Storage
Swiss Competence Center
for Energy Research

Lucerne University of
Applied Sciences and Arts

HOCHSCHULE
LUZERN

Technik & Architektur

Why do we need to store energy?

Jörg Worlitschek
SCCER Storage of Electricity and Heat

SCCER School - Shaping the Energy Transition

17 to 20 October 2017 in Engelberg

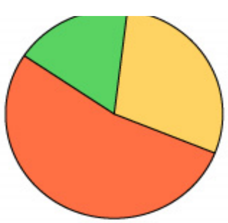
FH Zentralschweiz

EFQM
Recognised for excellence
5 star - 2015

How does he use his energy

10’800 MJ

10-15% Proteins



25-30%
Fats

> 50% Carbohydrate

60% Heat

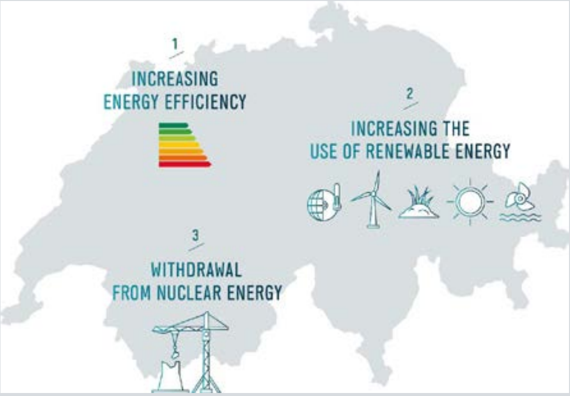
37°C constant

10% Movement

10 % Organs

10 % Thermogenesis

10 % Losses



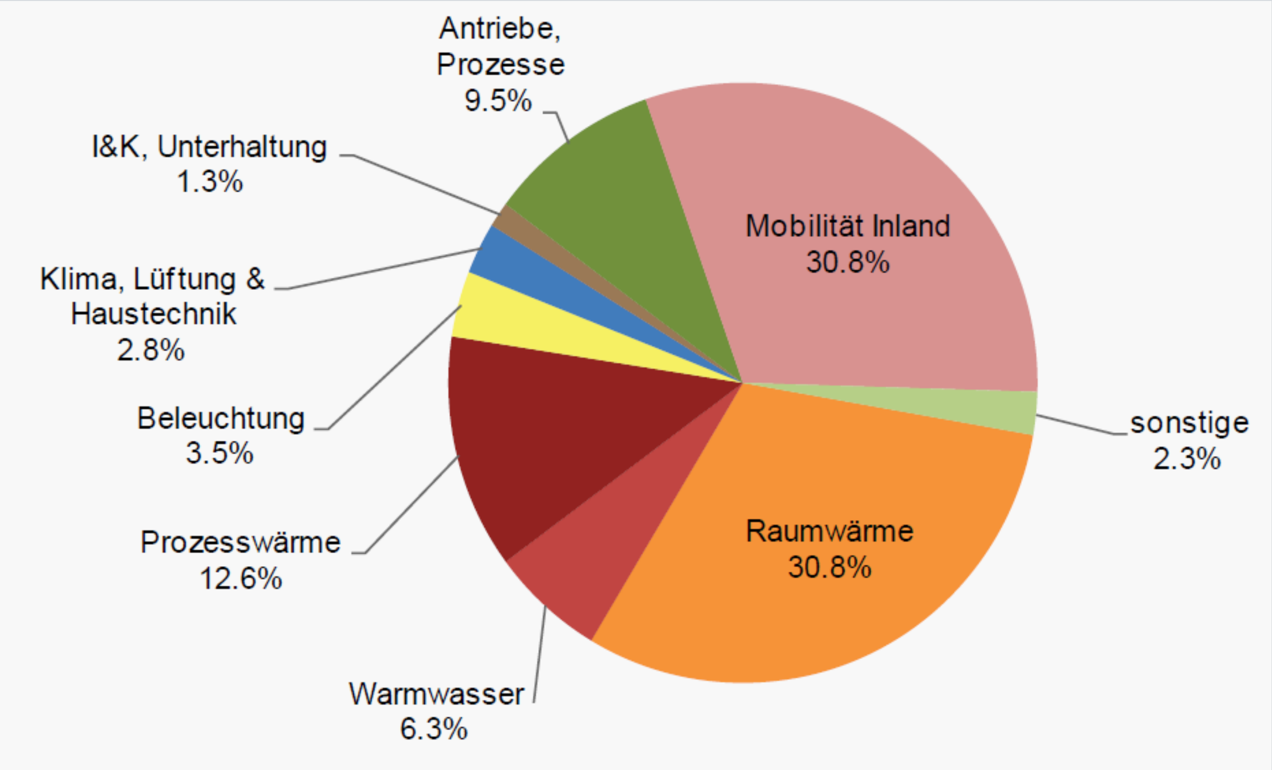
Energy Strategy 2050 –

Where do you see the strongest leverarms?

Energy Use – Switzerland Today

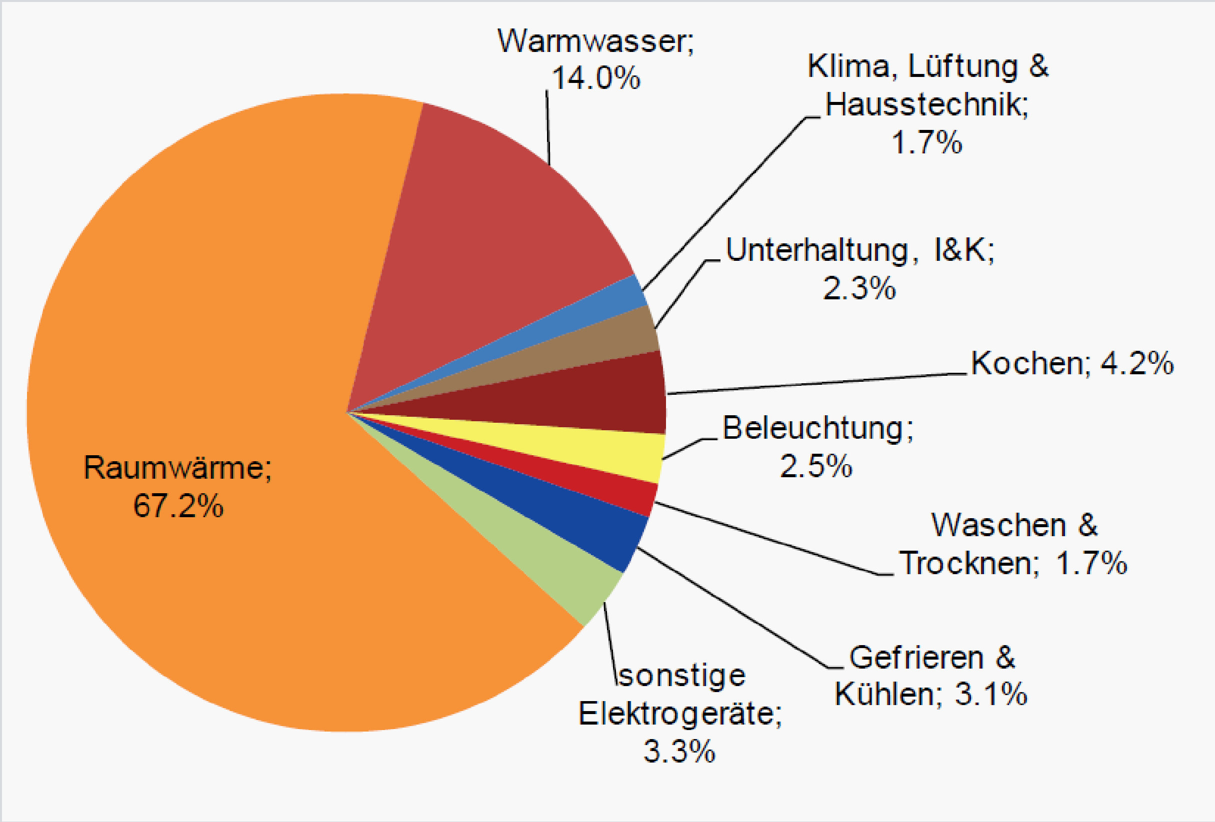
Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center
for Energy Research



Source: SFOE, 2016

Energy Use – Switzerland Today
Domestic

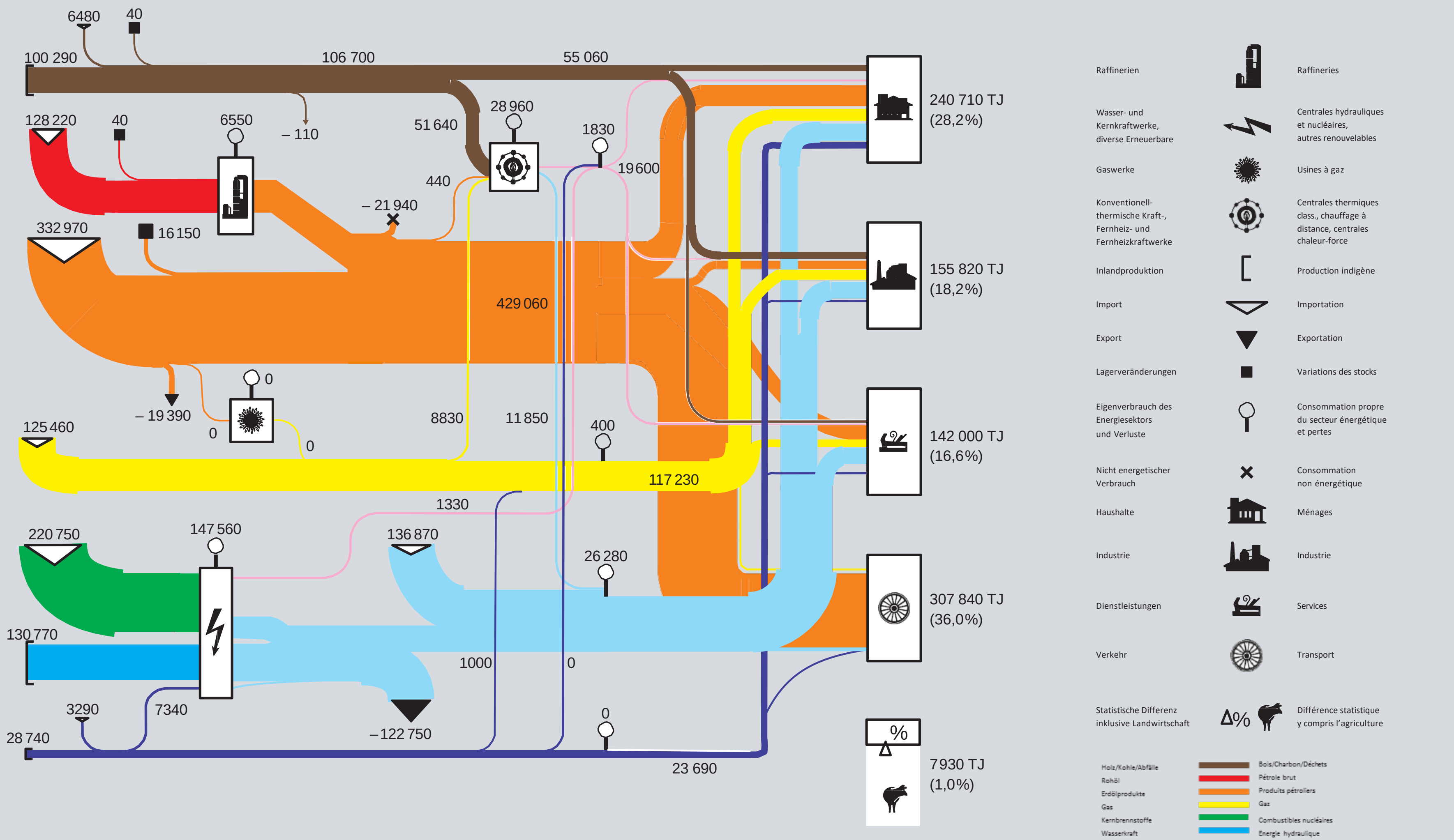


Source: SFOE, 2016

Energy Flow – Switzerland Today

Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center
for Energy Research



Source: SFOE, 2016

How would you define Energy Storage?

