Capacity	*0,009 Mwh*
Power	*0,032 Mw*
Storage Period	*Minutes/Days*
Sector	*Heat*
Application	*Building*

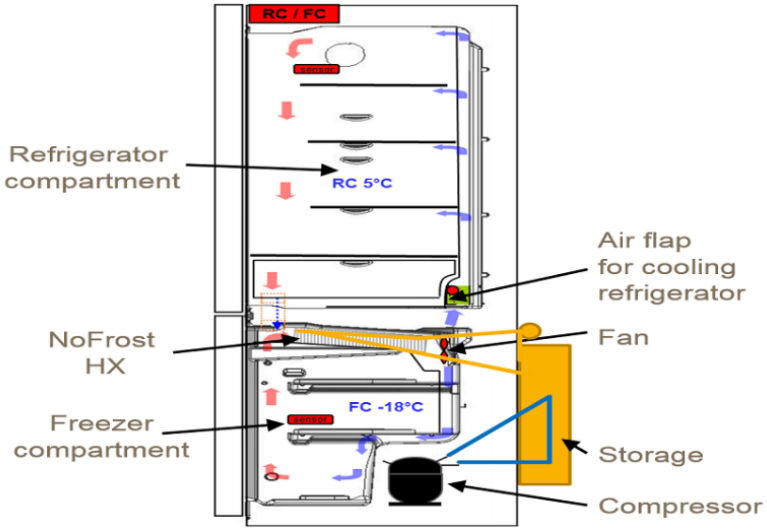
Describtion:

The system is implemented in a 300 square meter single family house for providing electricity from solar power (5 kW PV) and heating using air source heat pump. 9 kW hybrid storage lithium battery and a 400-liter water tank are used as sensible heat storage.

Dites4Grid ZAE, Germany

ZAE, Germany

TRL	*7*
Storage tech.	*Cold*
Capacity	*0,0006 Mwh*
Power	*0,00012 Mw*
Storage Period	*Hours/Days*
Sector	*Heat*
Application	*Buildings*



Describtion:

Within the scope of the DiTES4Grid project the ZAE is analysing to what extent latent heat storage systems made of phase-change materials (PCM) might be suitable for storing cold when there is excess electricity and releasing it back into the refrigerator when there is insufficient electricity.

Fraunhofer ISE, Germany

SQ Durlach

TRL	*10*
Storage tech.	*Heat*
Capacity	*0,35 Mwh*
Power	*0,26 Mw*
Storage Period	*Days*
Sector	*Heat*
Application	*Building*

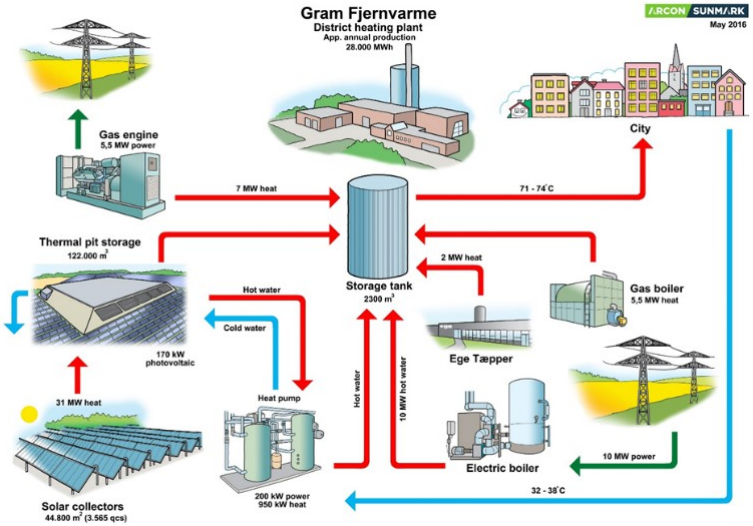
Describtion:

This project aims to design, implement and evaluate an efficient and economic energy supply concept for a cluster of five existing multi-family buildings. The concept consists of photovoltaic modules, two decentral heat pumps and a natural gas cogeneration unit with a small district heating network. As much electricity from PV and CHP should be consumed locally by the heat pumps and tenants.

