Institut für Gebäude- und Solartechnik
Prof. Dr.-Ing. M. Norbert Fisch
Mühlenpfordtstraße 23
D-38106 Braunschweig

www.tu-braunschweig.de/igs

Technische Universität Braunschweig

PV2Heat: Development of a vacuum insulated high temperature solid storage combined with PV

Prof. Dr.-Ing. M.N. Fisch
Dipl.-Ing. Mani Zargari

Institut für Gebäude- und Solartechnik
Prof. Dr.-Ing. M.N. Fisch

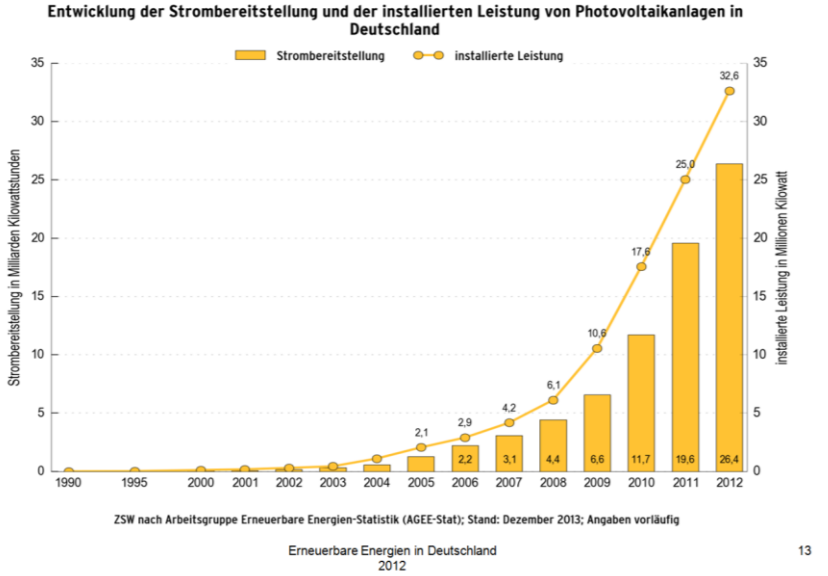
Technische Universität Braunschweig

Dialogplattform Power to Heat
5. + 6. Mai 2015

Content

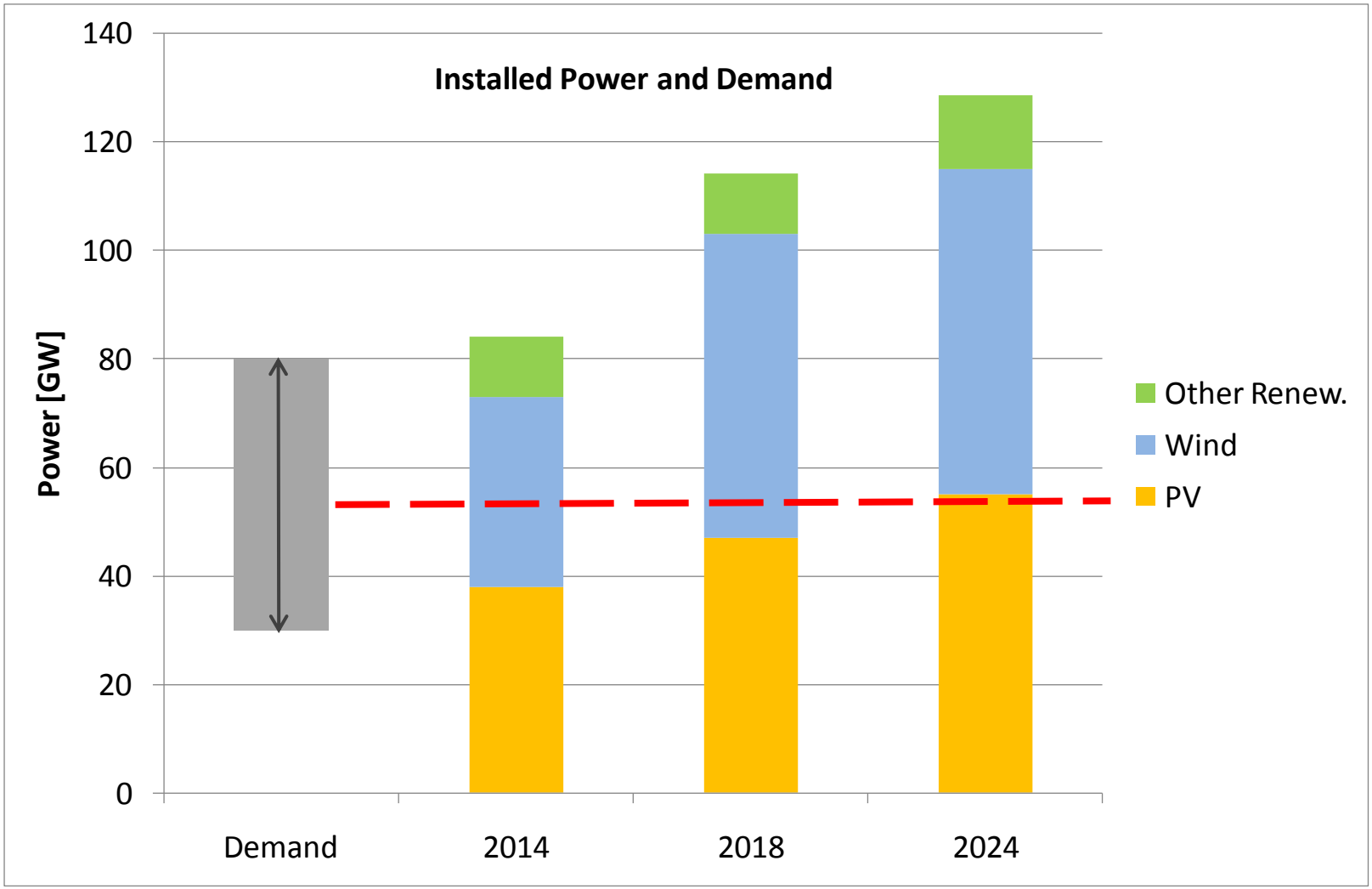
1. **PV in the Power Market: Challenges and Solution Approach**
2. **Technique of a High-Temperature-Solid-Storage (HTFS)**
3. **System Integration of a HTFS**
4. **System Comparison**
5. **About the Research Project**

