INSTITUT FÜR
ENERGIETECHNIK UND
THERMODYNAMIK
Institute for Energy Systems and Thermodynamics

Prospects for Energy Saving in Industry

The Future of Energy Systems in Austria and the Czech Republic

14.05.2013
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Content

- Energy savings by optimized production
- Heat recovery and power generation
- Heat recovery and storage
- Advanced production routes: Examples from steel and cement industry

Optimized Production: Very Simple Measures

- For offices and workshops – reduce heating and cooling load of buildings and work-shops as well as lighting by using simple measures:
  - Control temperatures (in winter and summer),
  - Reduce or rise temperature levels during production free periods (day / night, vaccation),
  - Close and open windows dependent on temperature not even in- but also out-side,
  - Take care of (electric) lighting – switch off, when leaving office or workshops! Use low energy lighting systems (if you didn`t get hopeless after the first experiences with them ☺).

Maybe you think, all the measures mentioned above are quite primitive!
But keep in mind: They are for free – except the last one!

Optimized Production: Simple Measures

- At workshops – reduce demand for electric and thermal power:

  - Reduce demand for compressed air – especially leakage at compressed air systems (CAS) generate a lot of costs. Finding leakages at CAS is laborious – often only possible at week ends.

  - Improve performance of pumps by reducing roughness of inner surface (rotor – and casing): e. g. by painting during normal maintainance –best with three different colour layers for inspection!

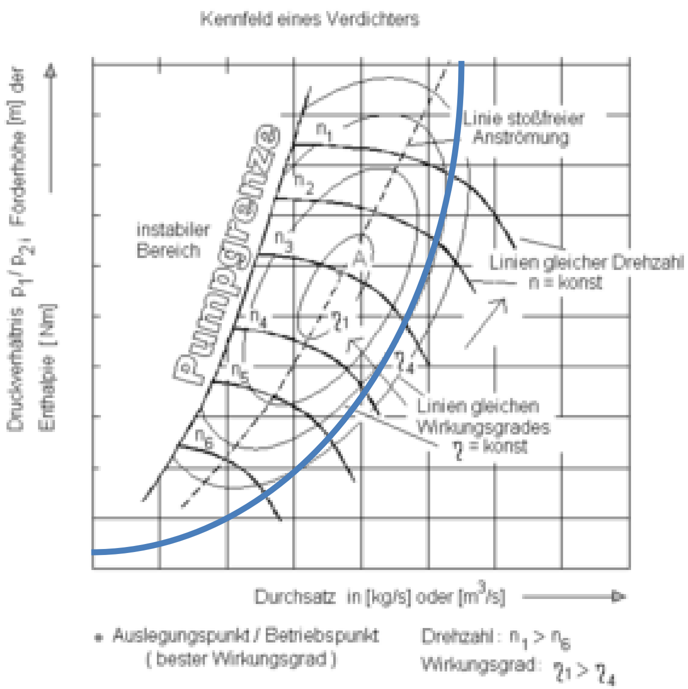
  - When operating process steam networks:
    - Take care of condenser water return – losses generate costs for demineralized water!
    - Condition of thermal insulation – esp. wet isolation enhances heat
    - conductivity significantly
    - If parallel lines exist – think about single line operation at part load production
  - Optimize production processes – when possible – prevent reheating processes e. g. at hot roll mills!

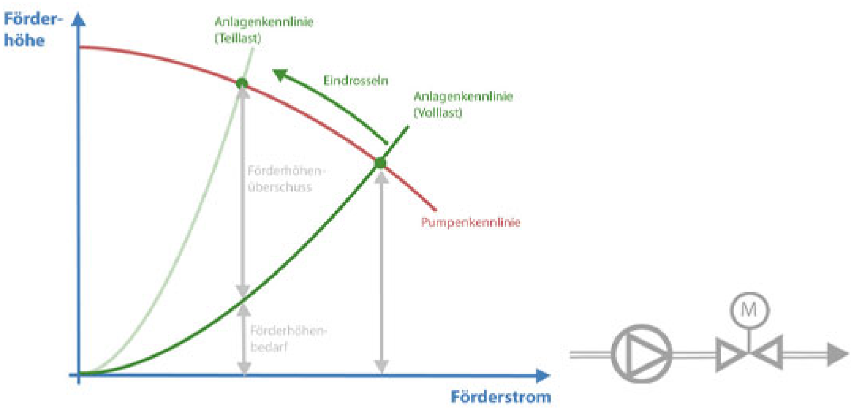
Optimized Production: Advanced Measures

- At workshops – further reduction of electric power consumption:

Use frequency control

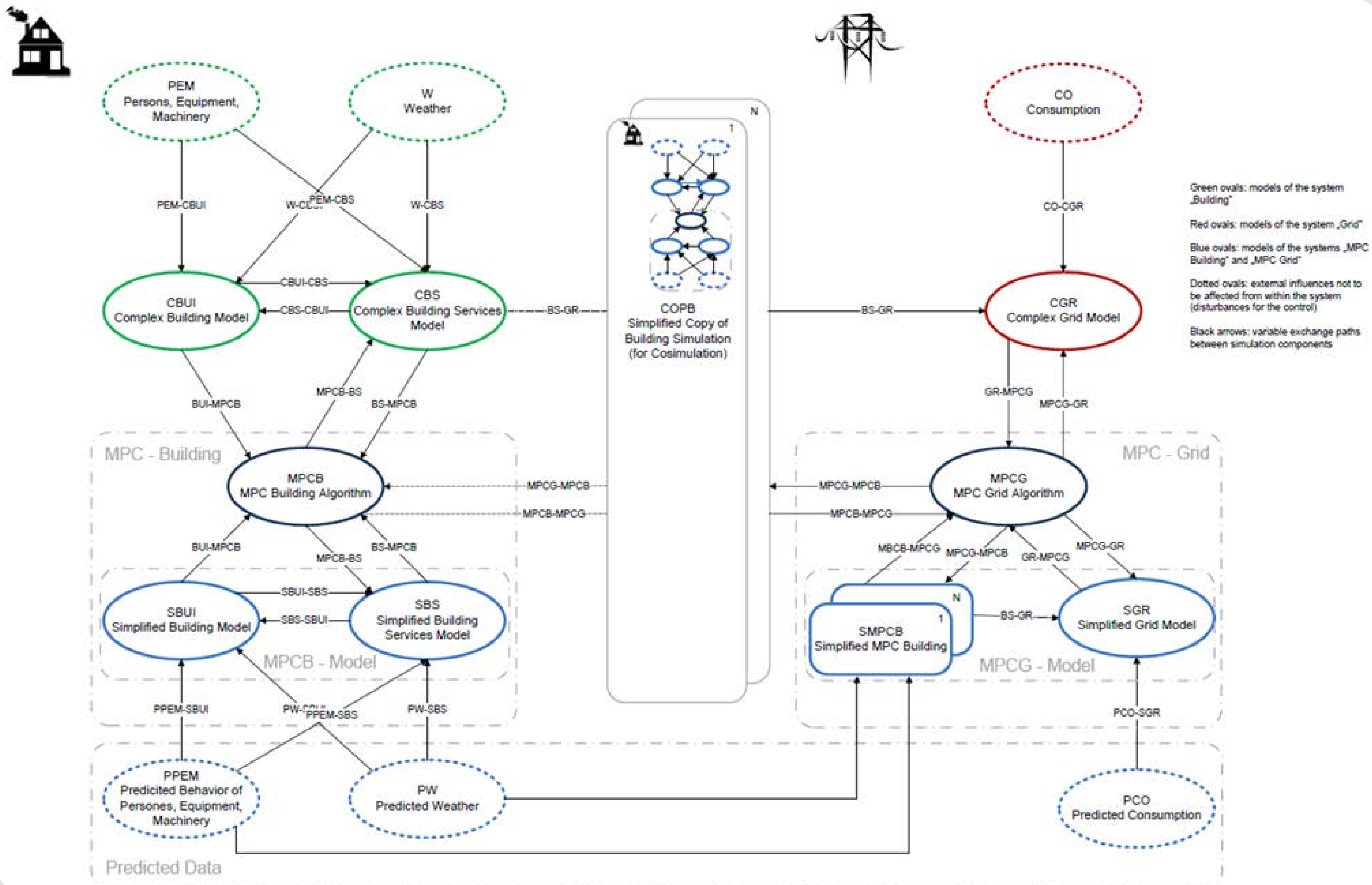
Instead of throttle control





This possibility exists for fans as well as for pumps
Costs for frequency controllers have been reduced significantly

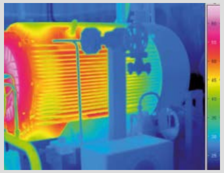
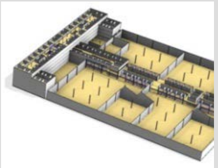
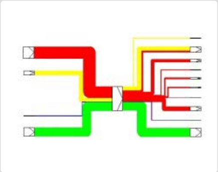
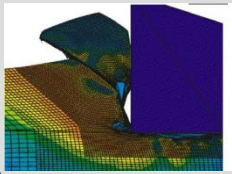
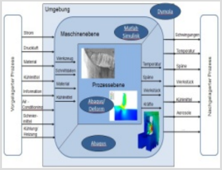
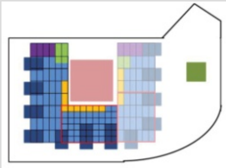
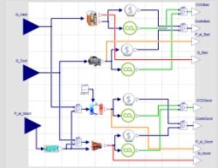
Optimised Prod.: Progressive Measures