Energy Storage – A Definition

Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center
for Energy Research

Energy Storage describes the natural or artificial accumulation of a potential of an energy form along an energy gradient.

- Here, the distinction between natural or artificial refers to the difference between making use of a given storage / inertia of a system and actively charging/discharging a technical storage system.
- Here, potentials of energy forms might be chemical, nuclear, mechanical, electromagnetic, thermal, gravitational potentials.
- Here, energy gradients might refer to one energy form or include the transformation of an energy form to another.

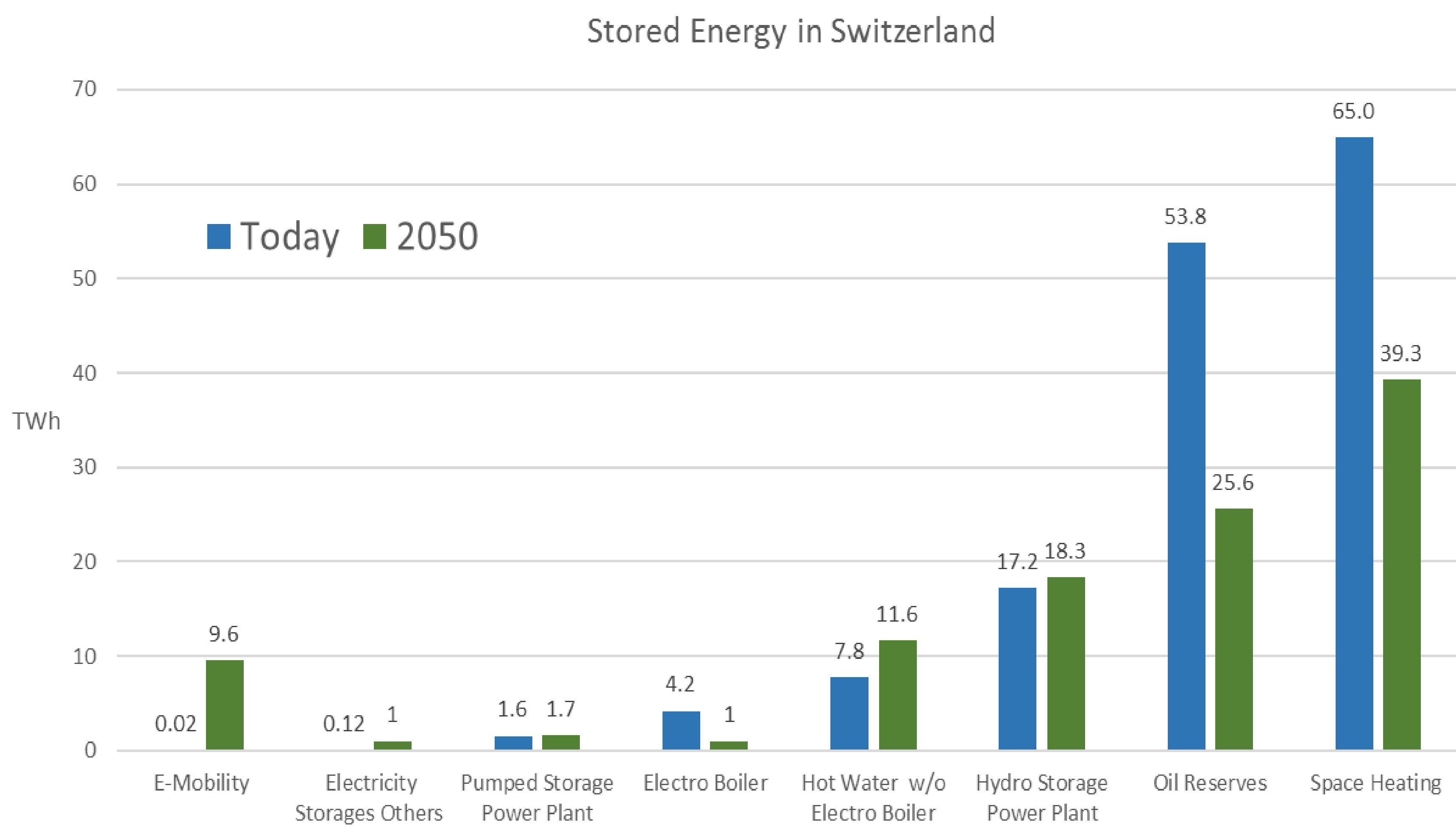
Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center
for Energy Research

Energy Storage in Switzerland

How do we store energy today ?

Energy Storage – Switzerland



Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center
for Energy Research

Energy Storage – Motivation

What are benefits of energy storage?

Energy Storage – Benefits

- Arbitrage
  - The act of purchasing and storing energy when energy prices are low and to resell it when prices are high.

- Black-start
  - Providing emergency power required to restore the grid operation after a failure.

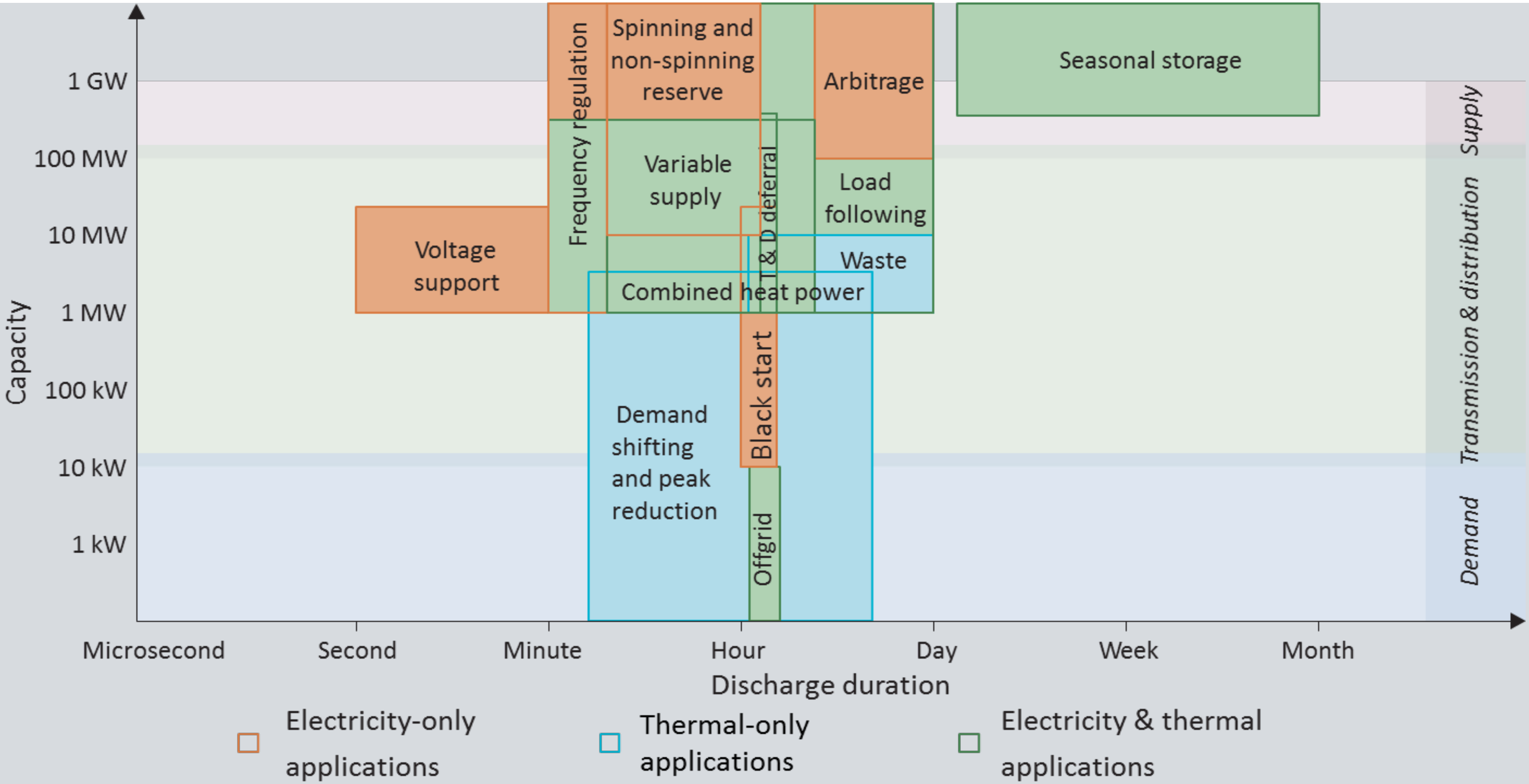
- Energy Balancing
  - Balancing supply and demand within the electricity grid for stable operation via the following options:
    - Spinning and non-spinning reserves
    - Demand shifting and peak reduction
    - Frequency regulation
    - Load following
    - Voltage support

Energy Storage – Benefits

- T&D grid congestion relief and infrastructure investment deferral
  - Shift of demand and supply to relieve congestion in the grid and to avoid the need to expand the T&D grid.
- Off-grid energy access
  - Energy storages can support the implementation of RES in remote regions where the grid lacks buffering quality.
- Increase self-consumption
  - Bridging the mismatch between local energy production and demand (e.g. residential PV).
- Integration of variable supply resources
  - Energy storage technologies provide resources for the energy system to deal with the challenges of integrating RE sources.

Energy Storage – Power requirement versus discharge duration

Hochschule Luzern
Technik & Architektur
Storage
Swiss Competence Center for Energy Research



Sources: IEA (2014), Energy Technology Perspectives, OECD/IEA, Paris, France. Battke, B., T.S. Schmidt, D. Grosspietsch and V.H. Hoffmann (2013), "A review and probabilistic model of lifecycle costs of stationary batteries in multiple applications", Renewable and Sustainable Energy Reviews Vol. 25, pp. 240-250. EPRI (Electric Power Research Institute) (2010), "Electrical Energy Storage Technology Options", Report, EPRI, Palo Alto, CA, United States. Sandia National Laboratories (2010), Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide, A Study for the DOE Energy Storage Systems, Albuquerque, NM and Livermore, CA, United States. IEA-ETSAP (Energy Technology Systems Analysis Programme) and IRENA (2013), "Thermal Energy Storage", Technology Brief E17, Bonn, Germany.