PlanEnergi, Denmark

Tank Thermal Storage in Gram

TRL	*8-9*
Storage tech.	*Heat*
Capacity	*150 Mwh*
Power	*0,015 Mw*
Storage Period	*Hours/Days*
Sector	*Heat*
Application	*Building?*



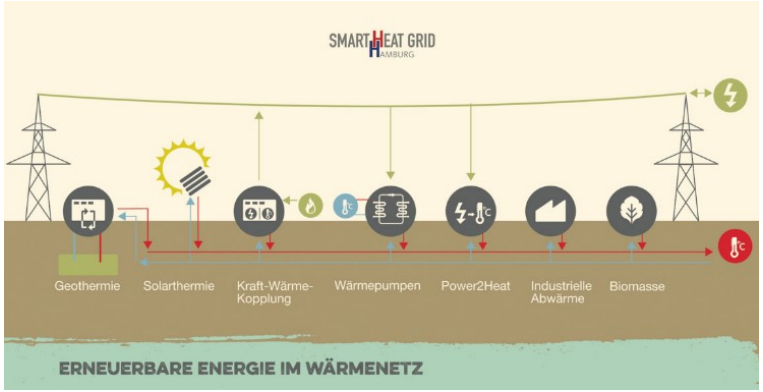
Describtion:

The storage tank is used to balance the short-term fluctuations in district heating demand as well as the supply from CHP, electric boiler, industrial excess heat and solar thermal connected to a seasonal P-TES facility. It is used as a buffer and accommodates the different flows and changes in the system.

HAW Hamburg, Germany

SmartHeatGrid Hamburg

TRL	*8*
Storage tech.	*Heat*
Capacity	*95 Mwh*
Power	*10,38 Mw*
Storage Period	*Hours/Days*
Sector	*Heat/Electricity*
Application	*Building*



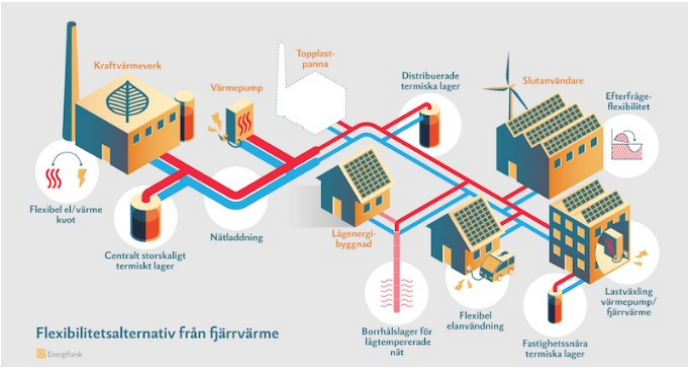
Describtion:

In the Smart Heat Grid Hamburg project, intelligent concepts for all levels of the heating network will be developed during a five-year period and their effectiveness will be demonstrated by extensive field tests in a large local heating network in Hamburg-Wilhelmsburg.