Oversupply of PV-Power



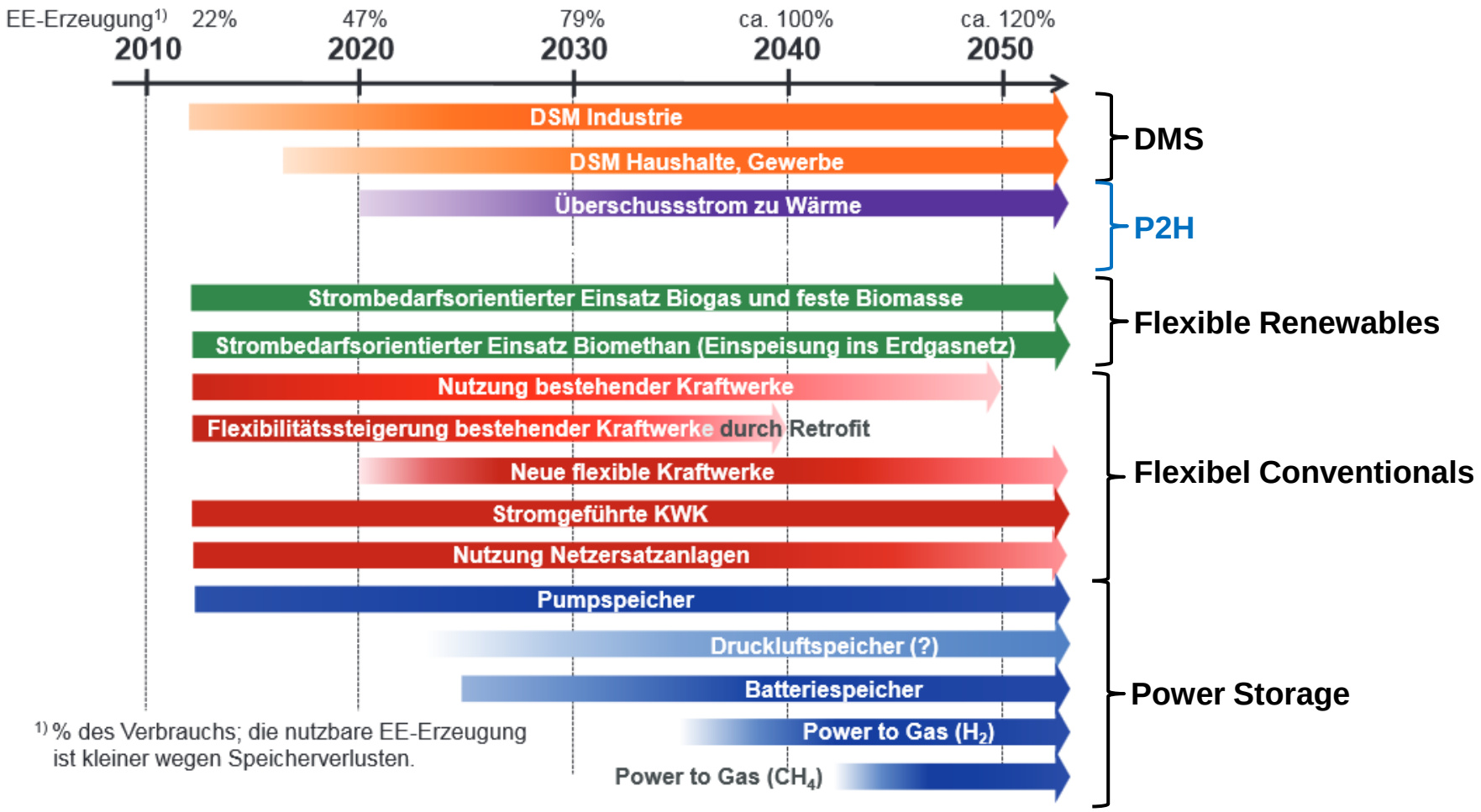
- **Turn down of convential power plants (grey) for renewables**
- **Price for power collapses at the spot market**
- **Cut-off of renewable power plants from the grid in future**