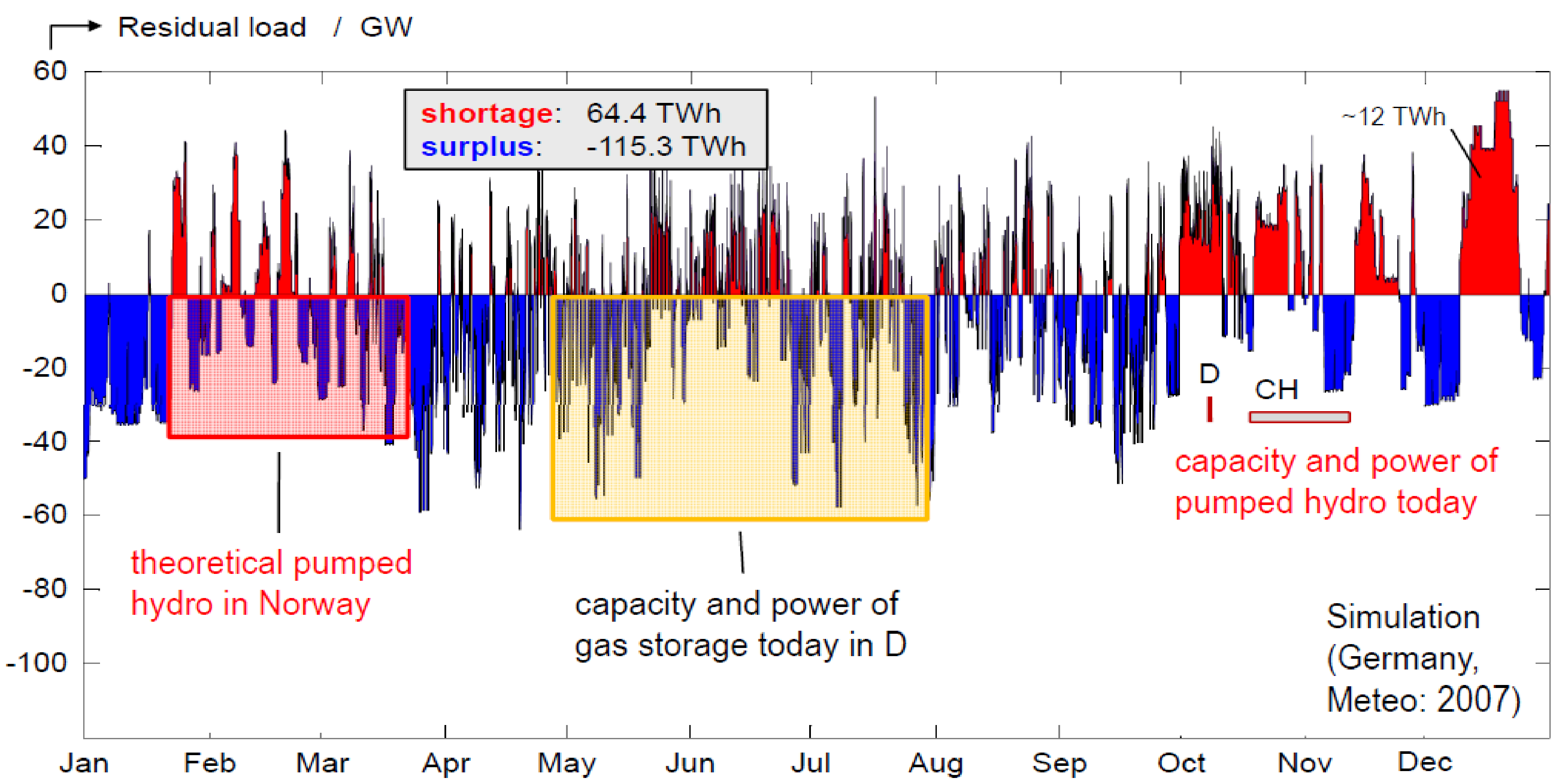
Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center
for Energy Research

Energy Storage – Motivation

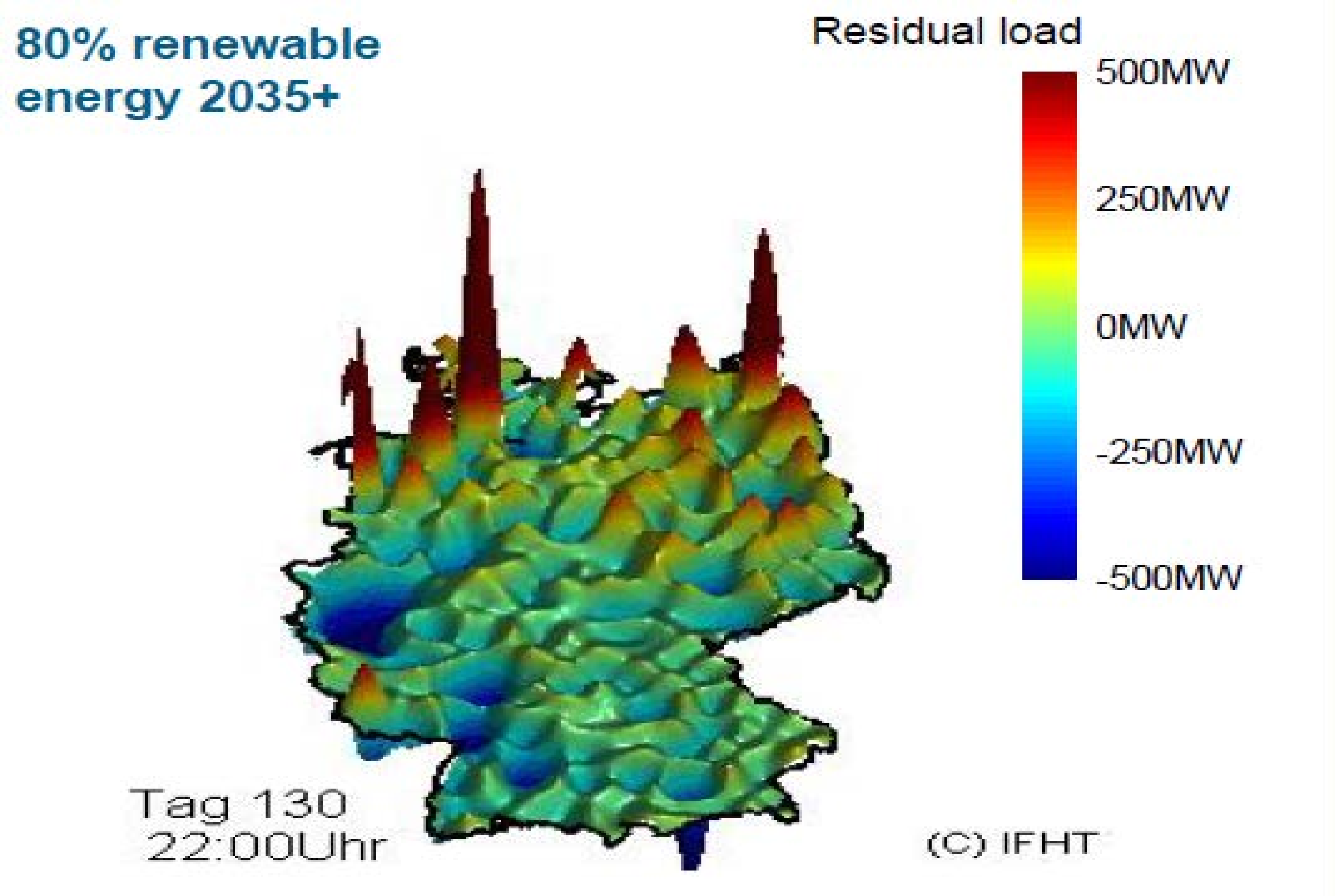
The integration of new renewable energy sources leads to an increase in storage needs?

Energy Storage - Motivation



Source: Fraunhofer IWES, 2013

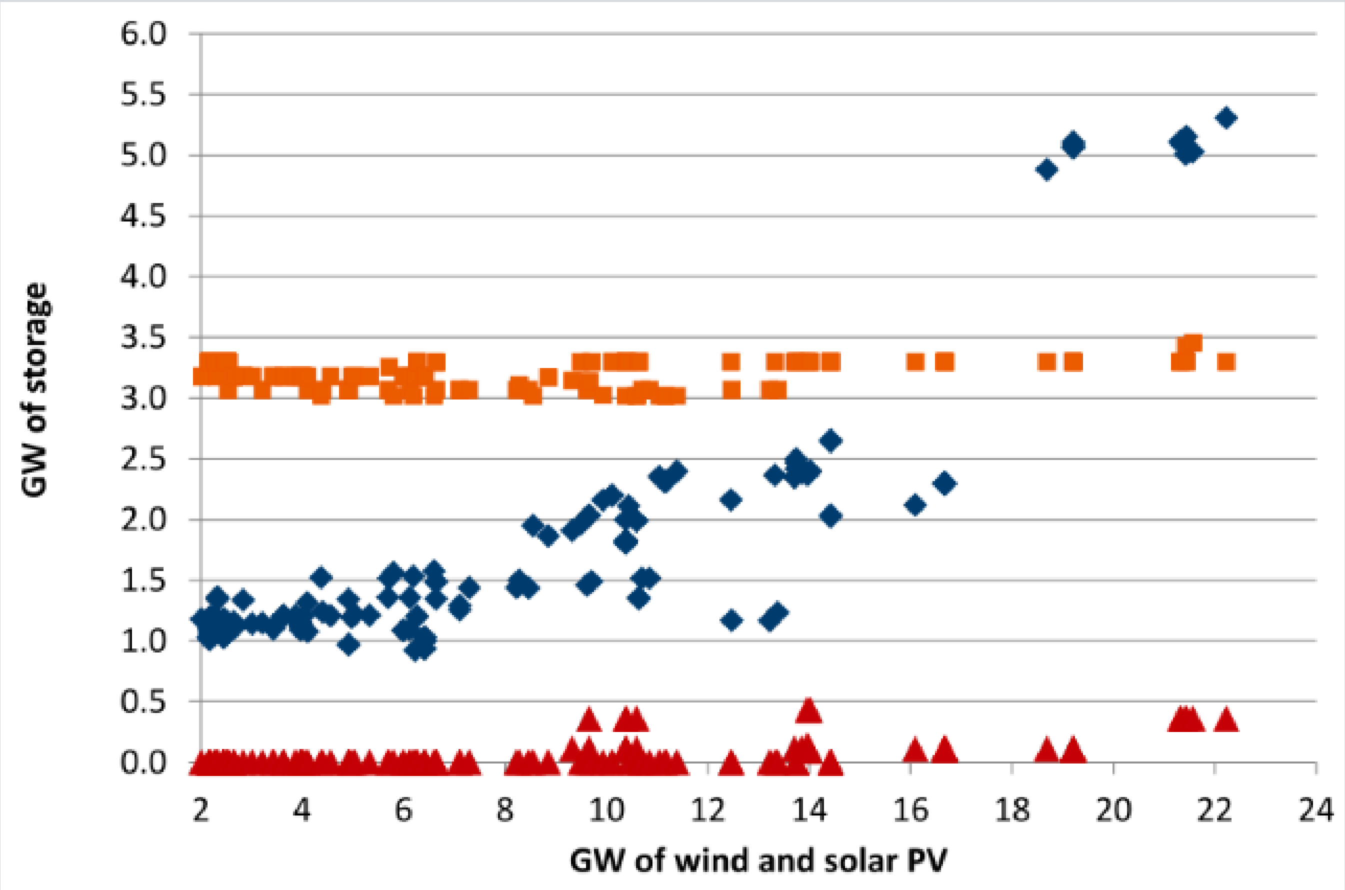
Energy Storage - Motivation



Siemens Multi-modal Energy System Design for Germany and Europe.