Distributed Cold Storage in District Cooling

KTH, Sweden

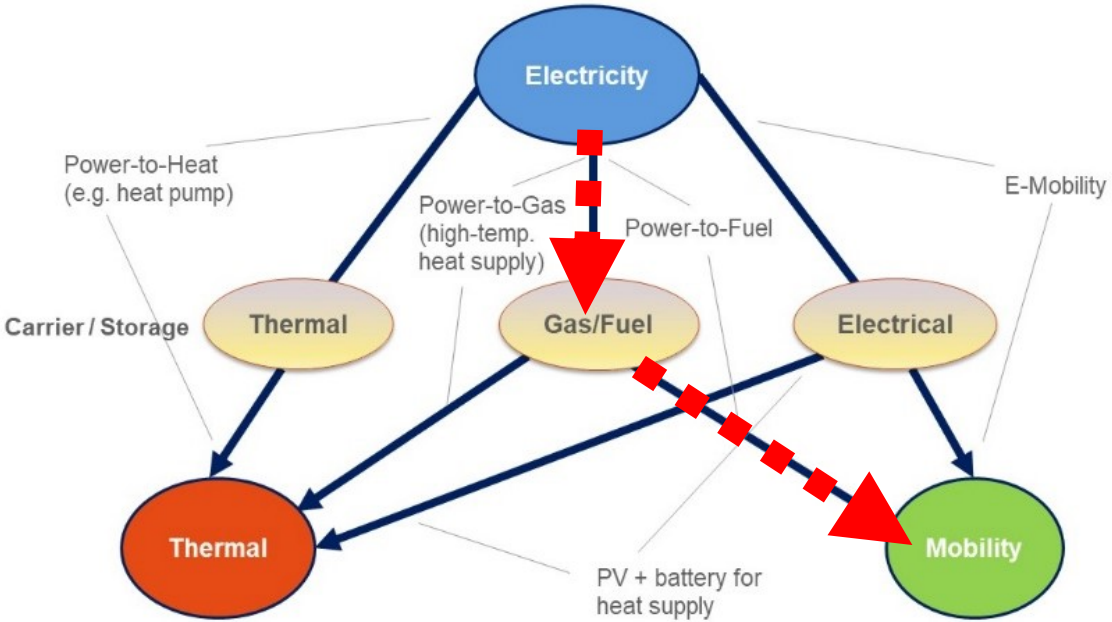
TRL	*8-9*
Storage tech.	*Heat*
Capacity	*70 Mwh*
Power	*10 Mw*
Storage Period	*Hours/Days*
Sector	*Cold*
Application	*Building*



Describtion:

Application: peak cold shaving, district cooling supply balancing, improve the renewable electricity utilization, optimized on lowering CO2 emissions, cost reductions, and increased efficiency. The cold storage is charged during off-peak hours, using free cooling complemented by cheaper nigh-time electricity. The cold storage is discharged to cover the peak cold need during the day.

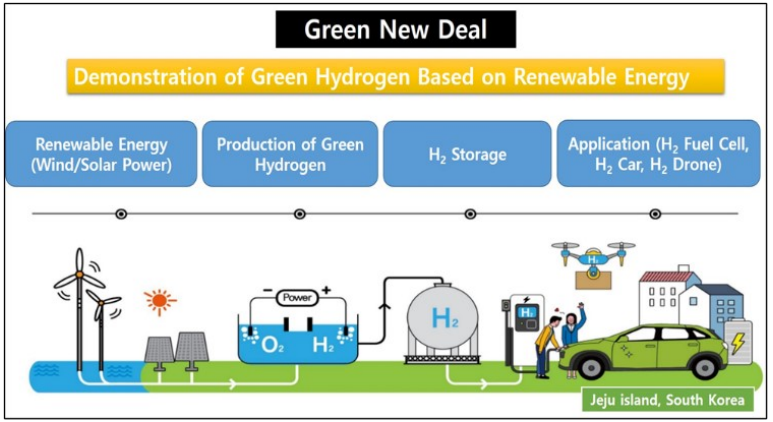
Power-to-Mobility with Gas Storage



Green Hydrogen

Jeju South Korea

TRL	*5-6*
Storage tech.	*H2*
Capacity	*2 Mwh*
Power	*3 Mw*
Storage Period	*Days*
Sector	*Mobility*
Application	*Heavy/Light*



Describtion:

This project is on alkaline electrolysis using renewable energy as an important component of its long-term hydrogen production strategy. During 2020-2023, Jeju Energy Cooperation will performe this project to build 3 MW electrolysis complex connected with wind power capable of producing 200 kg of hydrogen per day.

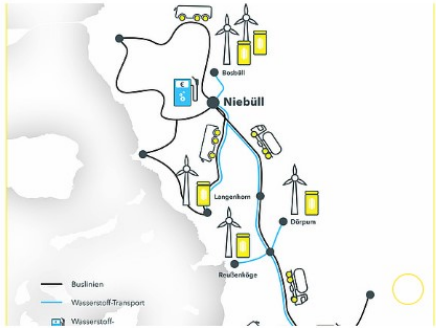
Green hydrogen for mobility

Husum, Germany

TRL	*10*
Storage tech.	*hydrogen*
Capacity	
Power	*1,124 MW*
Storage Period	*Days*
Sector	*Mobility*
Application	*Public transport*