PV-Gain and Demand



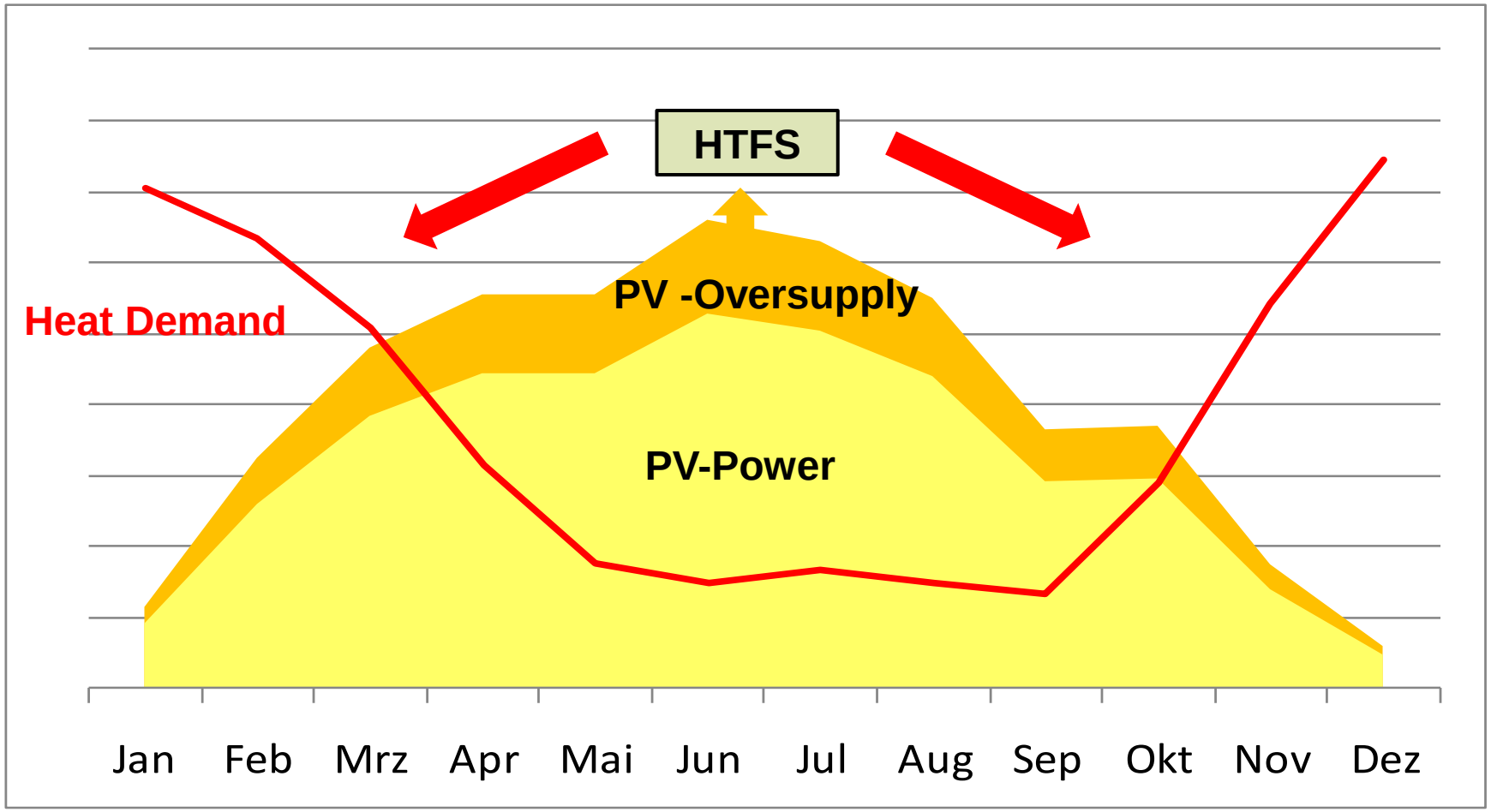
Renewable – Midterm – Prognosis of the German network operators 2014 (EEG Mittelfristprognose 2014)

Options for Flexibilization



BEE-Studie „Möglichkeiten zum Ausgleich fluktuierender Einspeisungen aus Erneuerbaren Energien“ 2013 im Auftrag BEE, Lichtblick und Enercon, ausgeführt von BET Büro für Energiewirtschaft und technische Planung GmbH