Source: Metzger et al., Siemens Multi-modal Energy System Design for Germany and Europe, Dechema Meeting, 2016

Energy Storage - Motivation



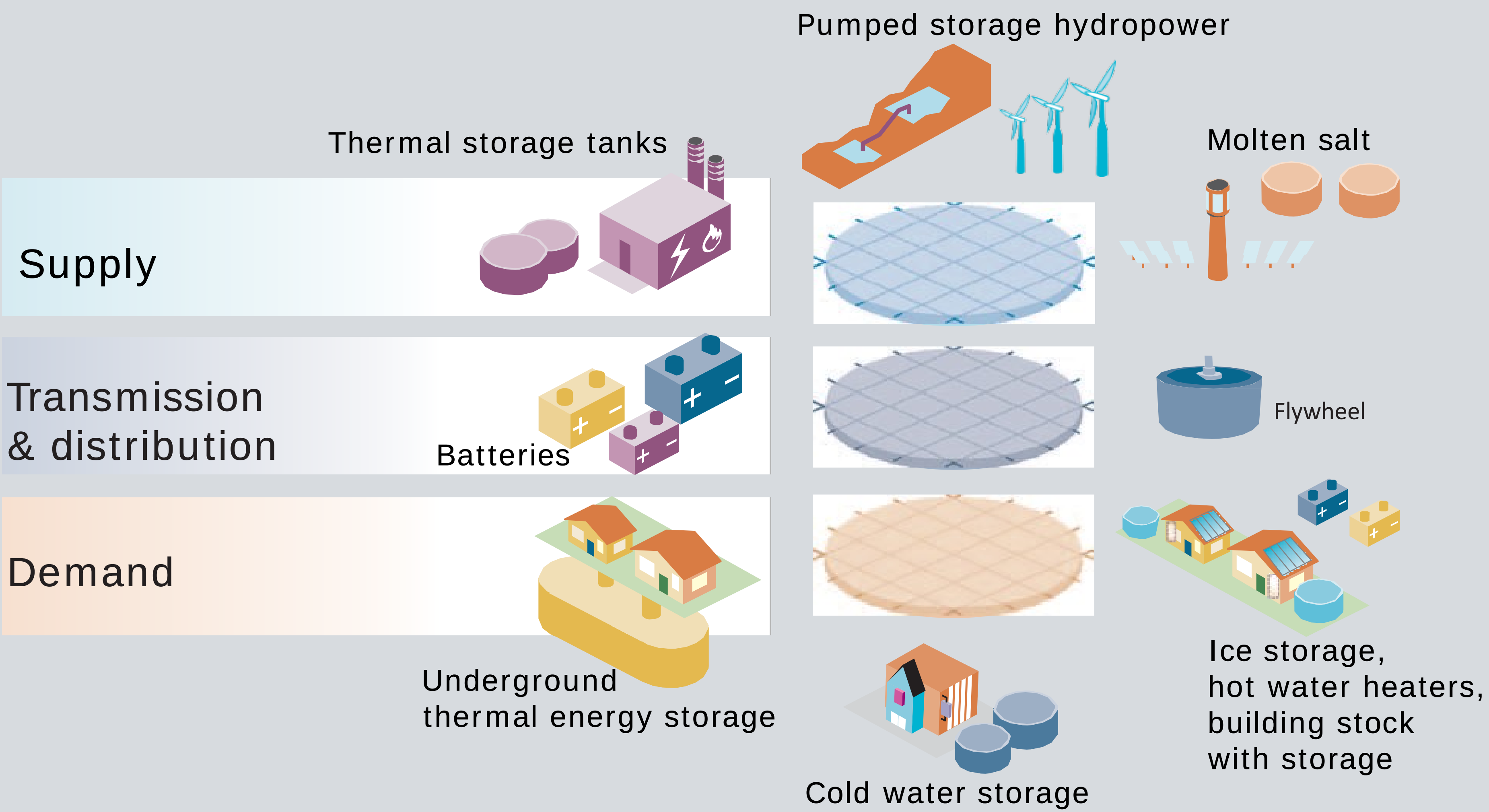
Requirements in Swiss electricity storage (GW) with respect to the installed capacity of wind and solar across all ISCHESS scenarios.

Source: Fuchs A, Demiray T, Evangelos P, Ramachandran K, Kober T, Bauer C, Schenler W, Burgherr P, Hirschberg S (2017) ISCHESS – Integration of stochastic renewables in the Swiss electricity supply system. Final project report, ETHZ & PSI *6*

Energy Storage –
Hypothetical Deployment Power System

Hochschule Luzern
Technik & Architektur

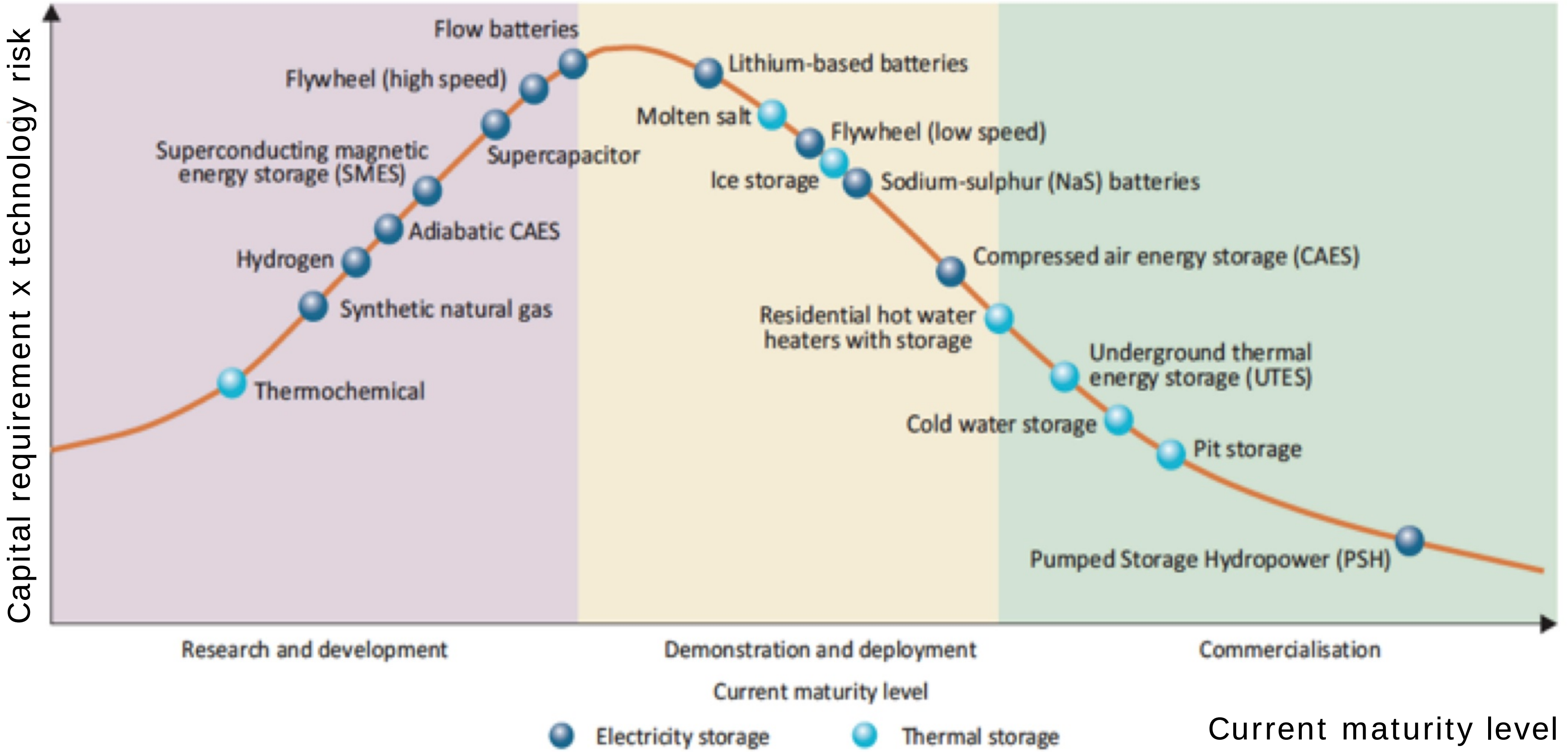
Storage
Swiss Competence Center
for Energy Research



Source: modified from EIA (Energy Information Administration) (2012), "Electricity storage: Location, location, location.....and cost", Today in Energy, Washington, DC, United States.

Hochschule Luzern
Technik & Architektur
Storage
Swiss Competence Center
for Energy Research

Energy Storage –
Maturity of energy storage technologies



Source: IEA (2014), Technology roadmap: energy storage. Decourt, B. and R. Debarre (2013), "Electricity storage", Factbook, Schlumberger Business Consulting Energy Institute, Paris, France and Paksoy, H. (2013), "Thermal Energy Storage Today" presented at the IEA Energy Storage Technology Roadmap Stakeholder Engagement Workshop, Paris, France, 14 February.

Storage
Swiss Competence Center
for Energy Research

Lucerne University of
Applied Sciences and Arts
HOCHSCHULE
LUZERN
Technik & Architektur

Storage for transportation, buildings, districts, and industry

Jörg Worlitschek
SCCER Storage of Electricity and Heat

SCCER School - Shaping the Energy Transition

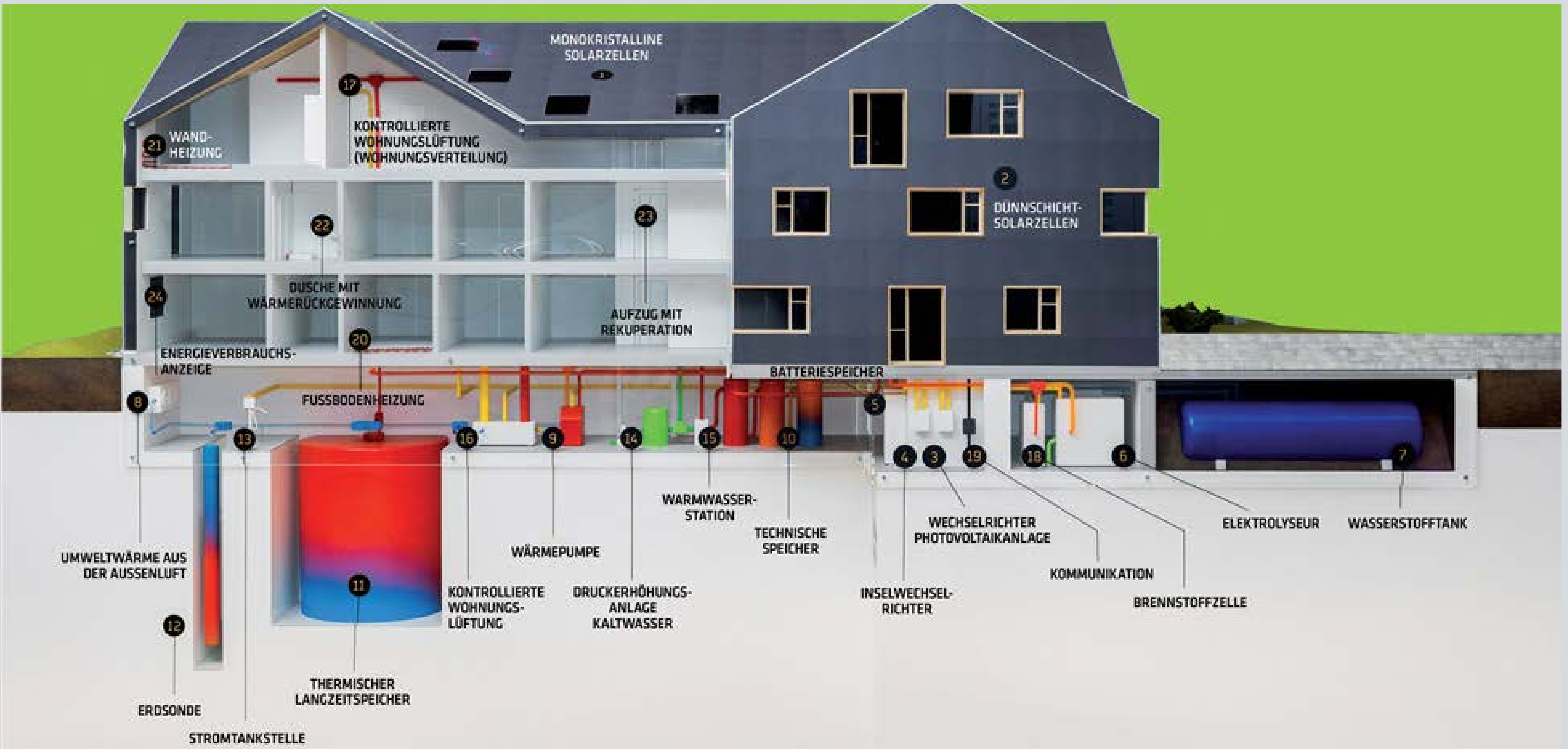
17 to 20 October 2017 in Engelberg

Energy Storage – Extreme Case:
Energy Self Sufficient Multi Family House

Source: Balmer et al, Umweltarena: Energy Self Sufficient Building, SSTES 2016.