Optimized Prod.: Progressive Measures

Project INFO

Fields of optimisation

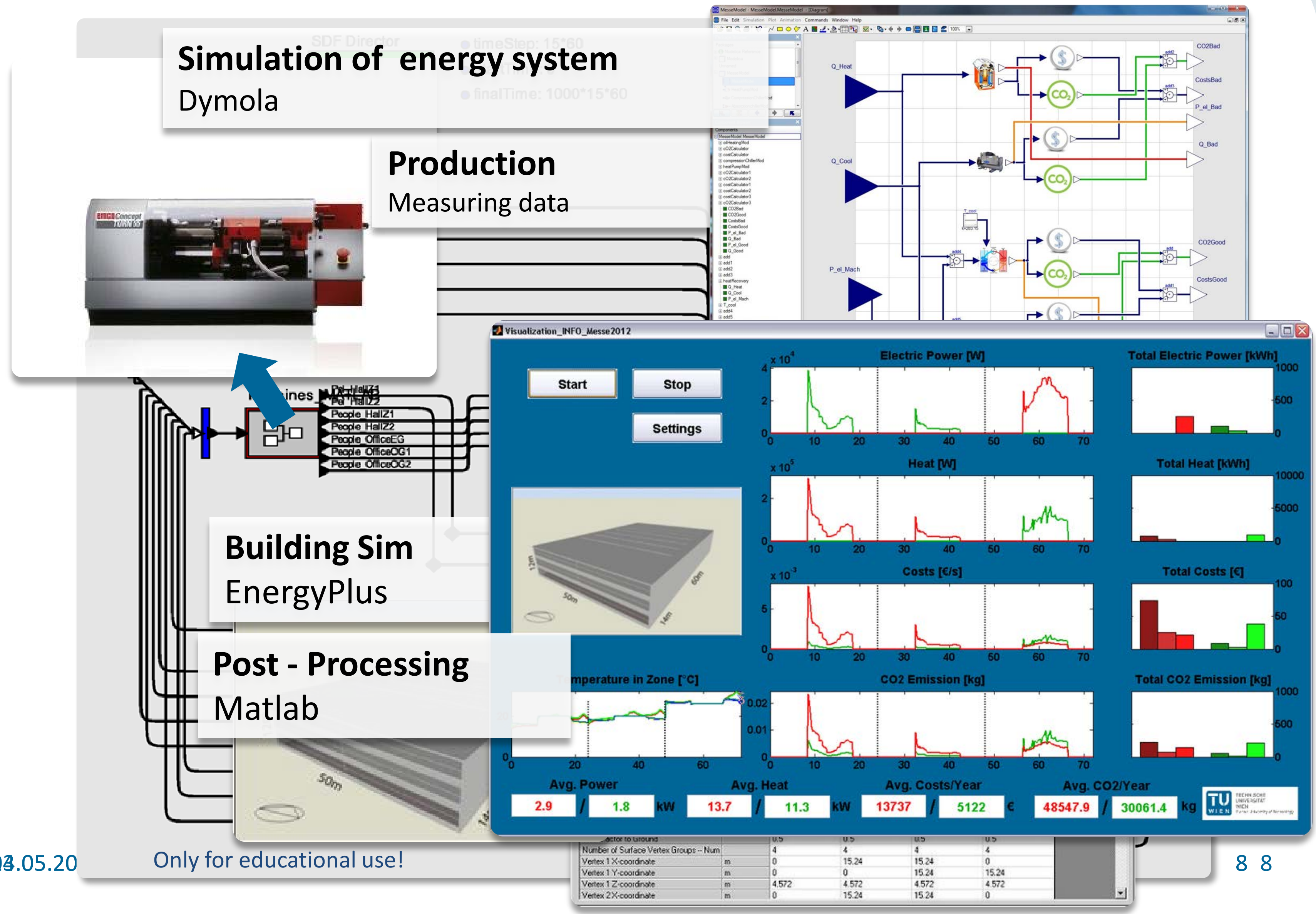
	Process	Machines	Production-system	Building	Energy-System
Analysis					
Modeling					

Optimization

Integrated simulation

... for energy optimized production
... to fulfill economic and ecologic targets

Optimised Prod.: Progressive Measures



Optimised Prod.: Progressive Measures

Further approaches of research:

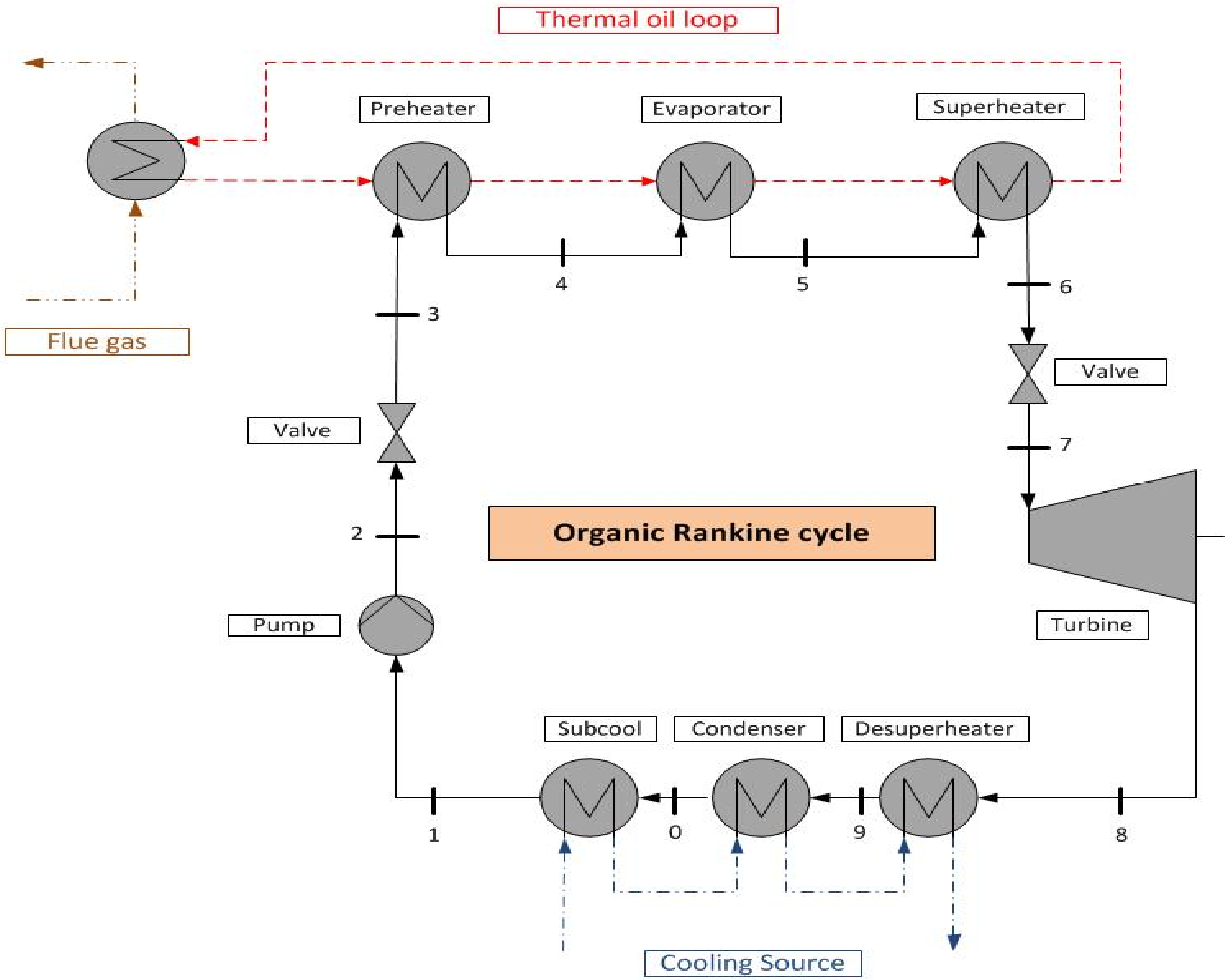
- Simulation based production for energy optimized production:
  Balanced Manufacturing

- Energy systems at food production
- Production in cities, including supply networks within the city