Description:

Electricity from windpower is converted to hydrogen by electrolysers, of which the waste heat can be fed into the local heating grid. The hydrogen produced is transported to tank stations, where electric buses and cars can be fueled. Presently, 12 buses are supplied with green hydrogen.
https://www.gp-joule.de/referenzen/efarm



Pictures: GP Joule

Power-to-Mobility with Electrical Energy Storage

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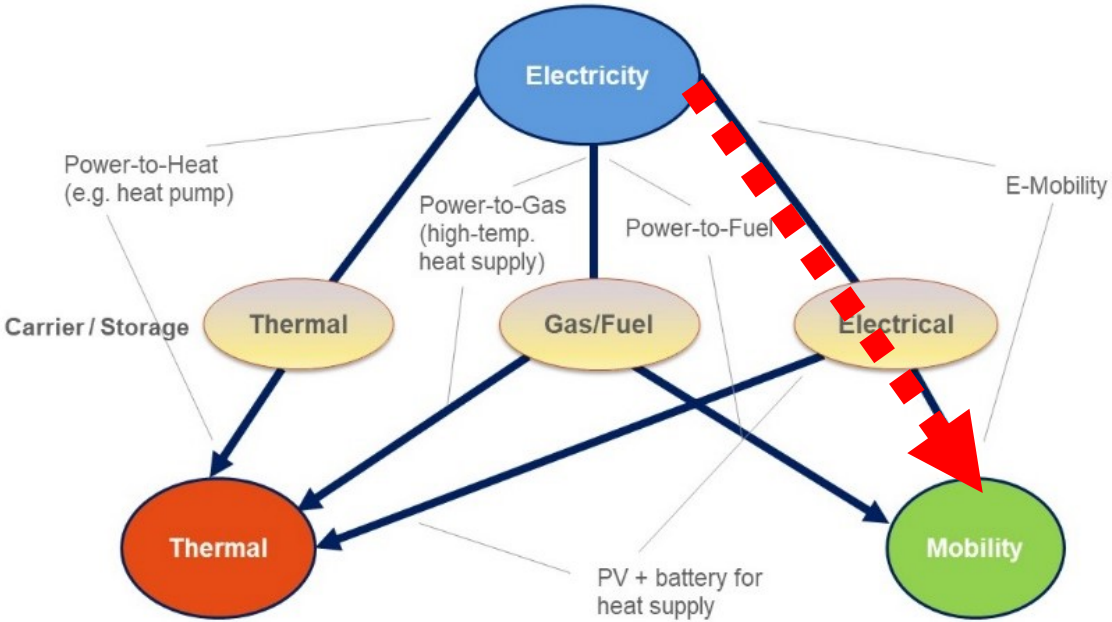

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Collection of FSC examples

Renewable Electricity (PV/Wind) for Batteries in Fast Charging Infrastucture:

- Batteries can replace grid upgrade
- Batteries can enable „Mobile Charging“ (e.g. for events like festivals)

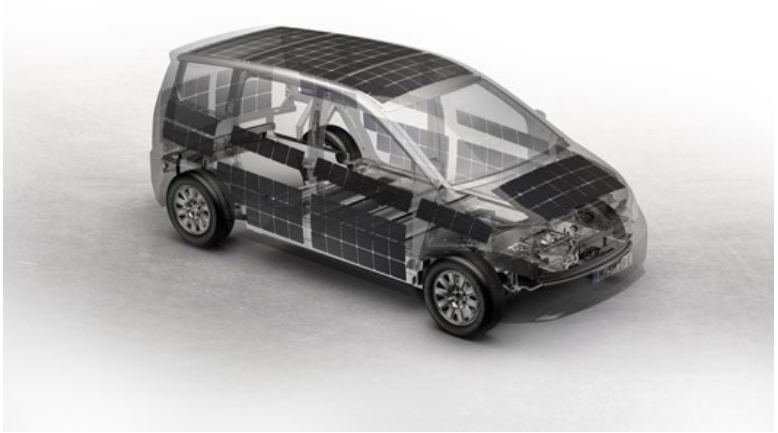
Picture: ADS-TEC

Picture: Porsche AG

Sonomotors, Germany

Bidirectional Solar Electric Vehicle

TRL	*5*
Storage tech.	*Electricity*
Capacity	*0,035 Mwh*
Power	*0,011 Mw*
Storage Period	*Days*
Sector	*Mobility*
Application	*Light*