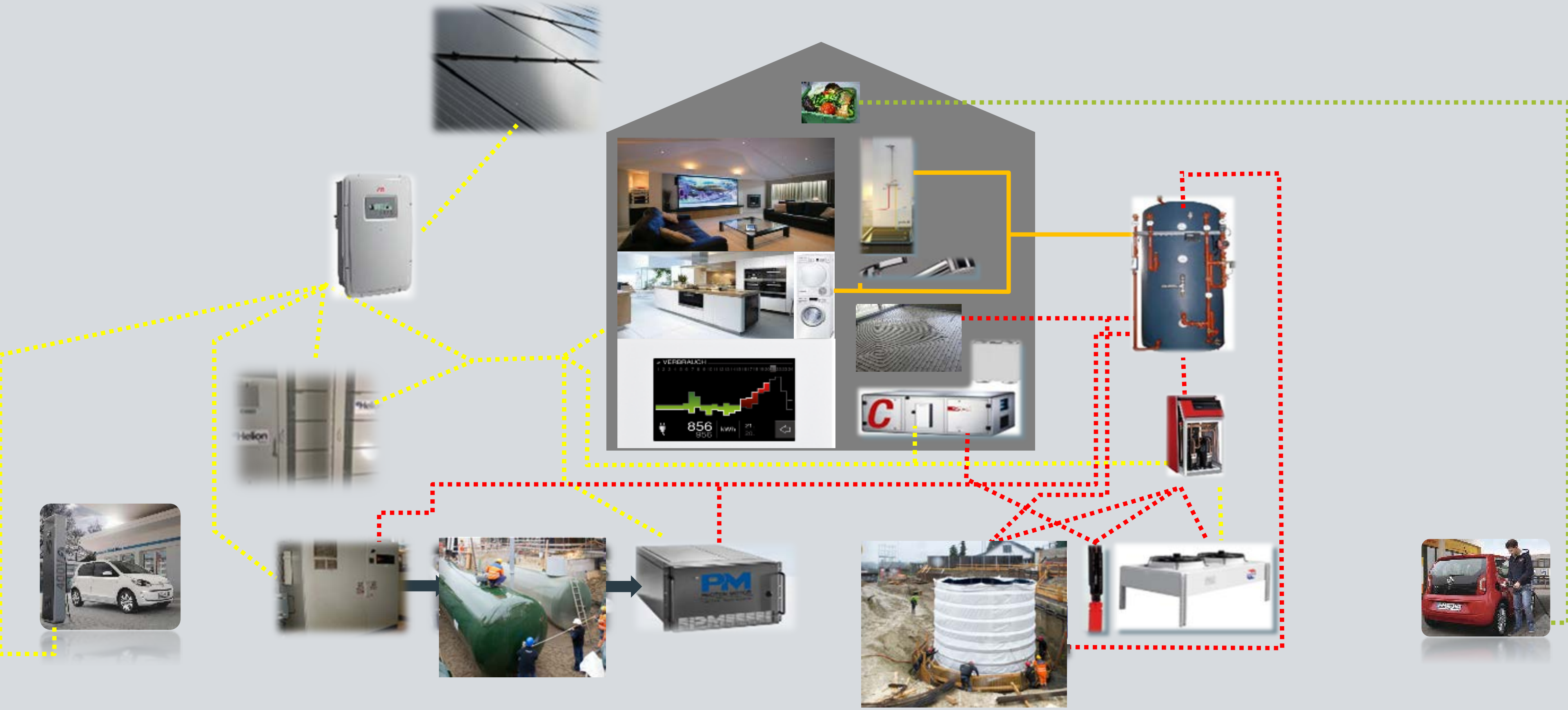
Energy Storage – Extreme Case:
Energy Self Sufficient Multi Family House

Hochschule Luzern
Technik & Architektur
Storage
Swiss Competence Center
for Energy Research



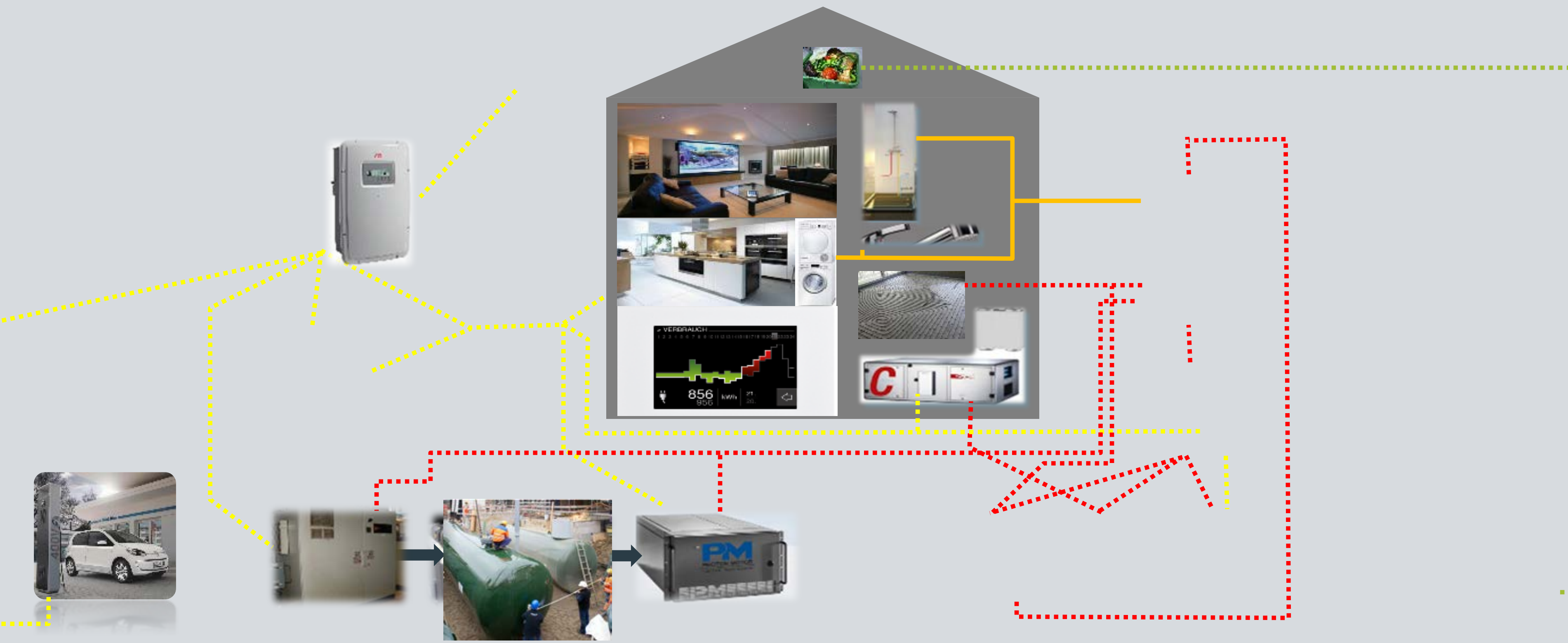
Source: Balmer et al, Umweltarena: Energy Self Sufficient Building, SSTES 2016.

Energy Storage – Extreme Case:
Energy Self Sufficient Multi Family House



Source: Balmer et al, Umweltarena: Energy Self Sufficient Building, SSTES 2016.

Energy Storage – Extreme Case:
A) Short to Long term Electricity Storage

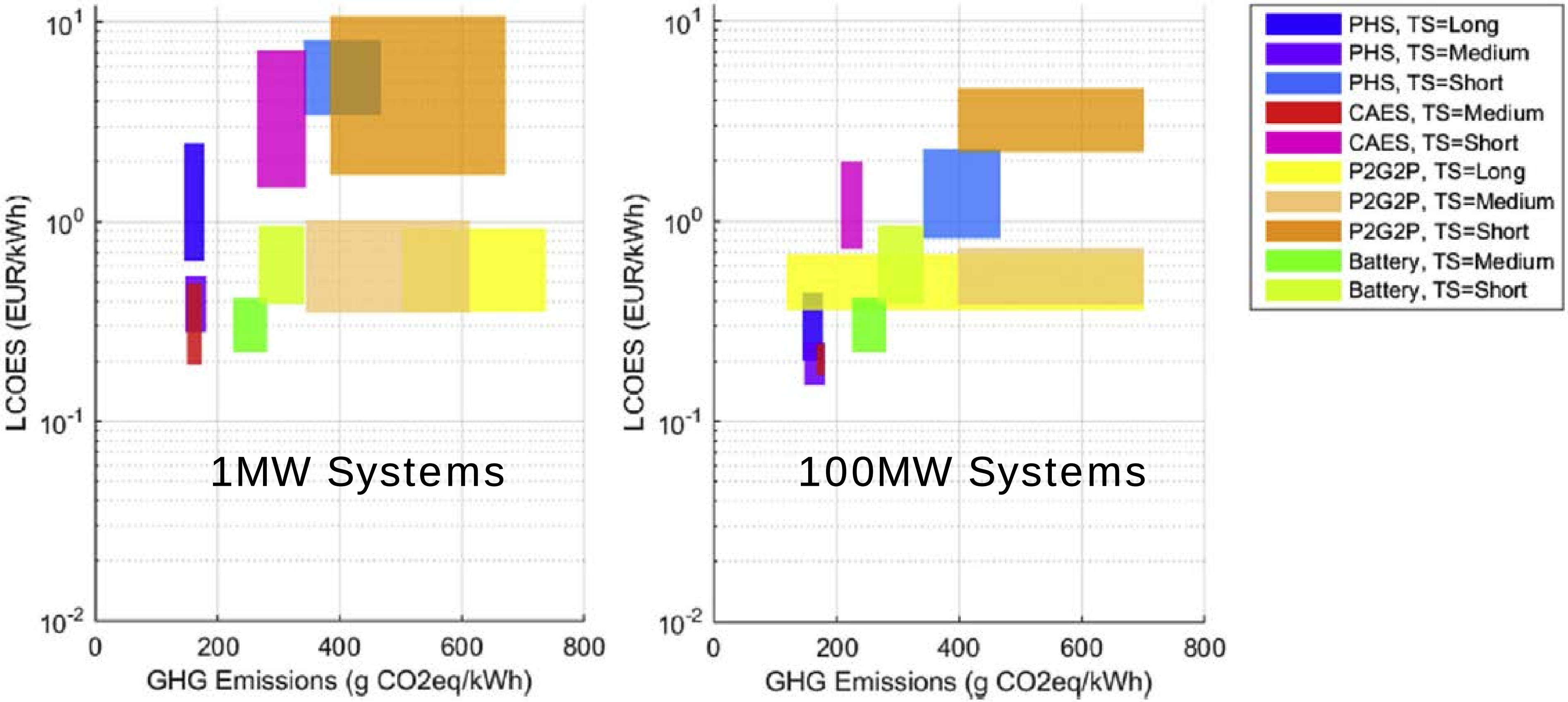


Source: Balmer et al, Umweltarena: Energy Self Sufficient Building, SSTES 2016.