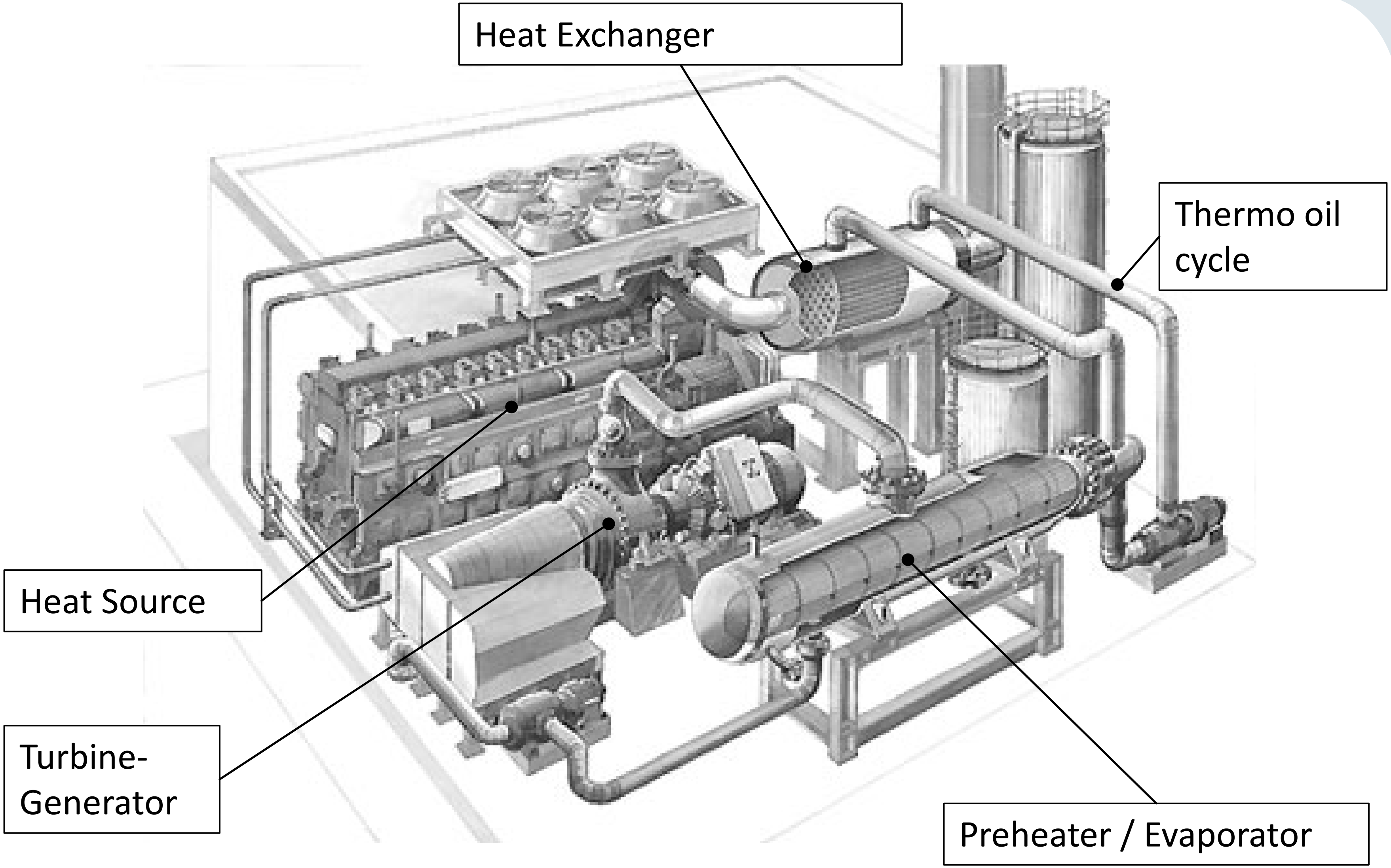
- Flexible energy systems for buildings
  energy systems for flexible usage/“Plug-and-Supply“ – systems

- Concepts for courses of instruction for energy comissioners at companies

Heat recovery and power generation

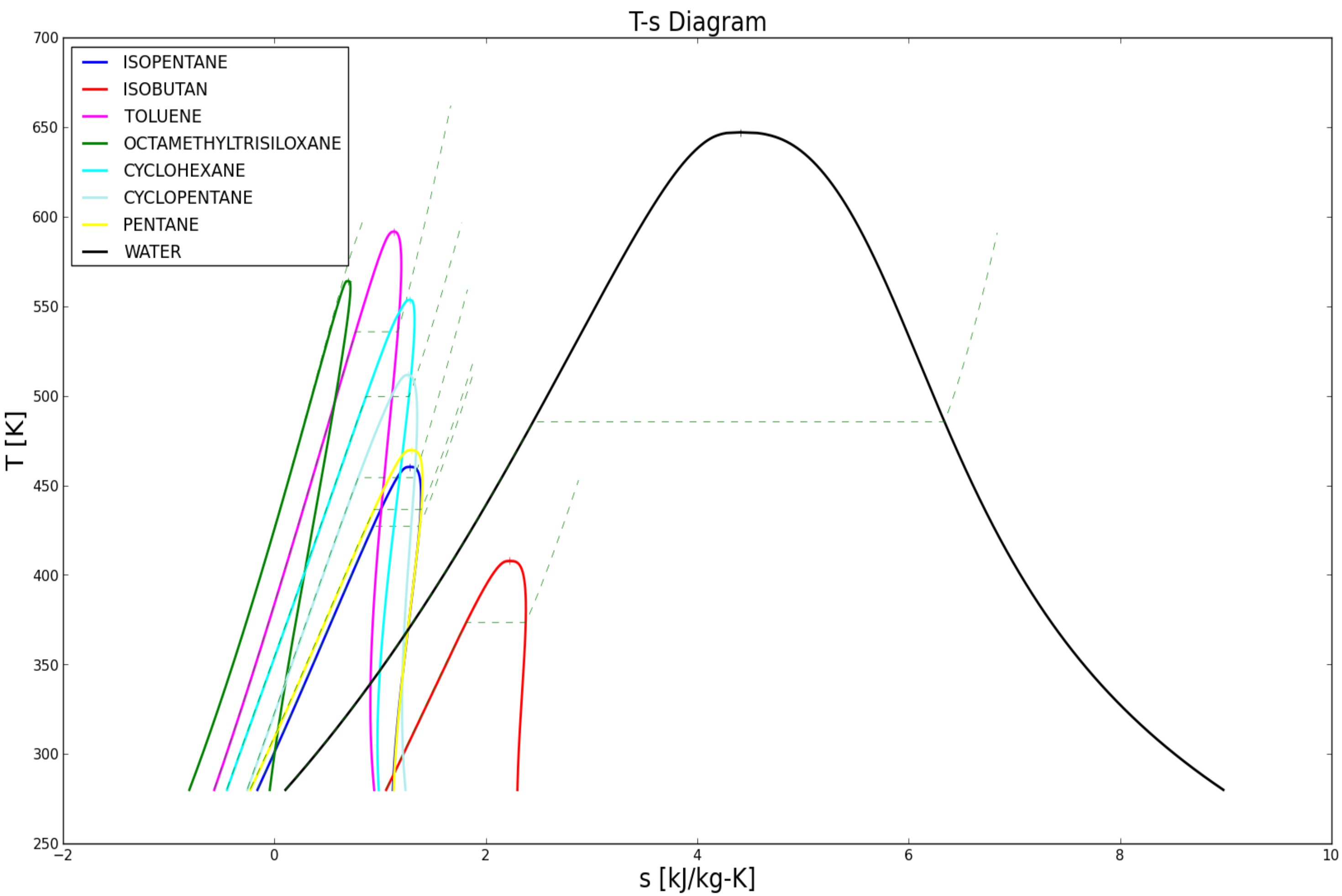


Heat recovery and power generation

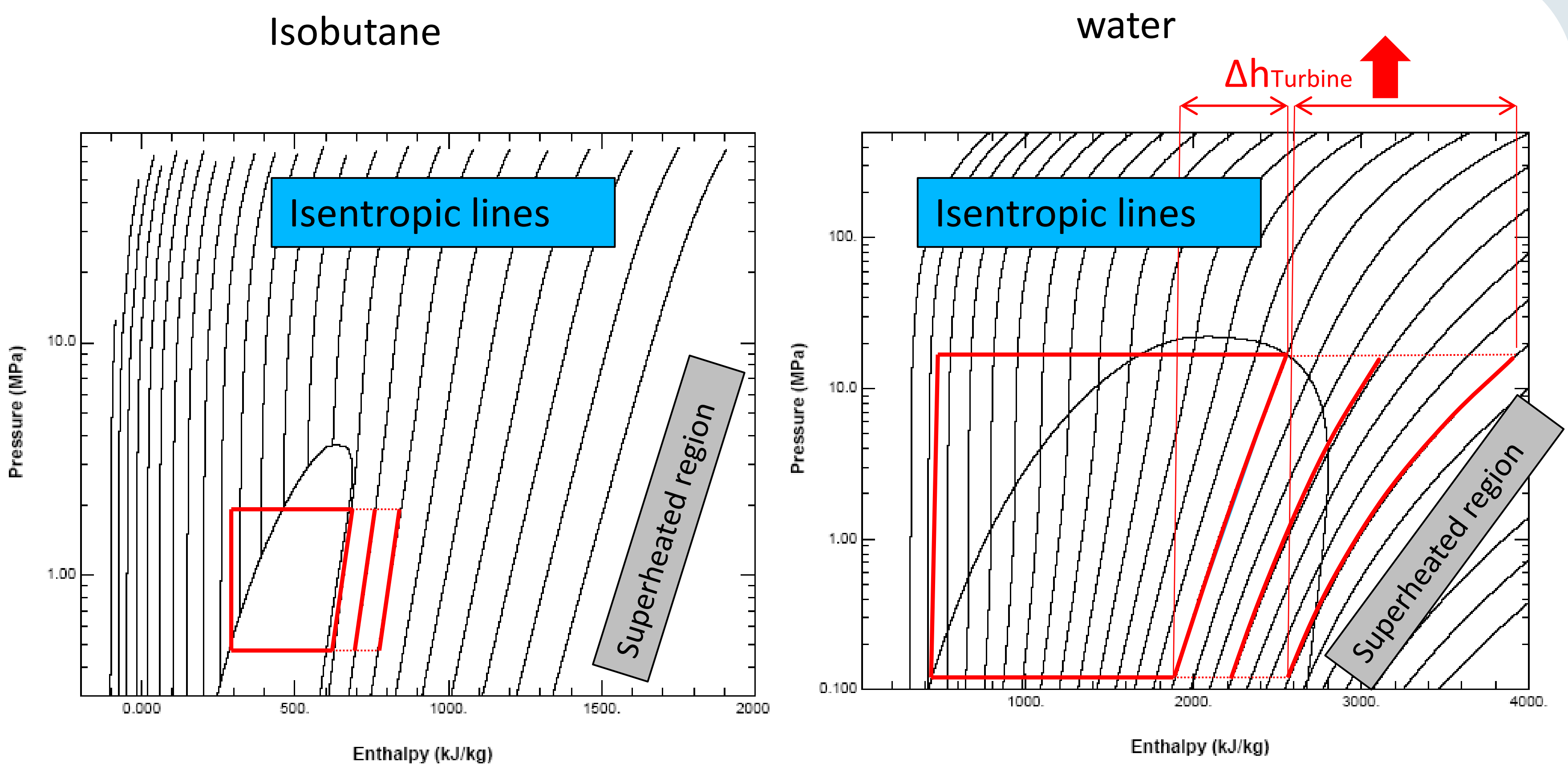


Source: http://www.gmk.info/ORC_Abwaerme.109.html?