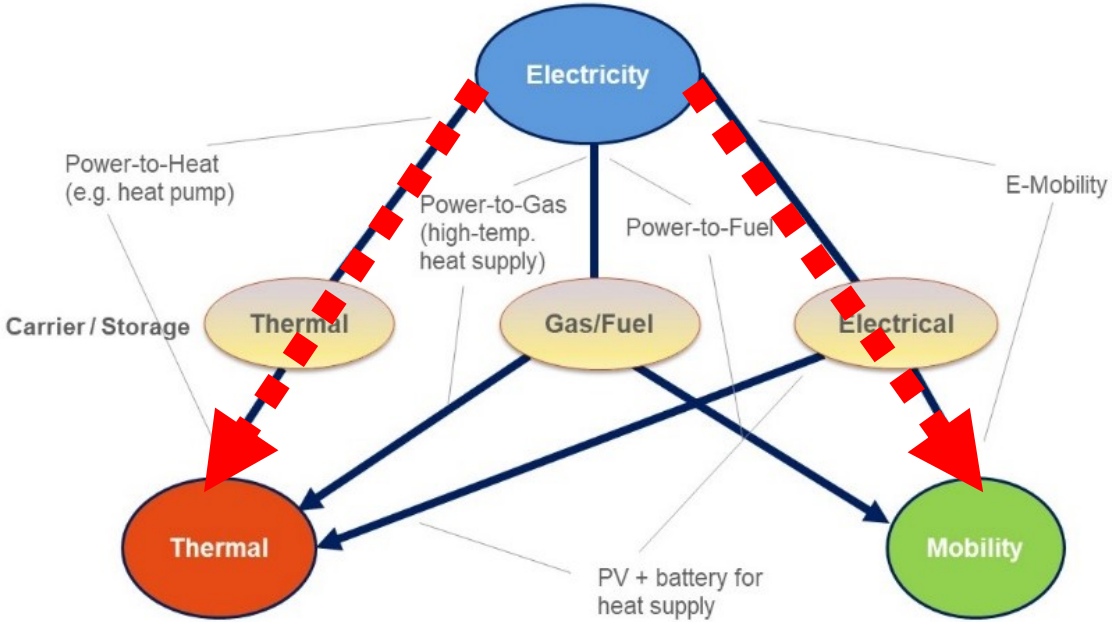


Picture: Sono Motors

Describtion:

The Solar Electric Vehicle (SEV) is equipped with mono-cristaline pv-cells. The cells are fully interated in the exteriour. On a sunny day the electricity generated is sufficient for a range of 34km. Moreover, the SEV can be charged with 11kW AC or up to 50kW DC via charging infrastructure. The installed On-Board-Charger is bidirectional and capable of suppling up to 11kW AC back to the Grid.

Power-to-Heat with Thermal Energy Storage & Power-to-Mobility with Electrical Energy Storage



AEE, Austria

SCORES

TRL	*4*
Storage tech.	*Heat*
Capacity	*0,24 Mwh*
Power	*0,03 Mw*
Storage Period	*Seasonal*
Sector	*Heat*
Application	*Building*

Describtion:

The SCORES concept is based on a hybrid system combining effectively and efficiently solutions that harvest electricity and heat from the sun, store electricity, convert electricity into heat, store heat, and manage the energy flows in the building.

HAW Mittelessen, Germany

Enff Stadt FlexQuartier

TRL	*8*
Storage tech.	*Heat/Electricity*
Capacity	*8,72 Mwh*
Power	*1,38 Mw*
Storage Period	*Minutes/Days*
Sector	*Heat/Moobility*
Application	*Building/Light*

Describtion:

Sector coupling in the district's energy center will be realized by developing a new type of high-temperature storage technology, in combination with a multifunctional battery storage system for electricity and a central hot-water stratified storage system for waste heat. Electromobility will be realized as an additional building block so that all consumption sectors are taken into account.