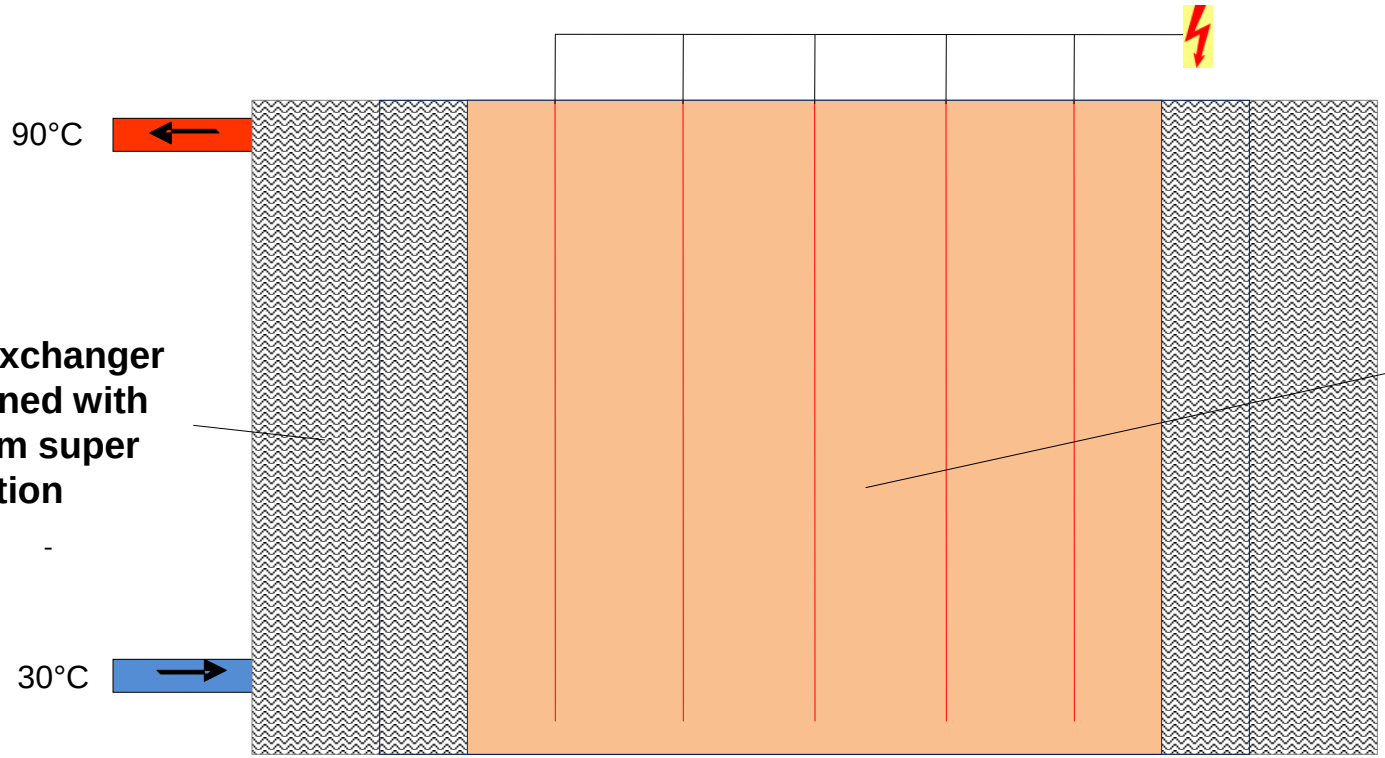
PV in the Power Market HTFS shifts PV-Power to the demand



HTFS connects the power-Market and heat-Market

Oversupply of PV-Power is transformed to heat and shifted to the time of demnad

HTFS in the Energy-Market



Heat exchanger combined with vacuum super insulation

-

Maghemite (iron ore) and heating rods

50°C to 750°C

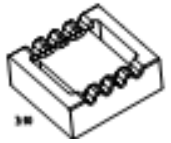
Advantages:

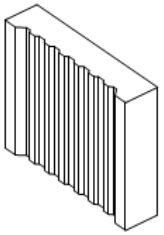
- **High-efficient**
- **Maintaince-free**
- **Cycle resistant**
- **Avoids network supply of PV-power**

State of the Art: Night Storage Heater

Core

• Fe_2O_3 , ρ = 3900 kg/m³ / Maghamit , „Magnetit“





Heating Rods

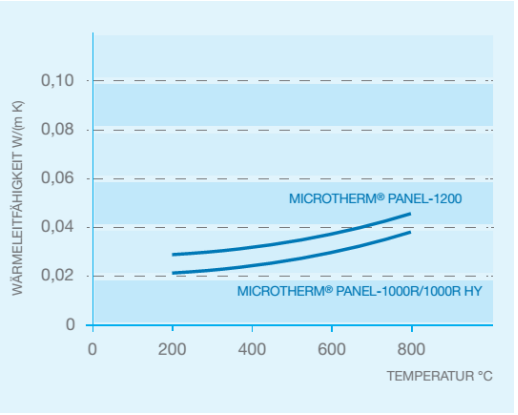
•Durability depends on the operating temperature (750°C: 10.000 h)

•Operating temperature limited to 750°C

Insulation

• 20 mm mikroporous material (Aerogel, Pyrotherm® λ=0,03 - 0,05 W/(m*K) / 20°C – 750°C)

•Outer Shell: ventilated air-layer



State of the Art: VSI-Hot Water Storage

Storage Media

• Water, oil (up to 250°C)

Vacuum Insulation

• Perlite, opacifer, vacuum < 0,1 mbar

Parameters

• Cooling rate

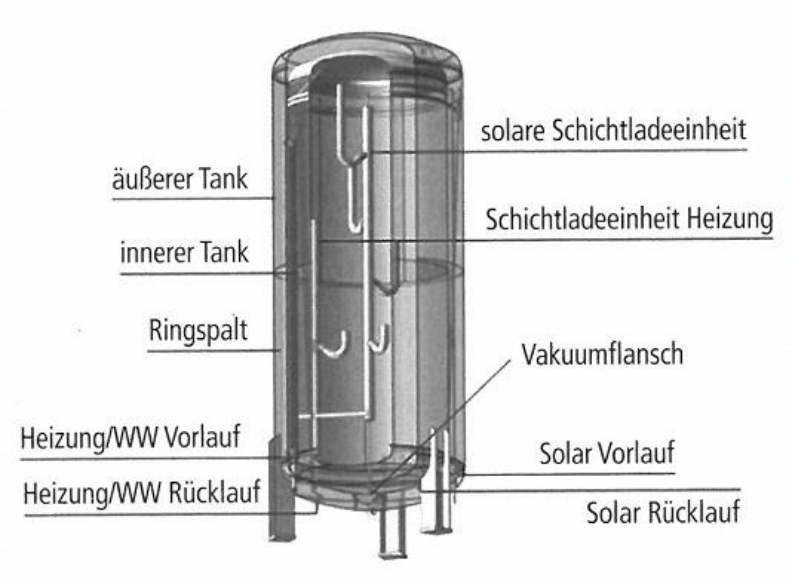
0,0026 K/(d*K) (conventional storage 0,0095 (K/d*K))