Energy Storage – Swiss Case
A) Short to Long Term Electricity Storage

Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center for Energy Research

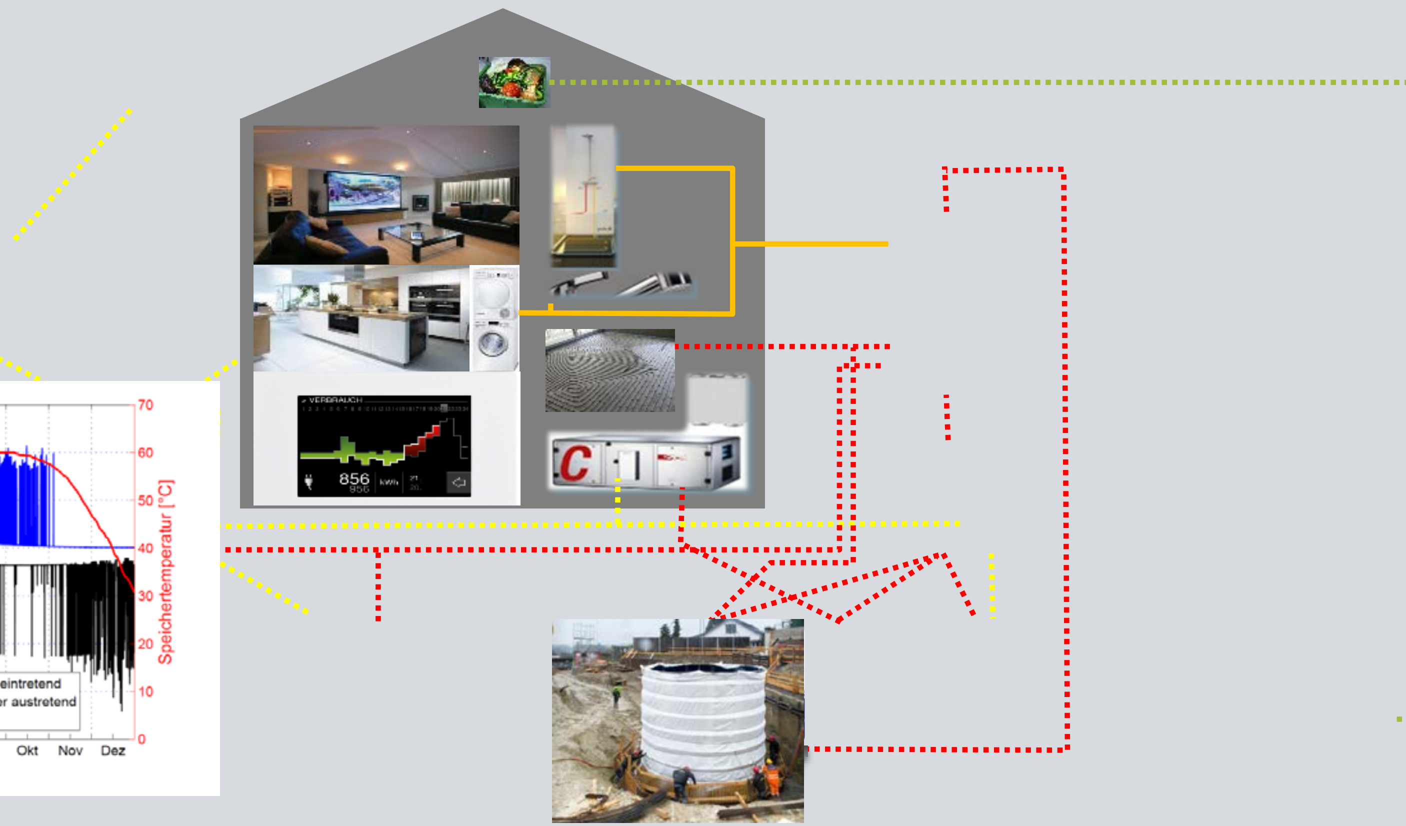


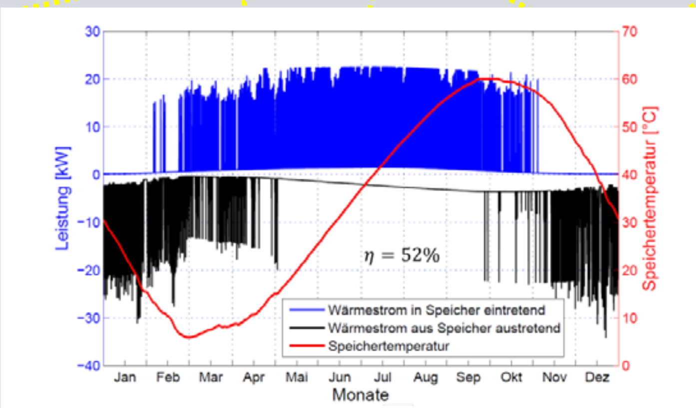
Source: Abdon A, Zhang X, Parra D, Patel M, Bauer C, Worlitschek J (2017) Techno-economic and environmental assessment of stationary electricity storage technologies for different time scales. Energy, 139, 1173-1187.

Energy Storage – Extreme Case:
B) Seasonal Thermal Storage

Hochschule Luzern
Technik & Architektur

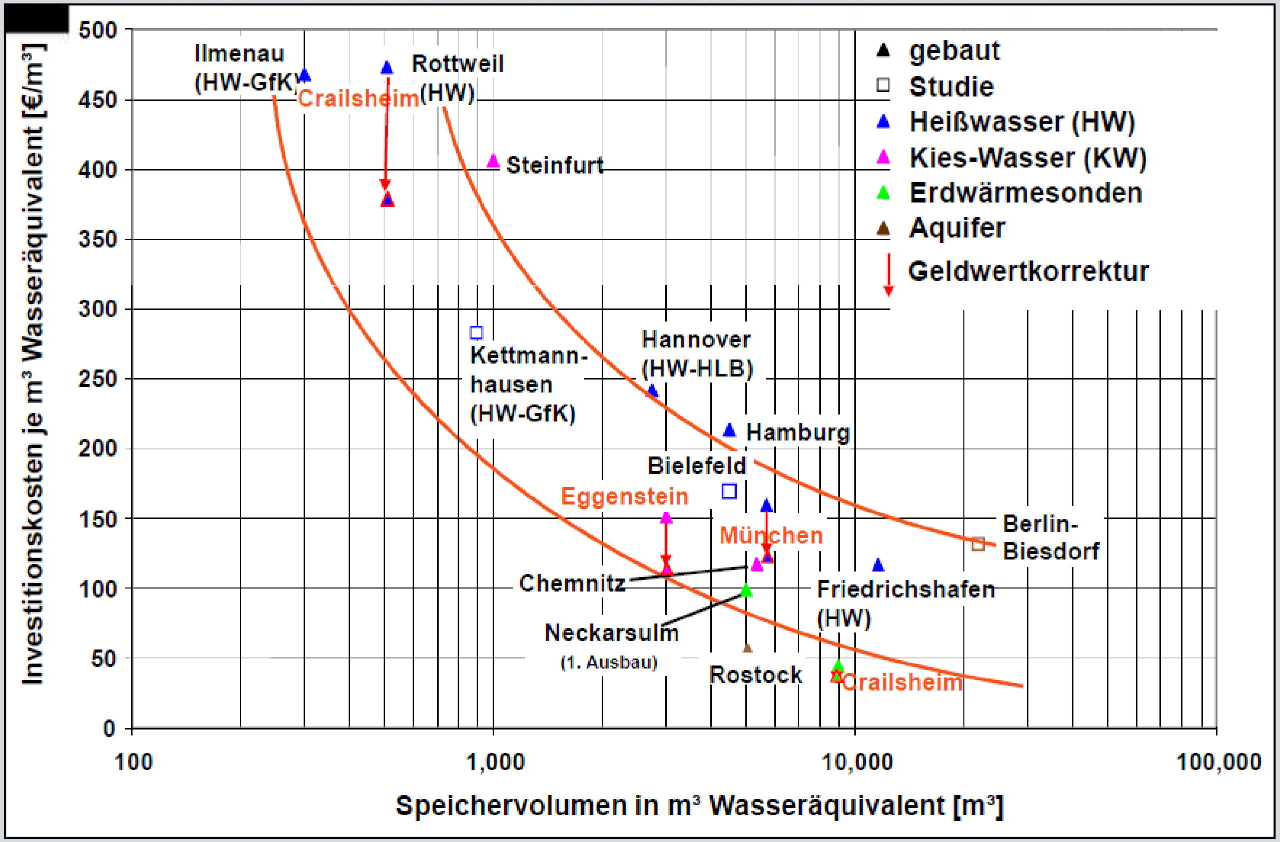
Storage
Swiss Competence Center for Energy Research

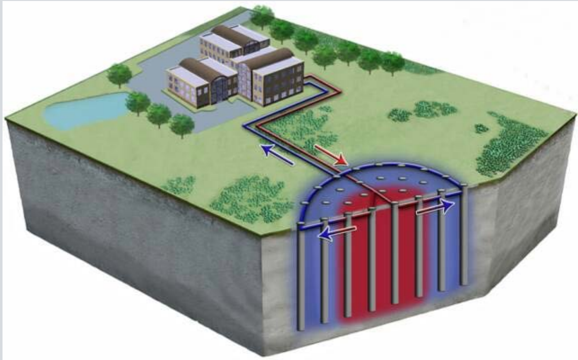




Source: Balmer et al, Umweltarena: Energy Self Sufficient Building, SSTES 2016.

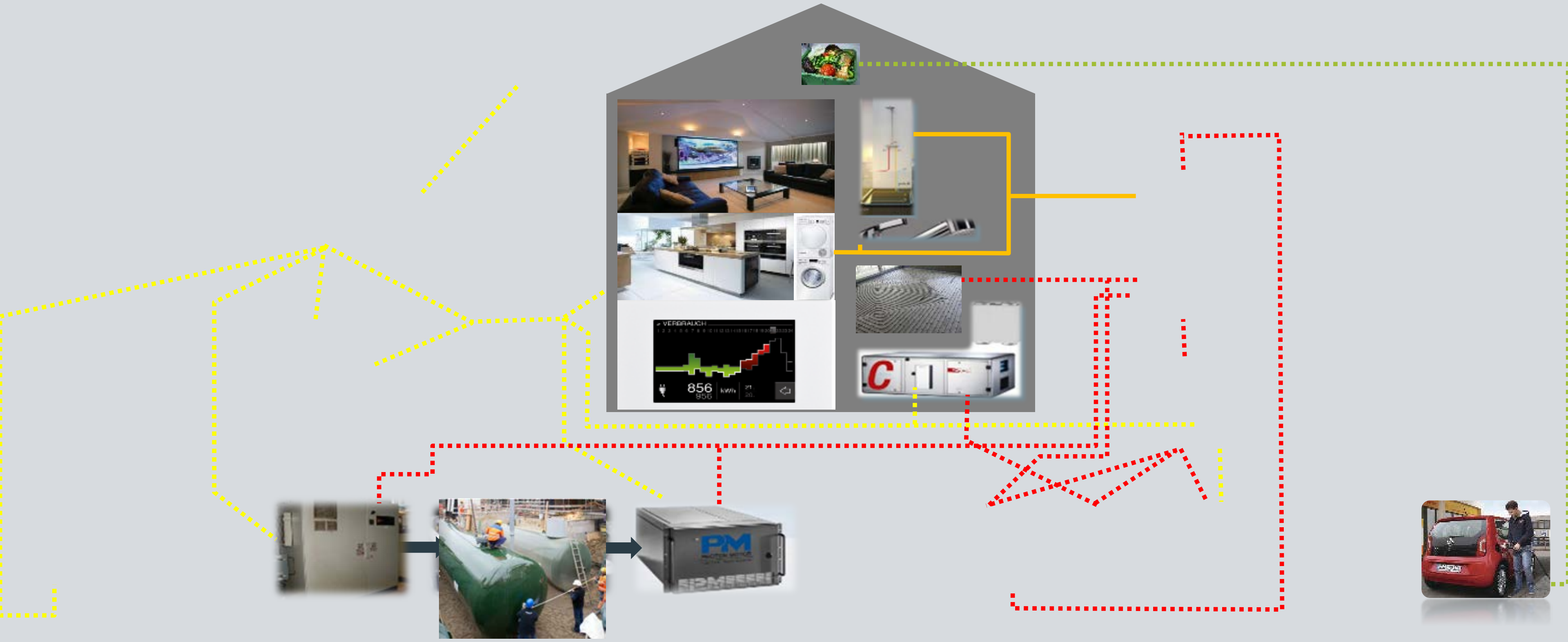
Energy Storage – Swiss Case:
B) Seasonal Thermal Storage