Example for FSC towards energy autarky

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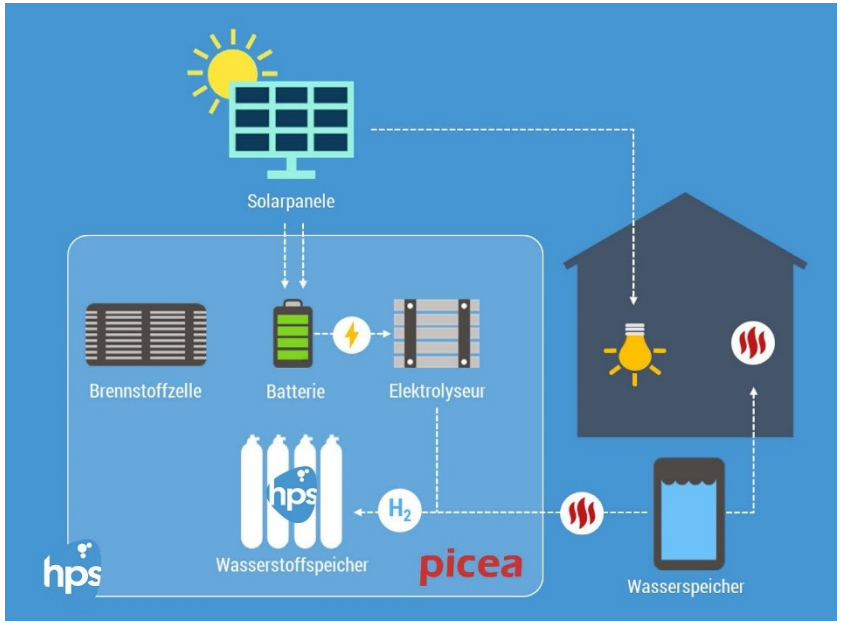

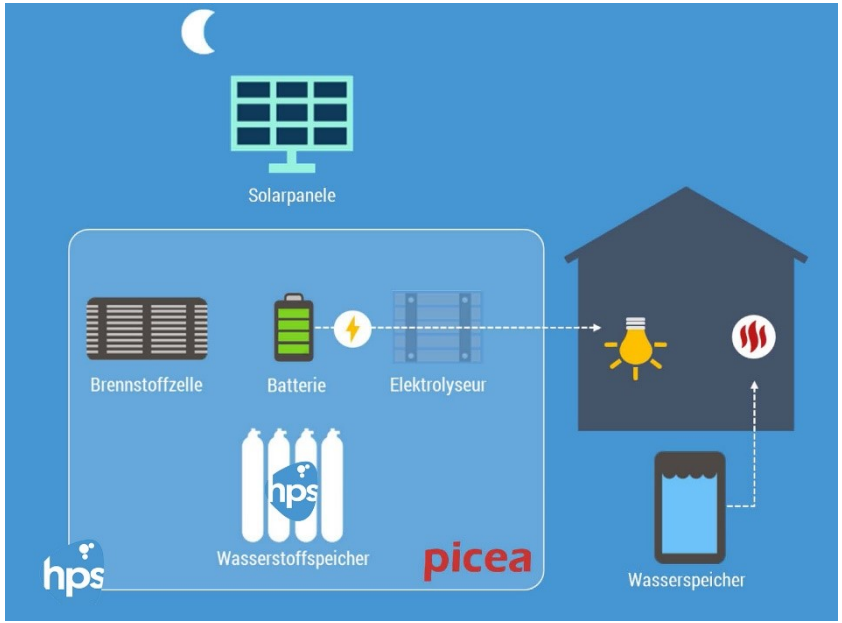

Pictures: HPS

Conclusions

Conclusions

- The electricity sector will have the highest share of renewable energy input.
- Thermal and the transport 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.

Vielen Dank für die Aufmerksamkeit!

Dr. Christoph Rathgeber

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Gefördert durch
Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

Bayerische Klima-Allianz

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