Heat recovery and power generation



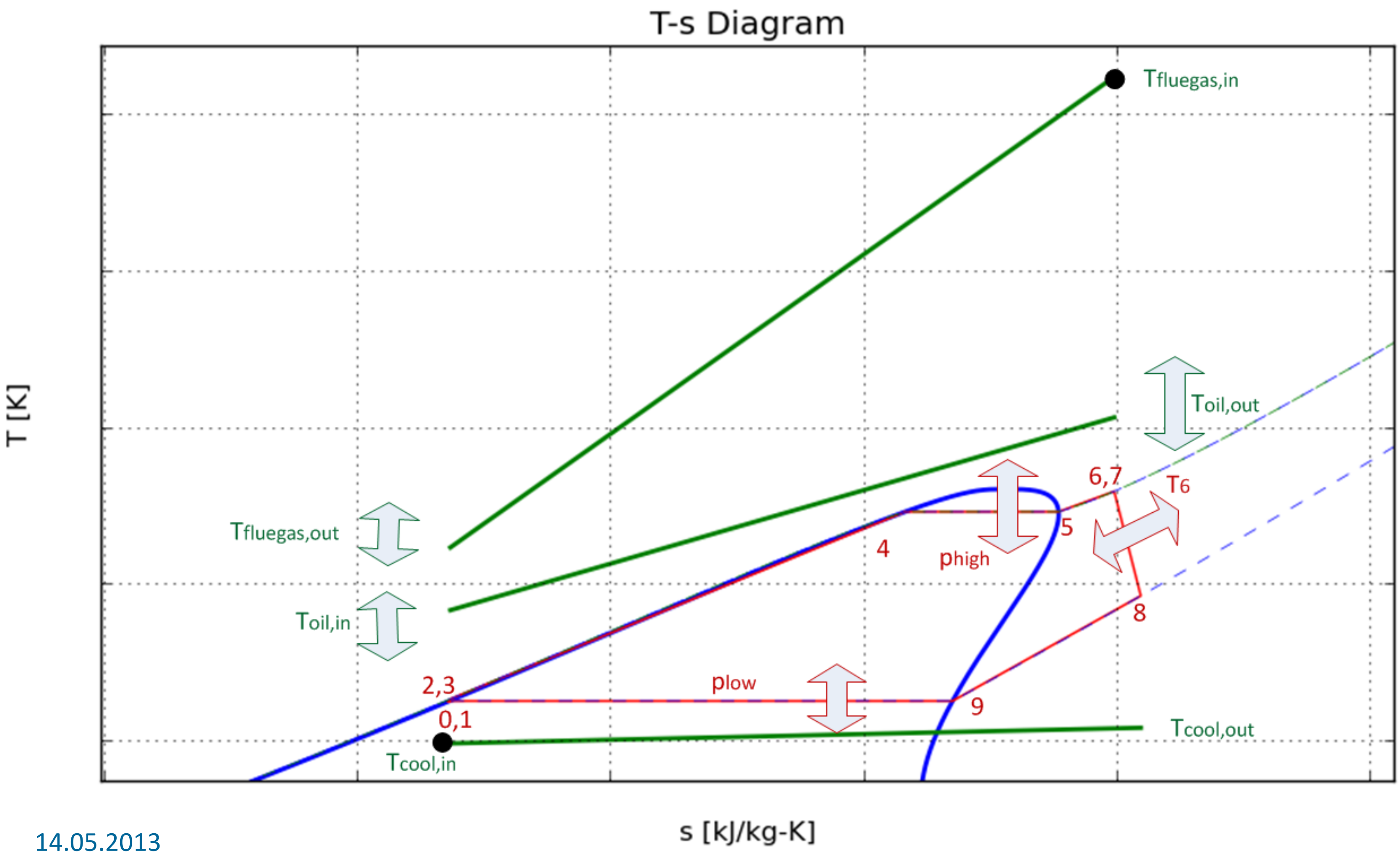
Heat recovery and power generation



Difference: Superheating at the water-steam cycle enhances enthalpy rapidly -> this effect is of minor influence at ORC's

Heat recovery and power generation

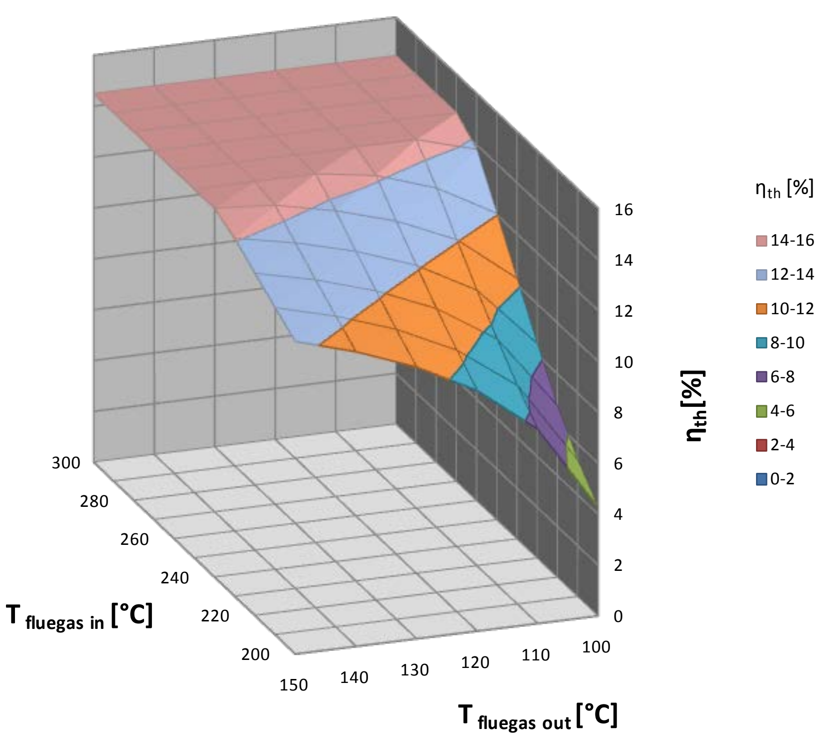
Given: $m_{fluegas}$, $T_{fluegas,in}$, $T_{cool,in}$,