•Thermal transition coefficient:

1/R=0,04 W/(m²*K)

Costs

• 5m³ - Storage: 16.000 EUR



Comparison of Storage Medias

	c [kJ/kgK]	ρ [kg/m³]	s [J/cm³K]	Costs [€/t]	Costs [€/(J/K)]
Brick	0,84	2000	1,7	150	179
Concrete	0,88	2300	2,0	52	59
Fire-Brick	1,00	2000	2,0	390	390
Ceramics	1,00	2500	2,5	200 / 1500*	200 / 1500*
Water	4,18	1000	2,4	0	0
Iron Ore Fe_2O_3	**0,92**	**3900**	**3,5**	**300**	**163**

*Bulk-Material/ Stones

Comparison of Insulation Techniques

	T [°C]	Λ [W/mK]	Costs [€/m³]	Cost [€/Storage Tank]*
Pyrogel (Aspen/Stadur)	200 600	0,028 0,089	1.000	12.000
Microtherm Panele (Night Storage)	229 750	0,032 0,053	3.600	43.000
Vakuum-Super-Insulation	**100** **400**	**0,009** **0,02**	**150**	**750**

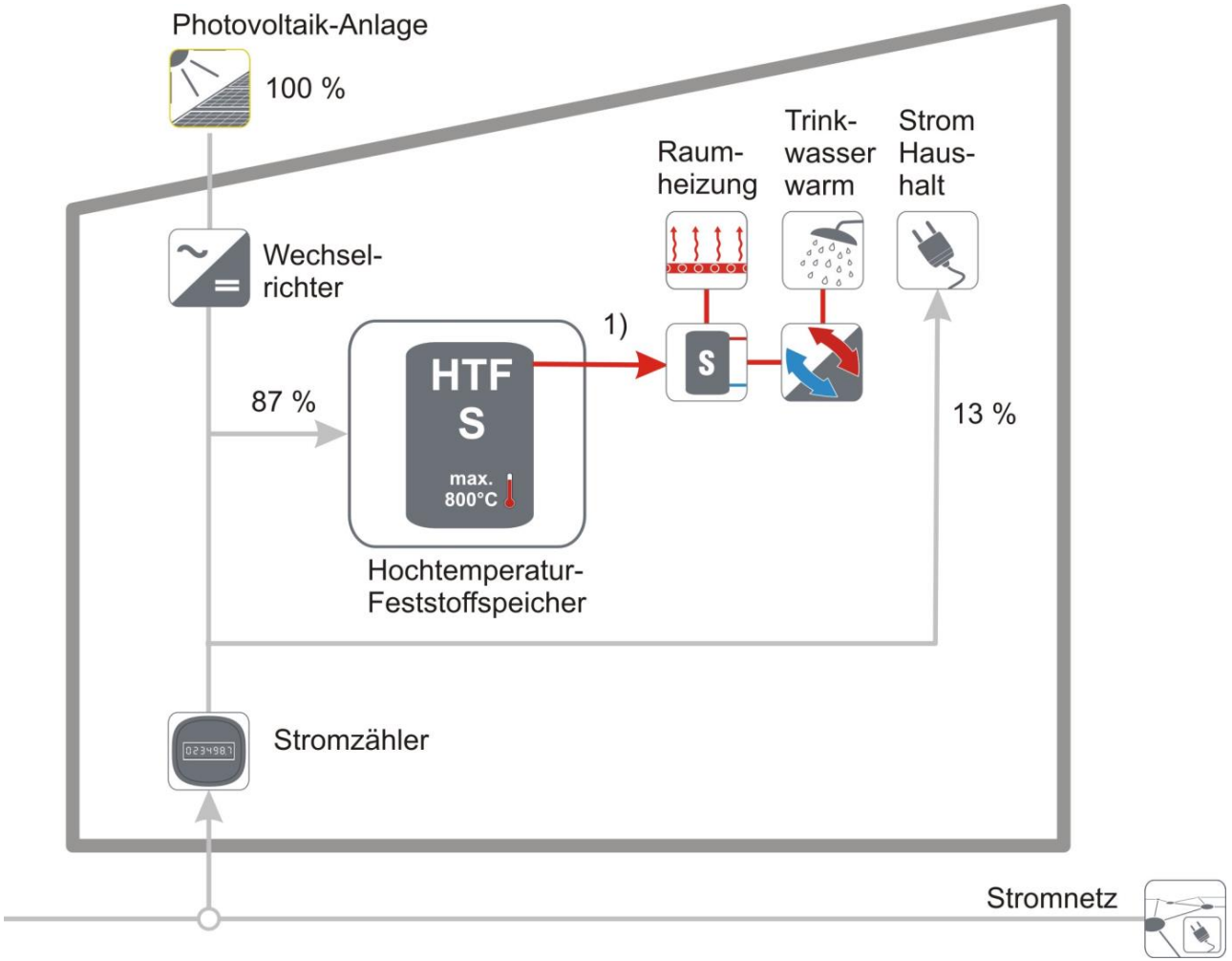
*Insulation Material for Heat Transfer Coeffcient of. 0,05 W/m²K, Costs only for insulation material, net price

Integration in a Residential Building

Simulation Studie

System Parameters:

- **PV-Generator: 10 kWp**
- **4 Persons**
- **Heat Demand (Water + Heating) 60 kWh/(m²*a)**
- **HTFS: 18t / 5m³**



Integration in a Residential Building

Simulation Studie

Energy Balance:

- **Total solar gain**

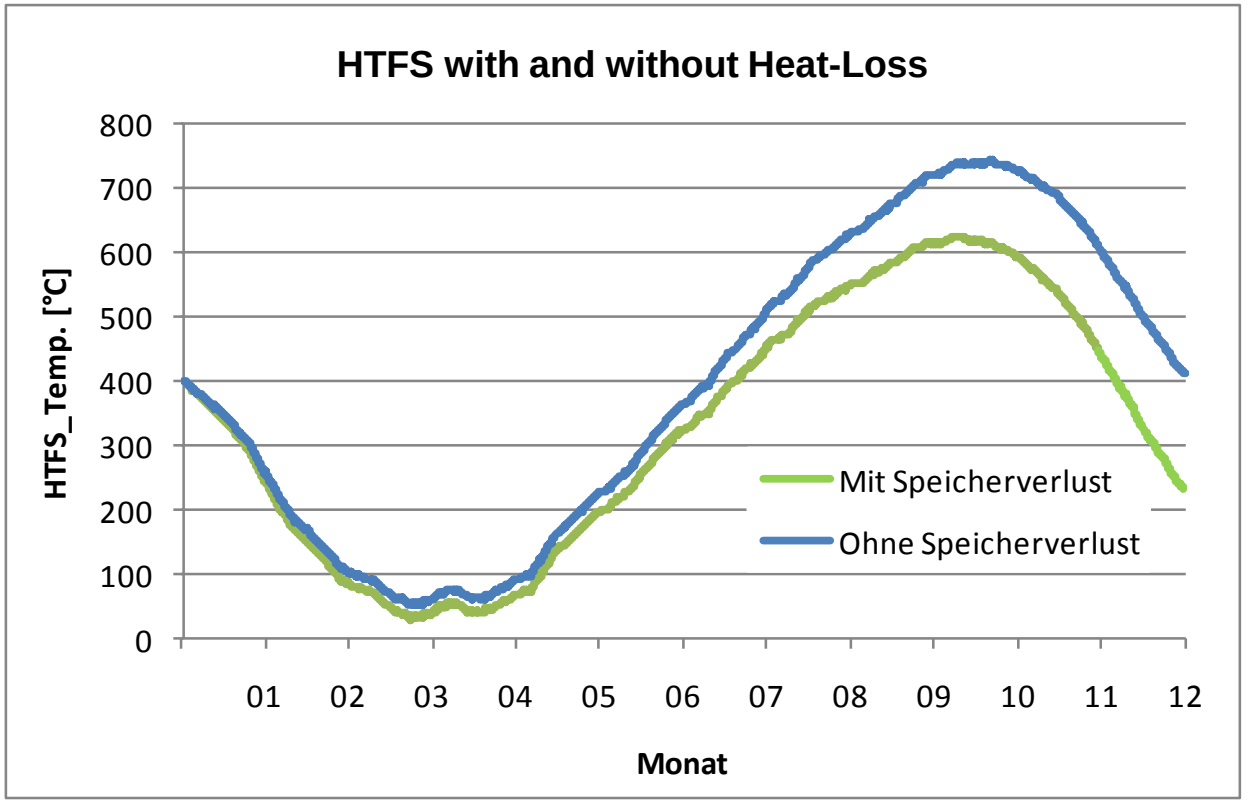
  9.400 kWh/a

- **Own use of solar power**

  1.200 kWh/a

- **Own use of PV-heat with the HTFS:**

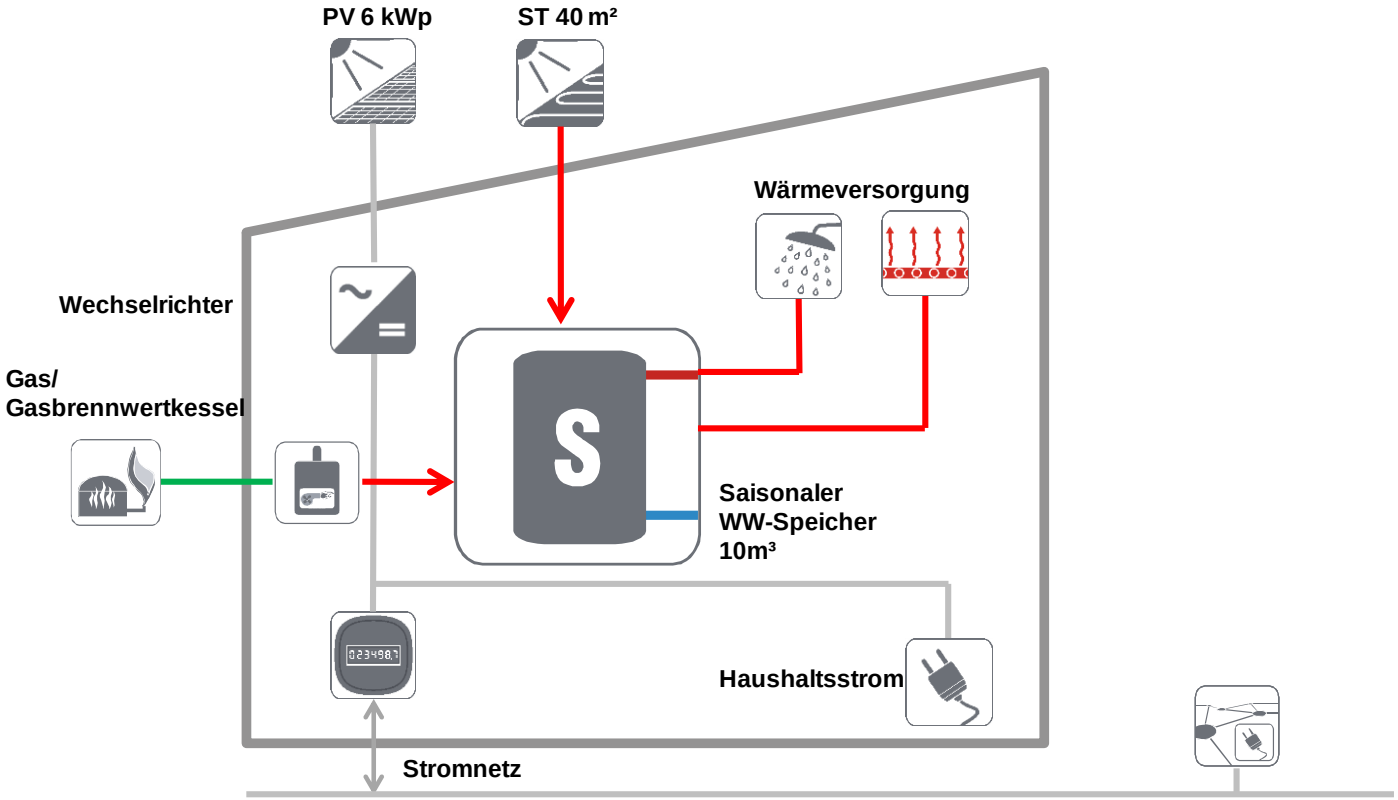
  8.200 kWh/a



Reference System