Source: Solites, SSTES 2016

Energy Storage – Extreme Case: Power to Gas or Power to Gas to Power

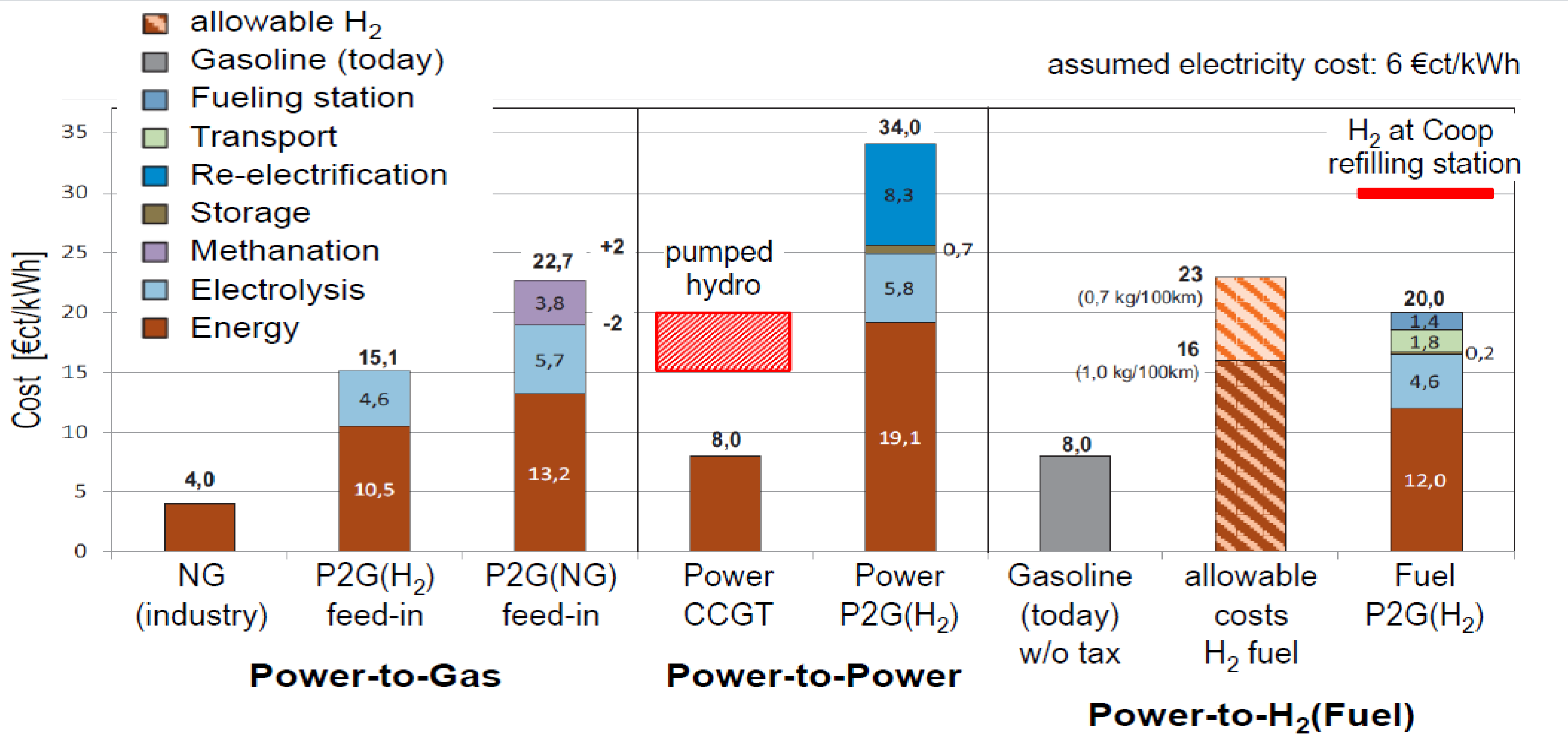


Source: Balmer et al, Umweltarena: Energy Self Sufficient Building, SSTES 2016.

Energy Storage – Swiss Case:
Power to Gas or Power to Gas to Power

Hochschule Luzern
Technik & Architektur

Storage
Swiss Competence Center for Energy Research



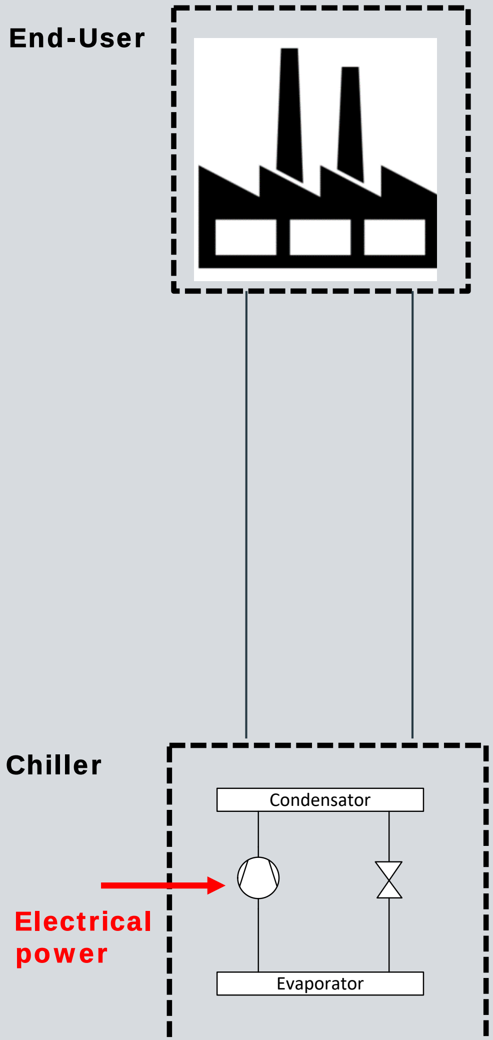
Source: Chem. Ing. Tech. 87 (2015) 17–89

Power to Gas

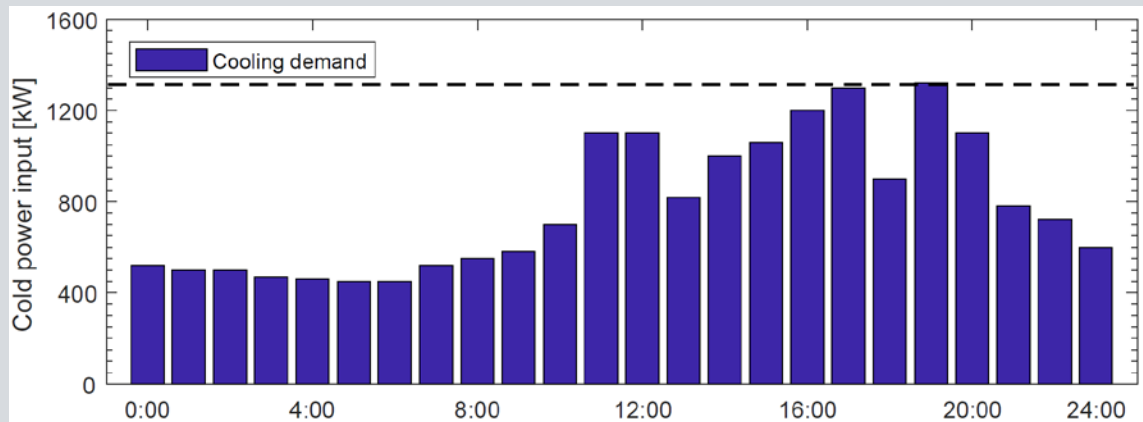
Page 44

Storages in Industry

Cold storage application: «Peak Shifting»

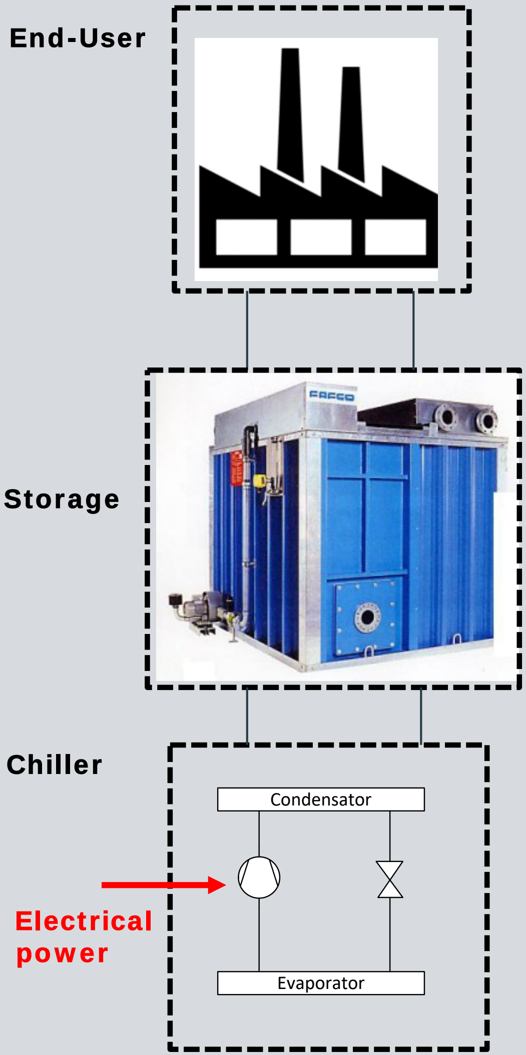


Without storage:

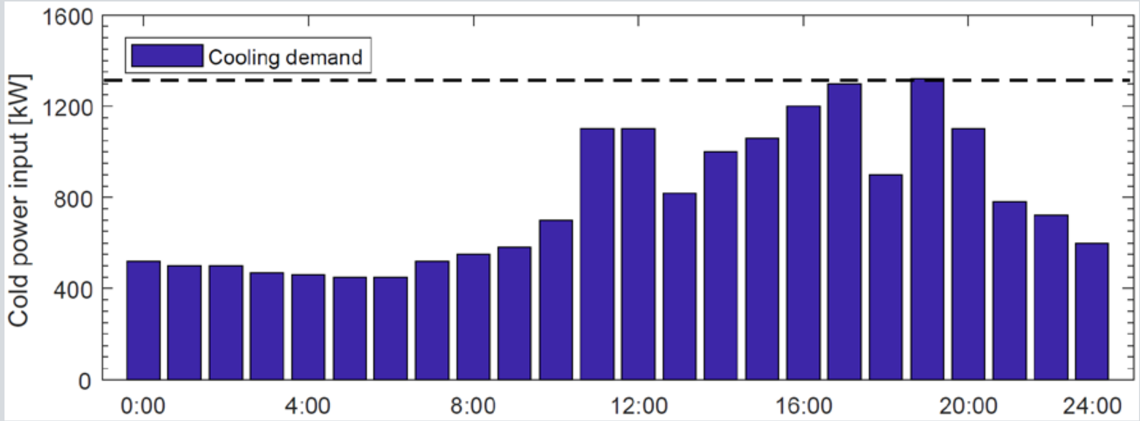


Storages in Industry

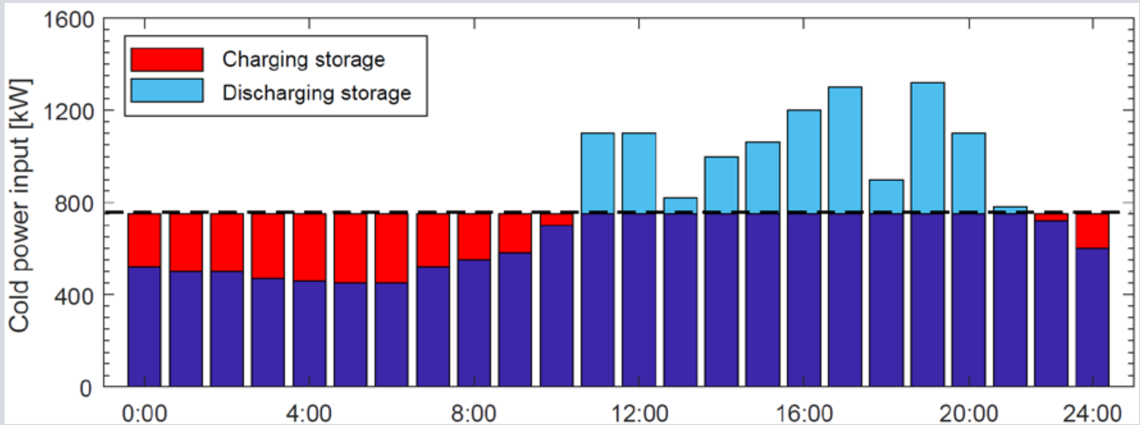
Cold storage application: «Peak Shifting»