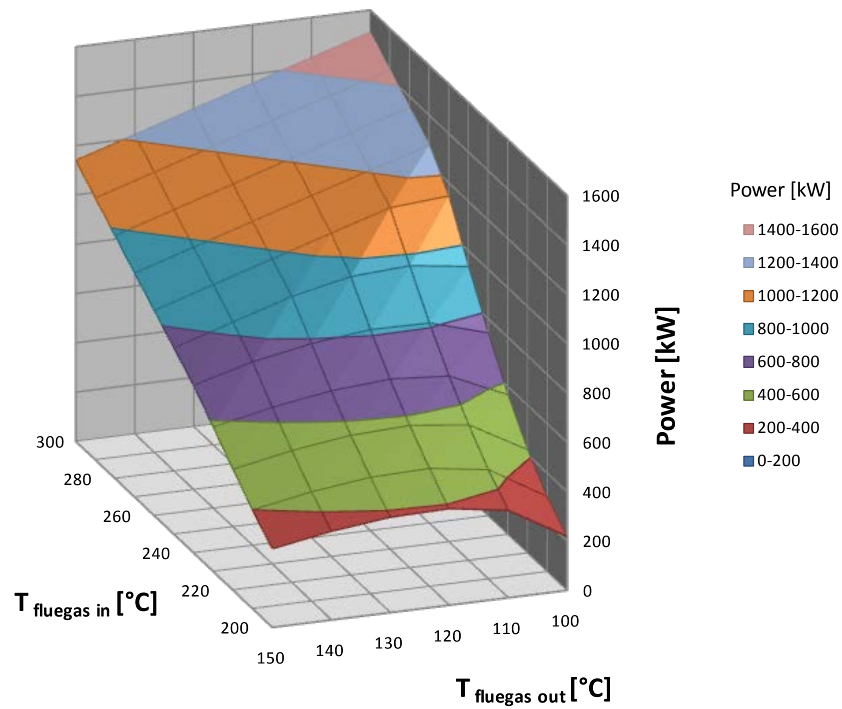
ORC: Selection of working fluid

Isopentan: $P = f(Q_{in}, \eta_{th})$

η_{th} vs. $T_{fluegas\ in}$ and $T_{fluegas\ out}$



Power vs. $T_{fluegas\ in}$ and $T_{fluegas\ out}$



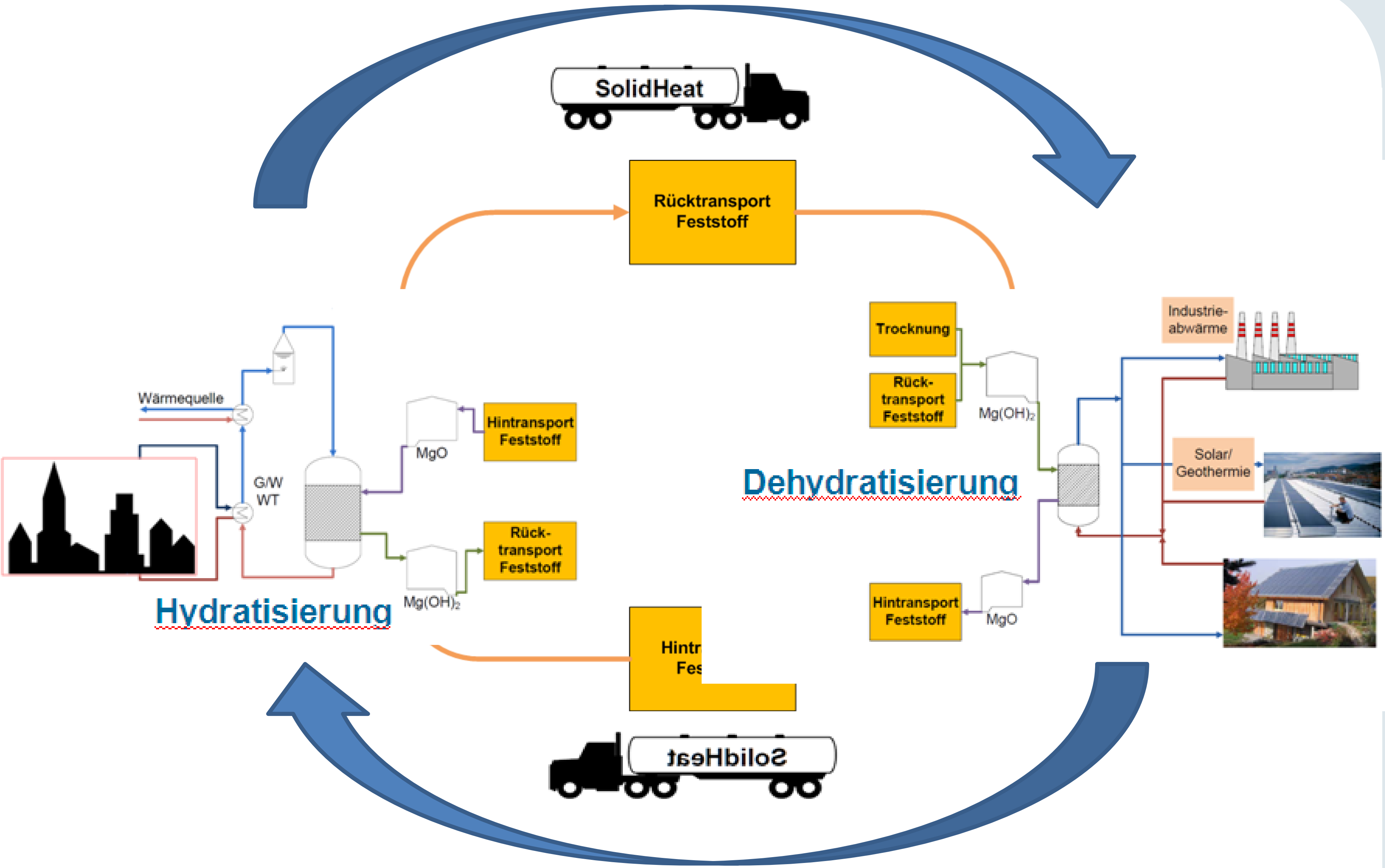
Global: all fluids

Performance	Tflue,in [°C]										
Tflue,out [°C]	200	210	220	230	240	250	260	270	280	290	300
100	ISOBUTAN	ISOBUTAN	ISOBUTAN	ISOBUTAN	IPENTANE	IPENTANE	IPENTANE	PENTANE	PENTANE	PENTANE	PENTANE
110	ISOBUTAN	ISOBUTAN	IPENTANE	IPENTANE	IPENTANE	IPENTANE	IPENTANE	PENTANE	PENTANE	PENTANE	CYCLOPENTANE
120	ISOBUTAN	IPENTANE	IPENTANE	IPENTANE	IPENTANE	IPENTANE	PENTANE	PENTANE	PENTANE	CYCLOPENTANE	CYCLOPENTANE
130	IPENTANE	IPENTANE	IPENTANE	IPENTANE	IPENTANE	PENTANE	PENTANE	PENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE
140	PENTANE	PENTANE	PENTANE	PENTANE	PENTANE	PENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE
150	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOPENTANE	CYCLOHEXANE

Heat recovery and storage

- Thermal storage based on internal energy (sensible heat)
- Phase change materials
- Thermochemical storage systemsa

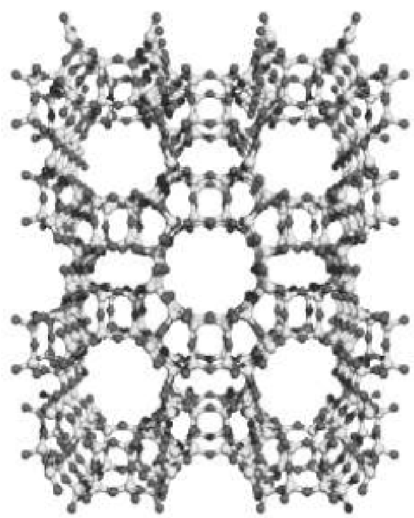
Thermochemical Storage

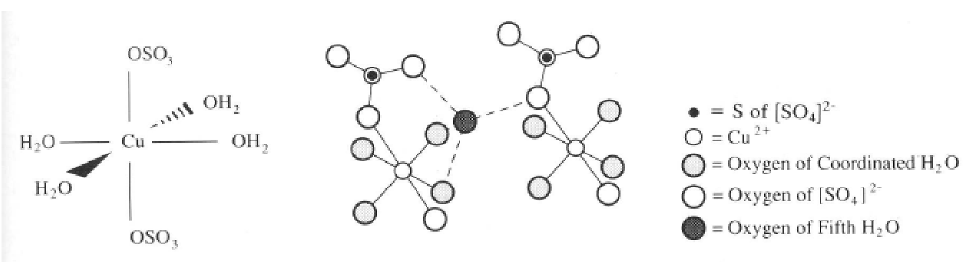


Types of chemical storage concepts

physical bonded water	chemical bonded water	Chemical bond

• Adsorption
  • Van-der-Waals Kräfte
  • Structural Water
• Zeolithe
• Silikagel
• Gashydrate
	• Absorption
	  • Chemische Bindung (Dipolbindung)
	  • Coordinating Water
	• Hydrate
	  • $MgSO_4 * 7H_2O$
		• Chemische Reaktion
		  • Reaktionsenthalpie
		• Oxid-Hydrid
		  • $MgO+H_2O=Mg(OH)_2$
		• Oxid-Carbonate
		  • $MgO+CO_2=MgCO_3$





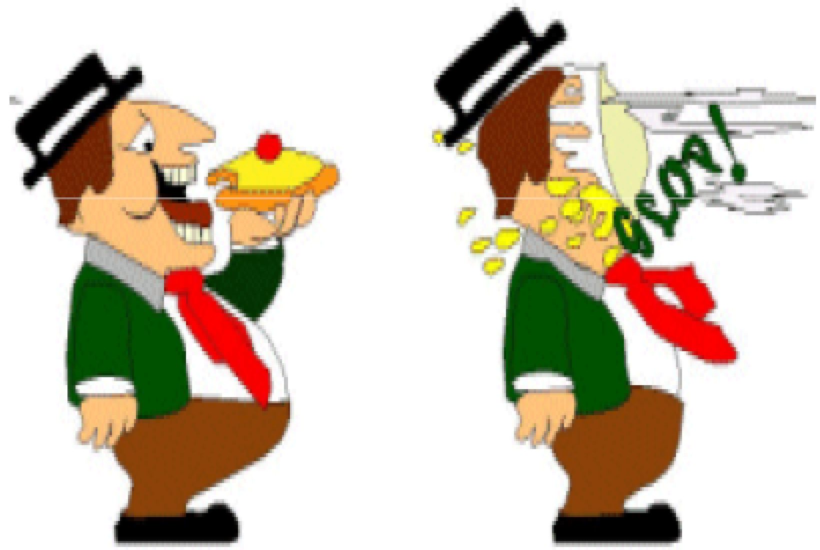
Mechanismus

How does it work?

Technically, two different mechanisms ‘under the hood’:

- **ab**sorption
  - chemisorption
  - volume

- **ad**sorption
  - physisorption
  - surface

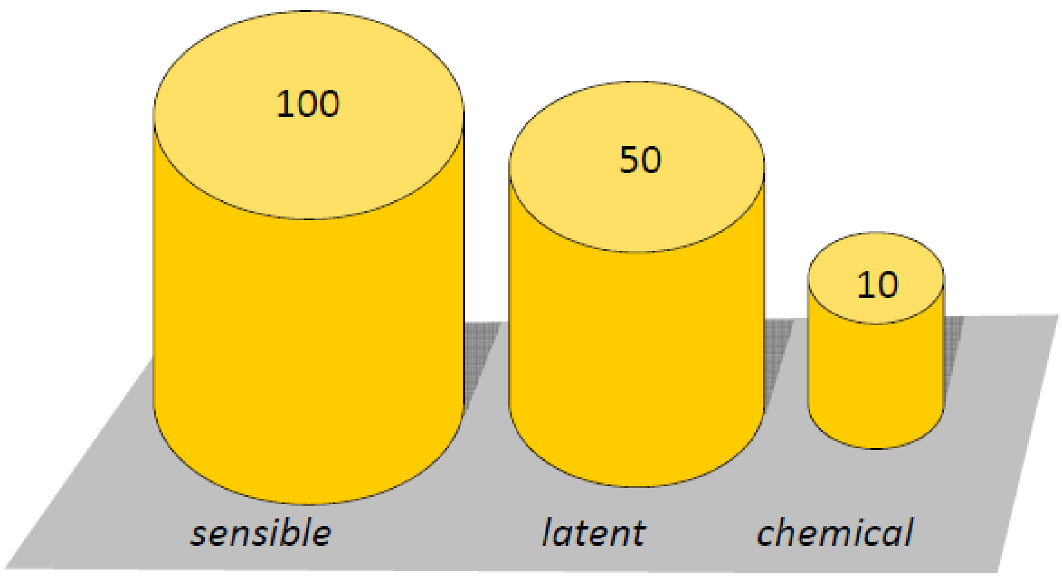


Capacity of different storage systems

ECN

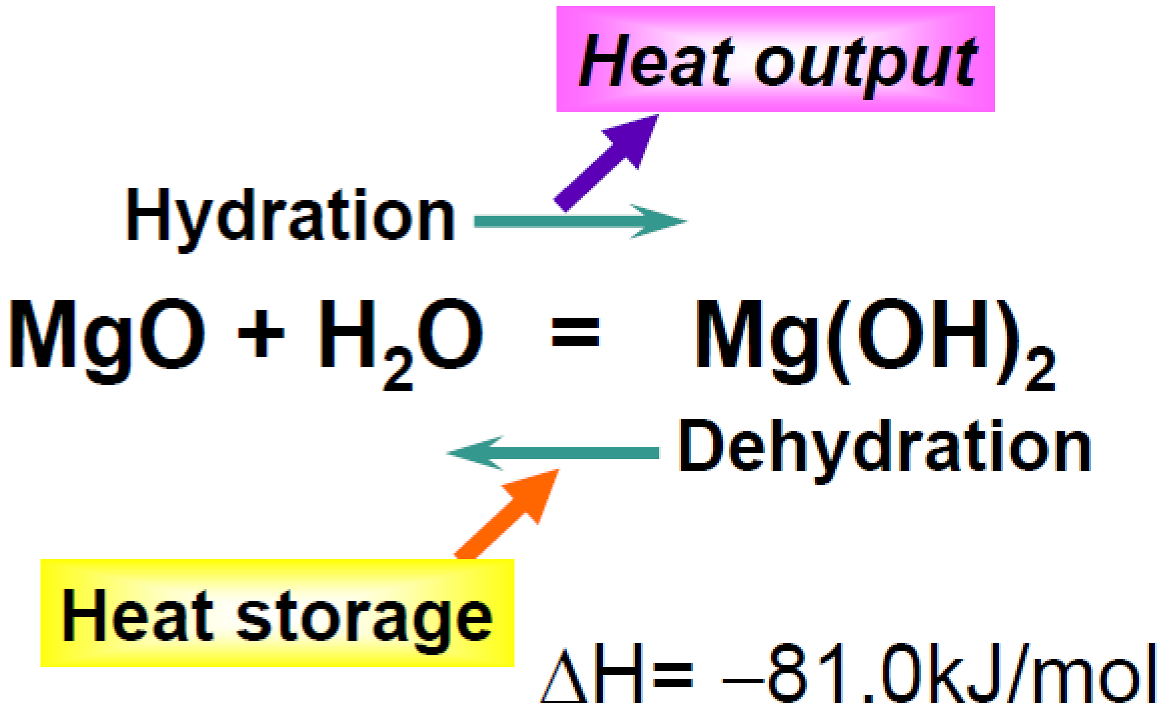
Heat storage principles

Example: storage volume in m^3 needed for full solar coverage of a very energy efficient household



System magnesium oxide

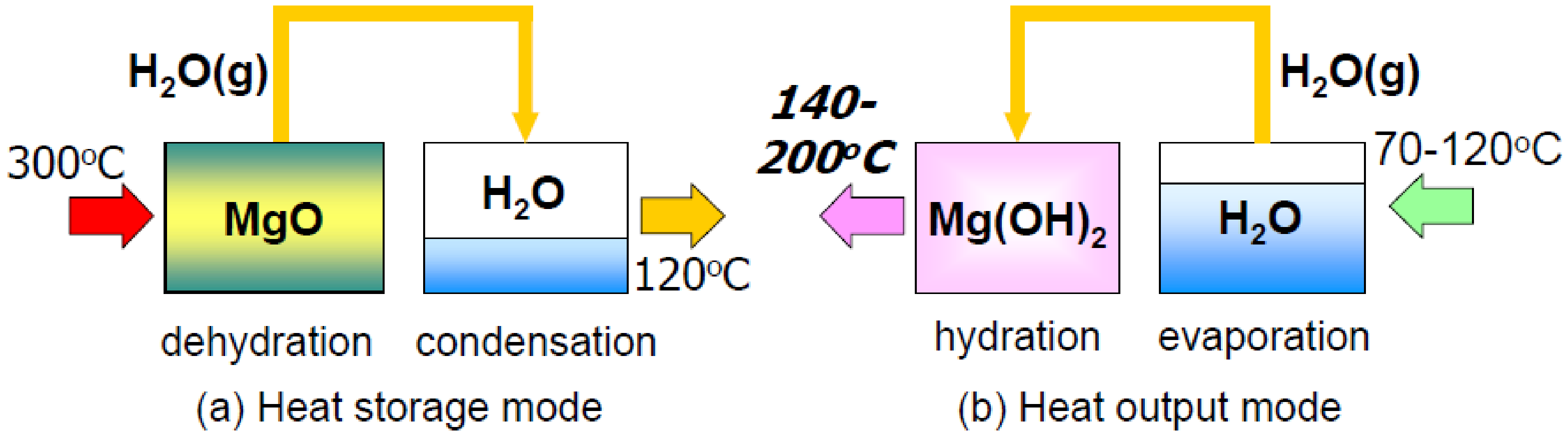
Kato et al, 2011



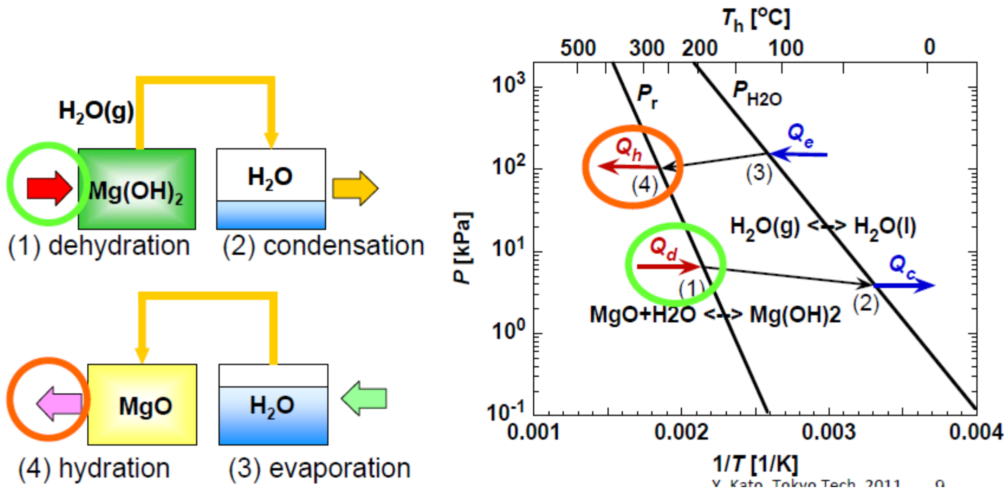
How does TCS work?

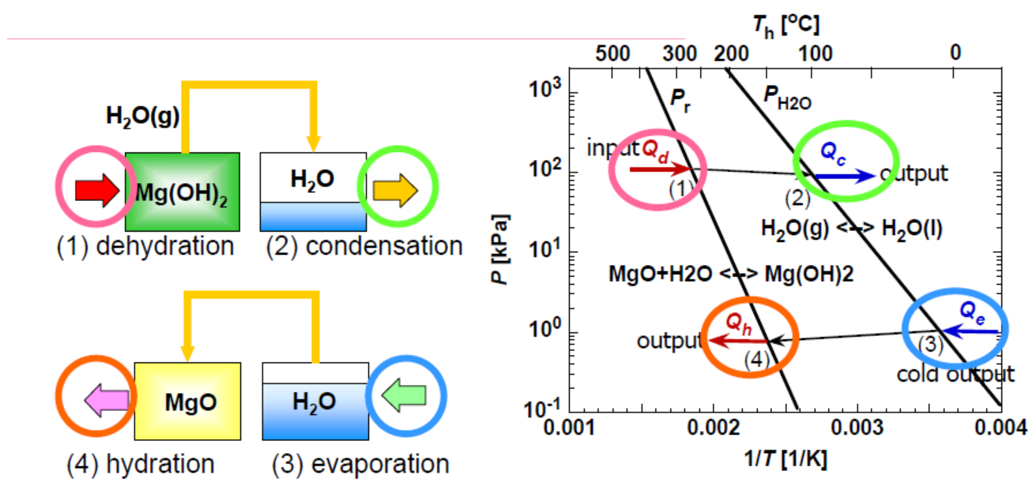
$MgO(s) + H_2O(g) = Mg(OH)_2(s)$ $\Delta H_1 = -81.02$ [kJ/mol]

$H_2O(g) = H_2O(l)$ $\Delta H_2 = -40.66$ [kJ/mol]