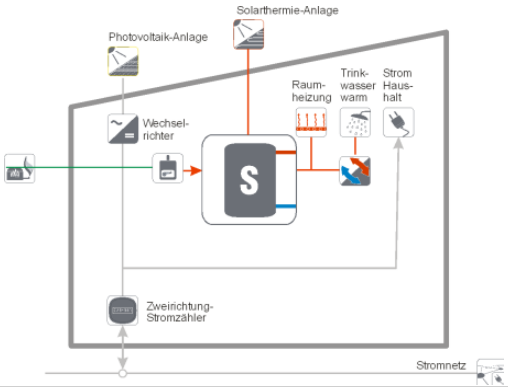
Reference System:

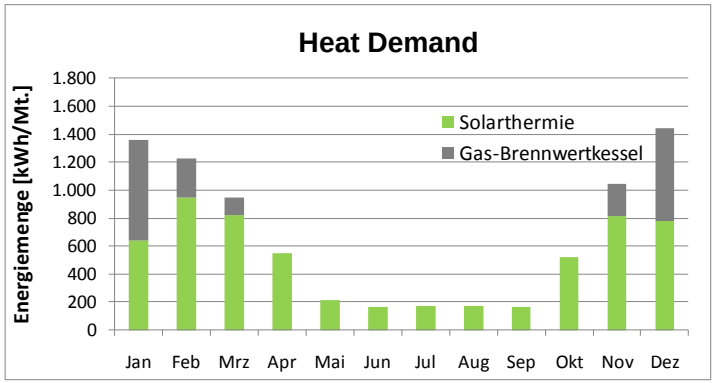
- **Residential building (research project Future:Solar)**
- **Solar-thermal plant 40 m²**
- **Seasonal hot water Storage 10m³**
- **Gas boiler (condensing)**
- **PV-generator 6 m²**
- **High solar fraction in the heat supply**



Reference

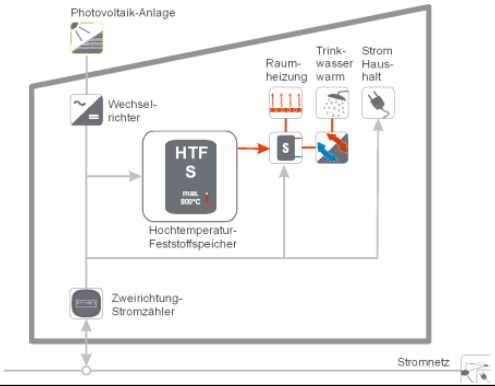
(Future Solar_Combi System)
ST + LZWS + GT + PV
ST: 40 m²; PV: 6 kWp; LZWS: 10m³/10t