Without storage:

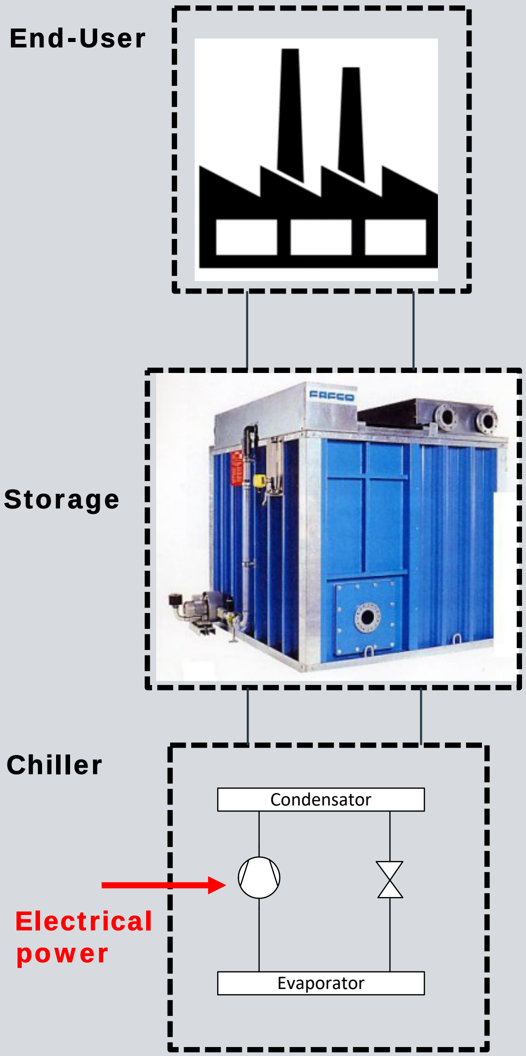


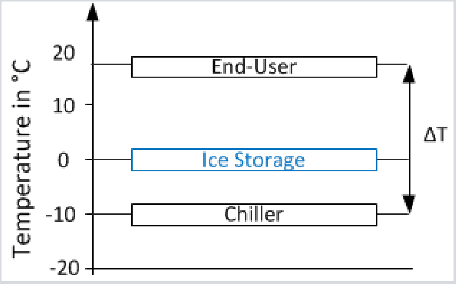
With storage:



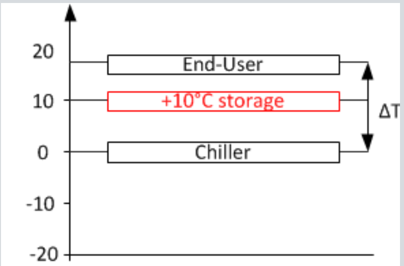
Storages in Industry

Cold storage application: «Peak Shifting»

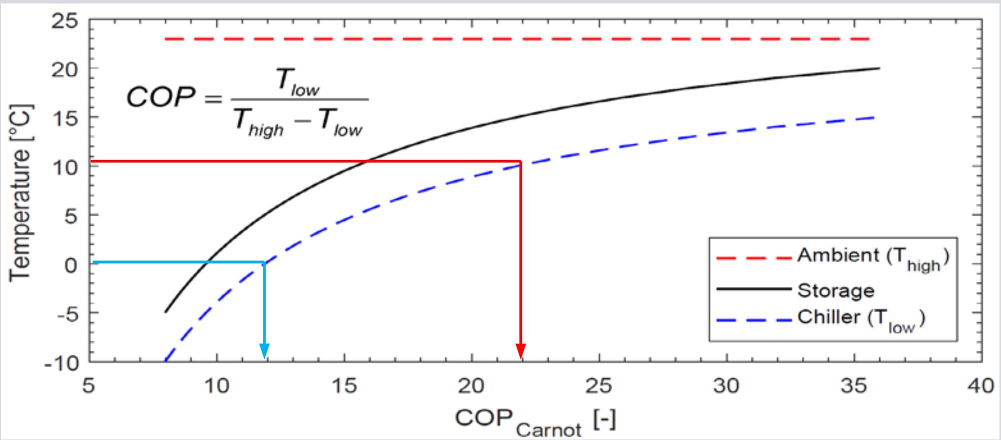




ICE Storage
- Storage Temperature 0°C
- End-User Temp: 20°C

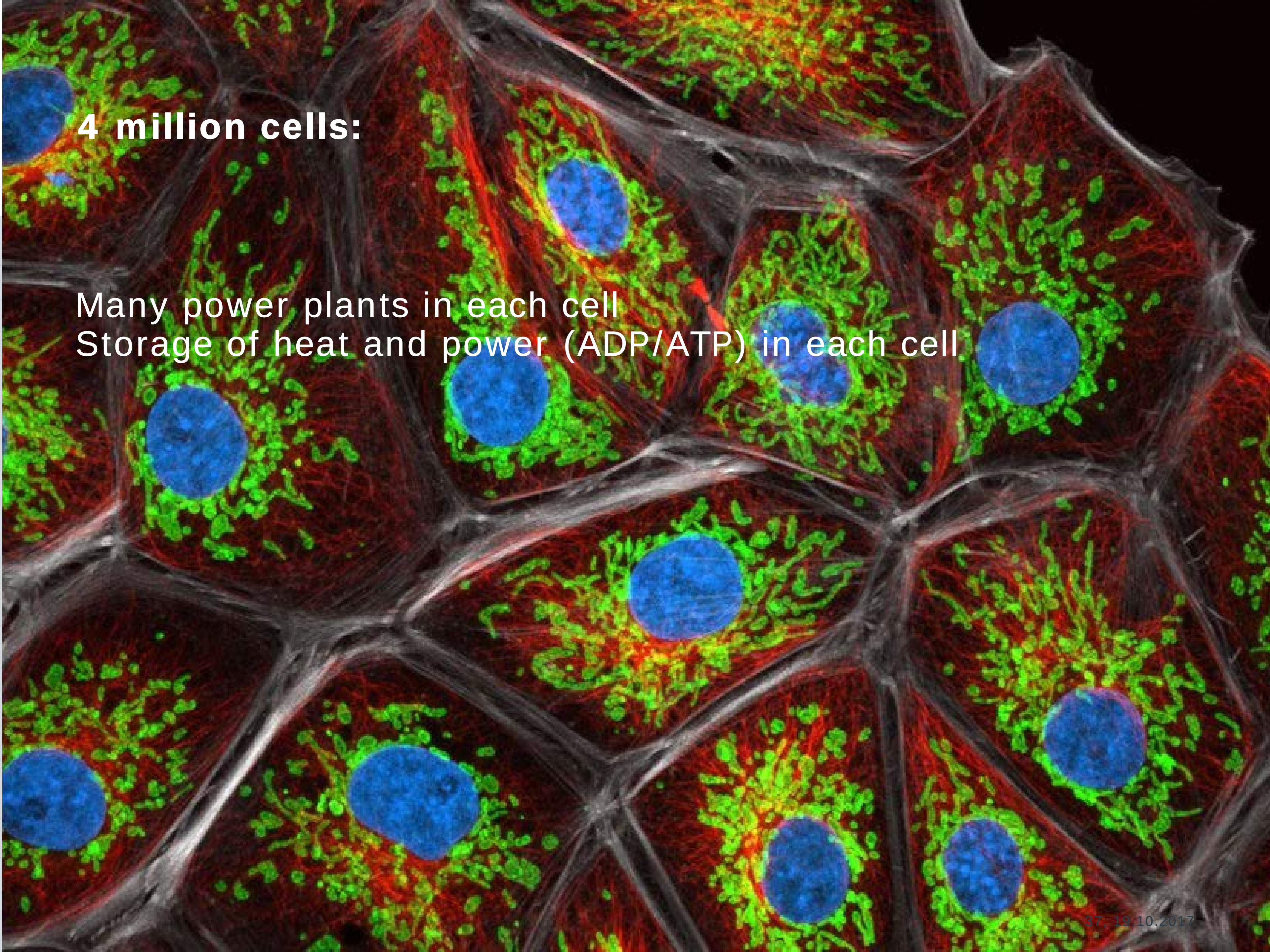


+10°Storage
- Storage Temperature: 12°C
- End-User Temp: 20°C



Zooming into 4 million cells

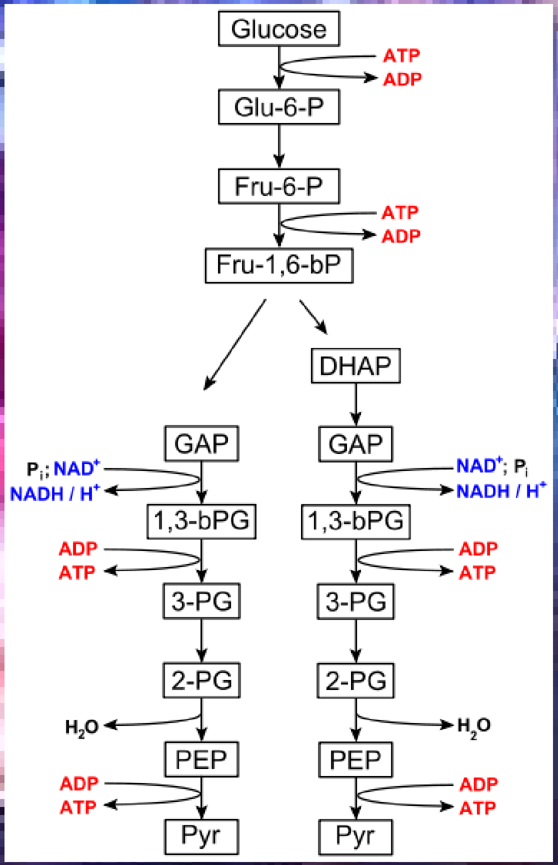
0.5cm^2 Skin: 4 Million cells


4 million cells:
Many power plants in each cell
Storage of heat and power (ADP/ATP) in each cell

One power plant: Mitochondrium

A couple of power plants in each cell: Conversion

ATP/ADP



If Switzerland was a Bear

- It had with 4 million house holds 80 million power plants with combined heat and power technology

- It had several storages in each of those house holds

- It had a grid that was transporting heat and electricity in one grid

- The grid would be an additional storage

Storage
Swiss Competence Center
for Energy Research

Lucerne University of
Applied Sciences and Arts
HOCHSCHULE
LUZERN
Technik & Architektur

Questions?

Jörg Worlitschek
SCCER Storage of Electricity and Heat

SCCER School - Shaping the Energy Transition

17 to 20 October 2017 in Engelberg