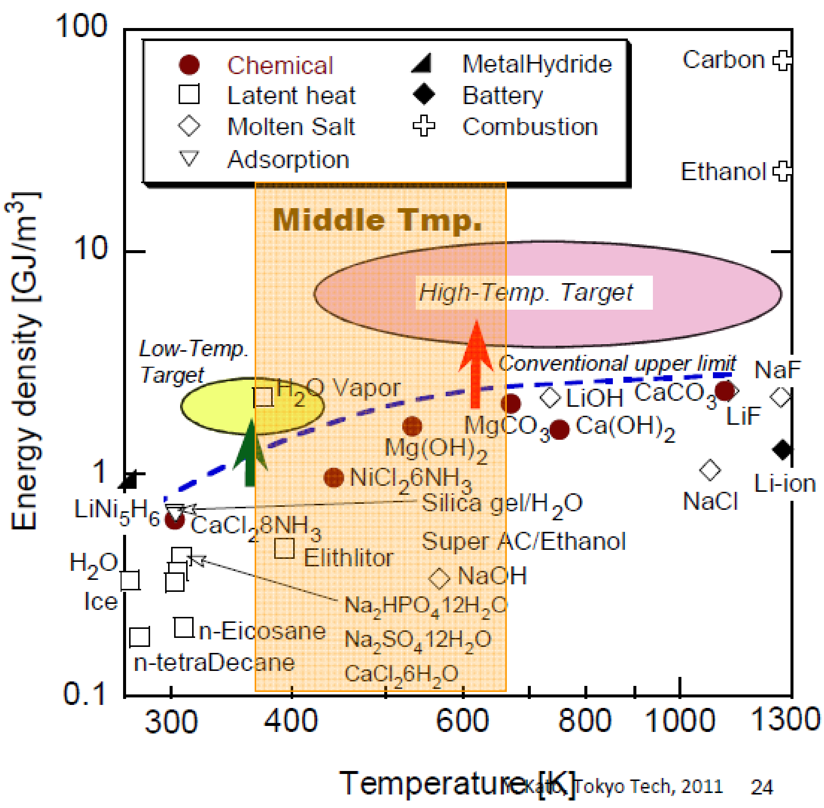


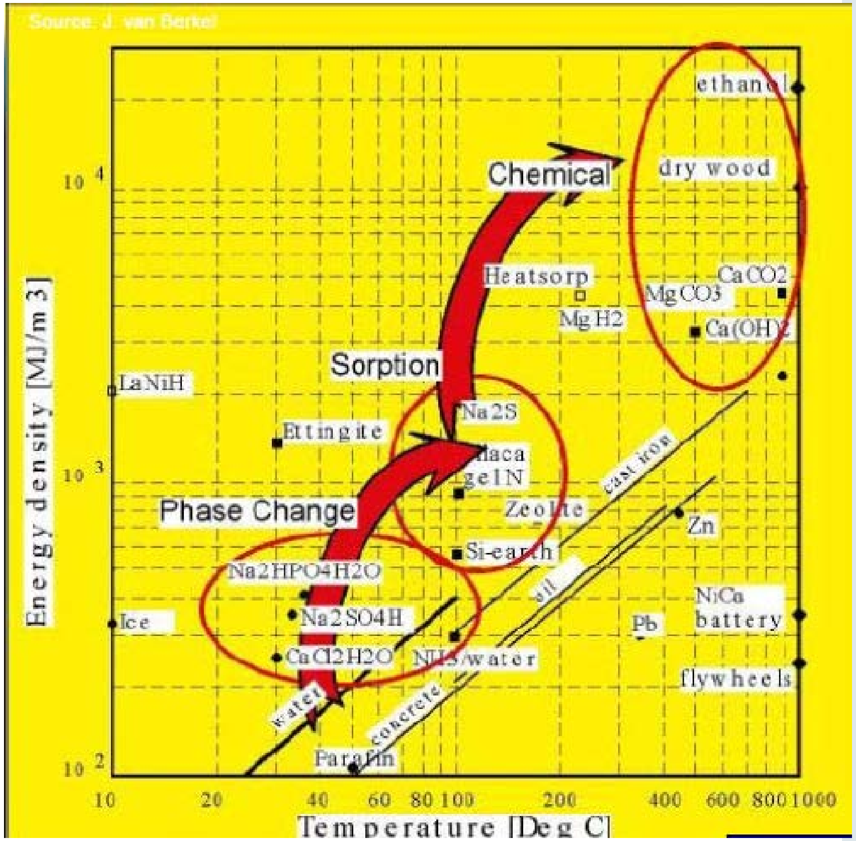
To be taken into account: chemical equilibrium





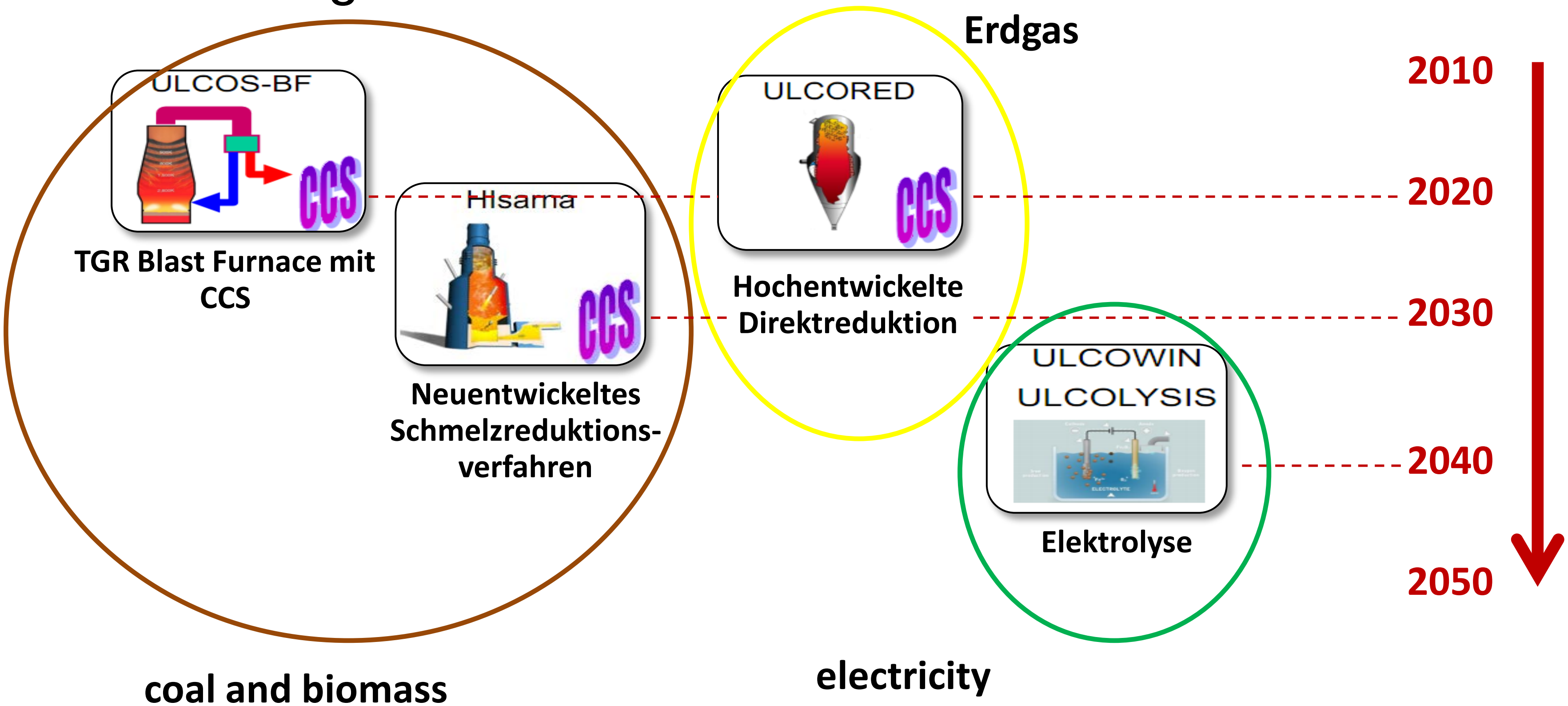
Materials f. TCS and energy storage





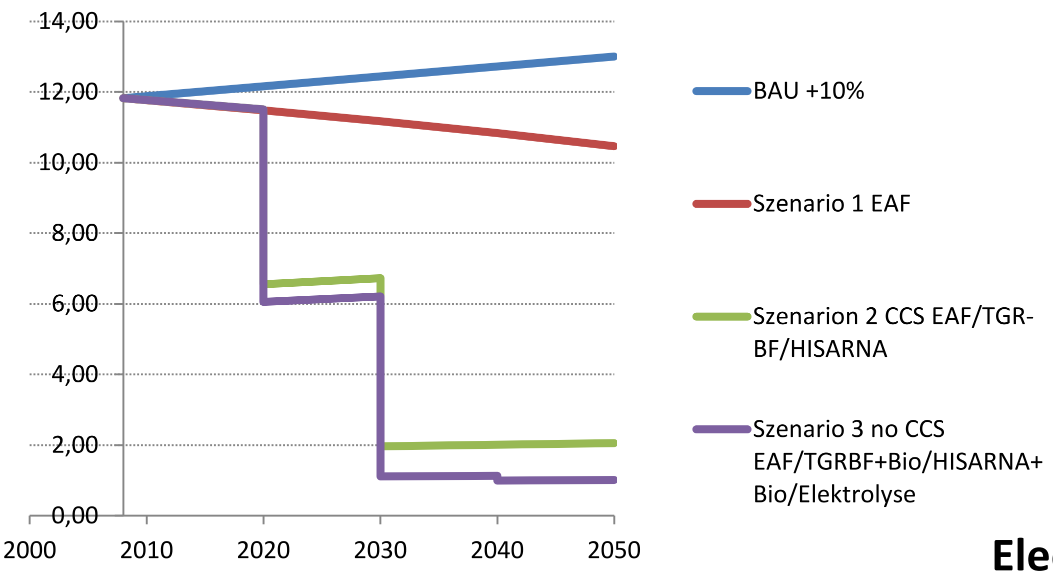
Advanced production technology

- Project of European steel companies ULCOS (Ultra Low CO_2 Steelmaking)
- Technologies to subtstitute blast furnace



Advanced production routes for iron and steel industry

CO_2-emissions (Mio t)