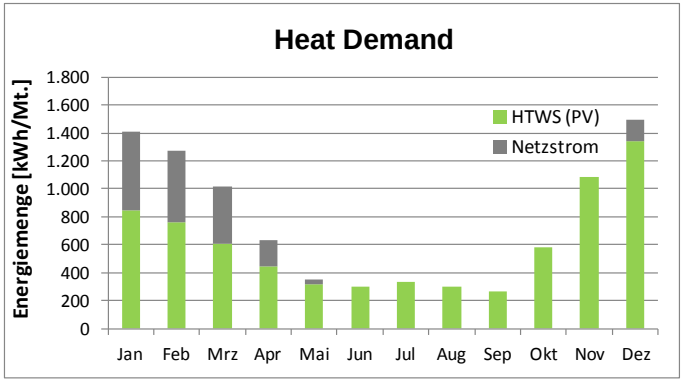




HTFS

(HTFS)
PV + HTFS
PV: 10 kWp; HTFS: 5m³/18t



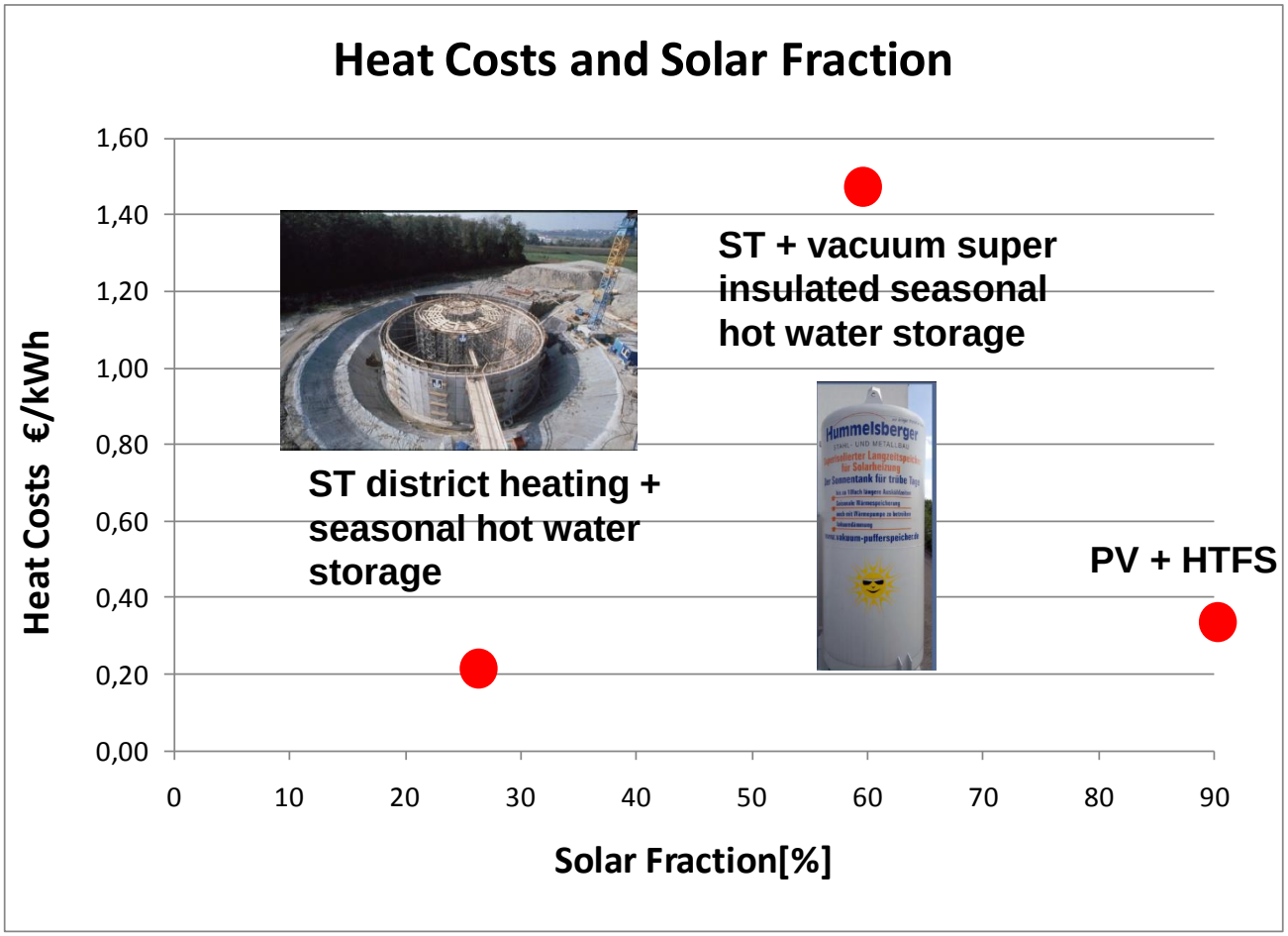


Heat Production Price

EFH (VAR 1_100%_Future Solar) ST + LZWS + GT + PV ST: 40 m²; PV: 6 kWp; LZWS: 10m³/10t	EFH (HTfS) PV + HTFS PV: 10 kWp; HTFS: 5m³/18t
Solar Fraction (Heat) **75%**	Solar Fraction (Heat) **90% (estimated)**
Investment Costs* 47.000 EUR	Investment Costs 42.000 EUR
Costs per Year 2.700 EUR/a	Costs per Year 3.000 EUR/a
Heat Production Price **0,35 EUR/kWh**	Heat Production Price **0,38 EUR/kWh (for 90% solar fraction)**

***All net prices for Heat Supply only**

Heat Production Price and Solar Fraction



Heat costs escalate with increasing solar fraction

Applied Research Project HTFS: Tasks
1. System analysis and -development with plant simulation
2. Design and construction of an prototype of an HTFS (with CFD/FEM)
3. Realized prototype at laboratory of the IGS at TU Braunschweig and test Operation
4. Analysis and optimization, analysis of effects of a HTFS on the grid
5. Preparing for series production

Project Partners

STIEBEL ELTRON

BAYERISCHES ZENTRUM FÜR ANGEWANDTE ENERGIEFORSCHUNG E.V.
ZAE BAYERN

Hummelsberger
STAHL- UND METALLBAU

elena
Institut für Hochspannungstechnik und Elektrische Energieanlagen