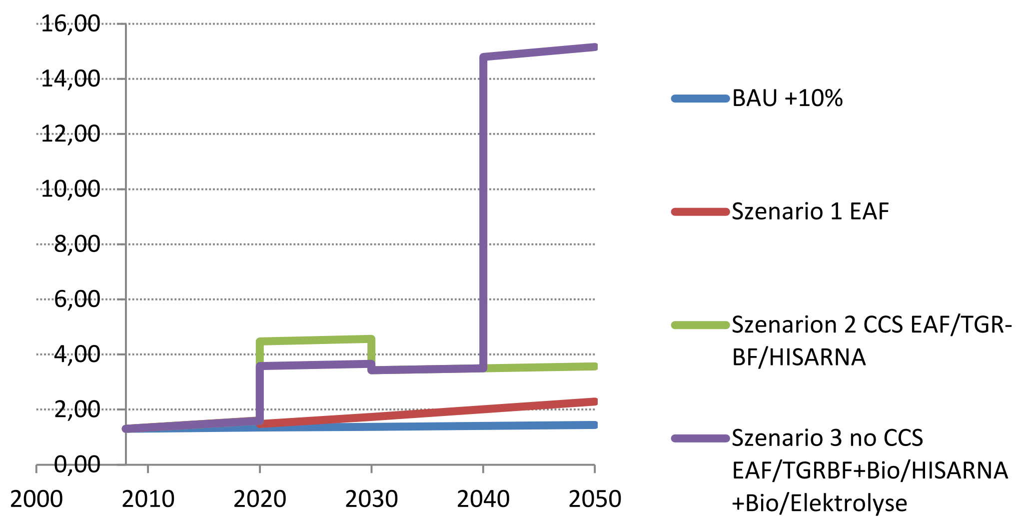


Summary:

+ Development of future steel demand is difficult to estimate,

+ technologies are under develop- which will reduce CO2-emission considerably

Electricity demand (TWh)

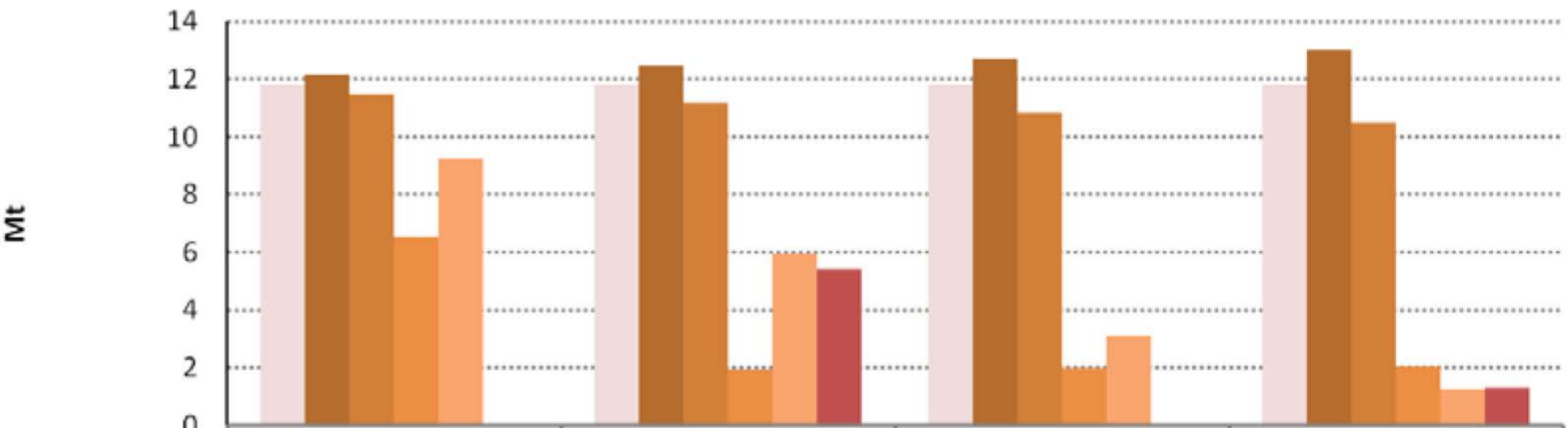


Remarks:

-The change to other reduction agents is necessary if the blast furnace will be the main production system in future

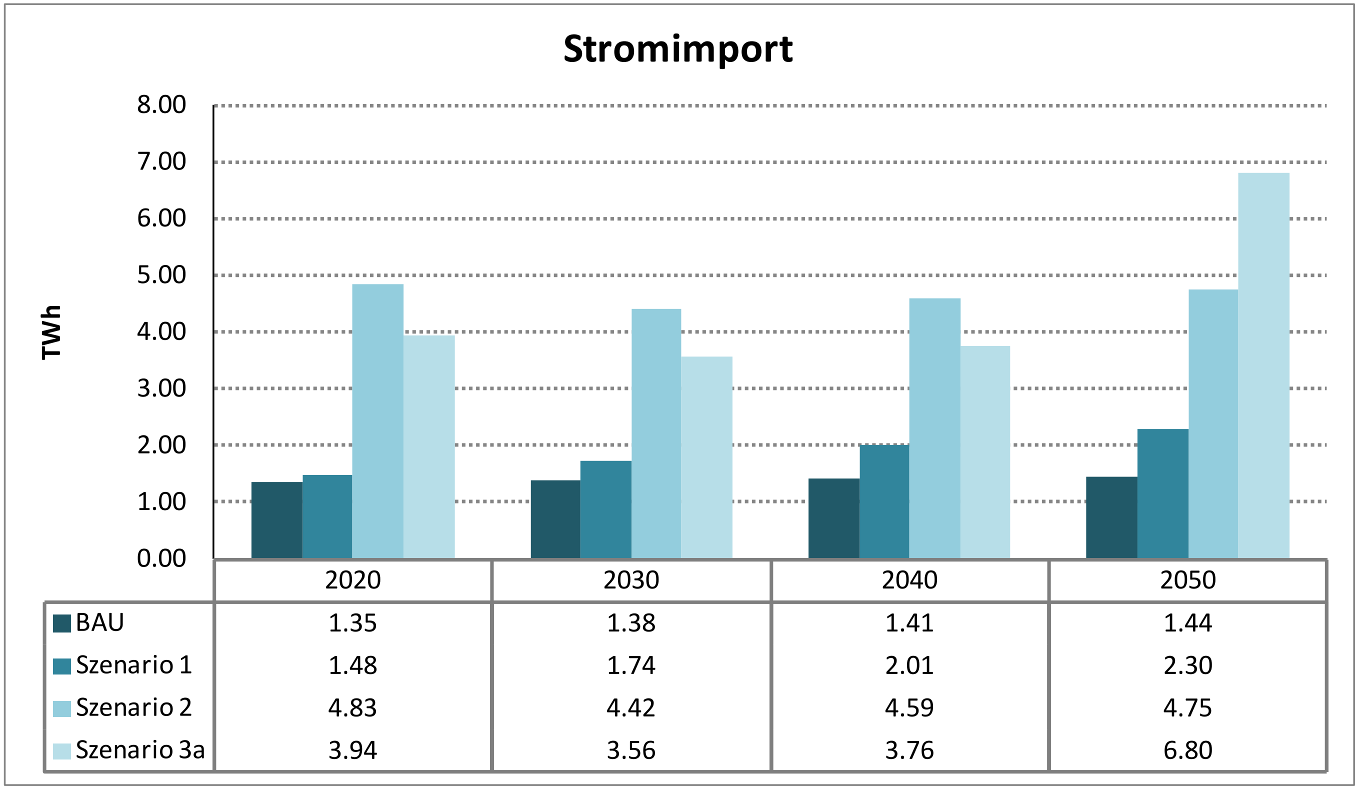
- the use of local biomass to substitute coal char seems to be impossible

CO_2-Emissionen



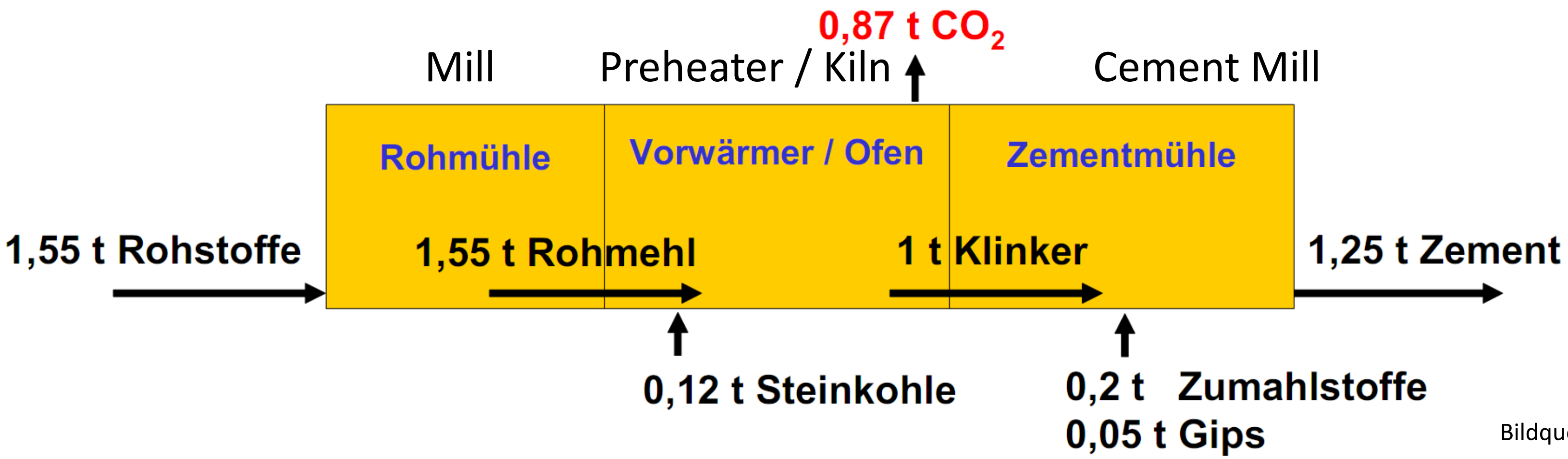
	2020	2030	2040	2050
Referenz 2008	11.82	11.82	11.82	11.82
BAU	12.16	12.44	12.72	13.00
Szenario 1	11.48	11.17	10.83	10.47
Szeanrio 2	6.54	1.96	1.99	2.03
Szenario 3a	9.25	5.94	3.11	1.26
EU-Vorgabe		5.40		1.29

Advanced production routes for iron and steel industry



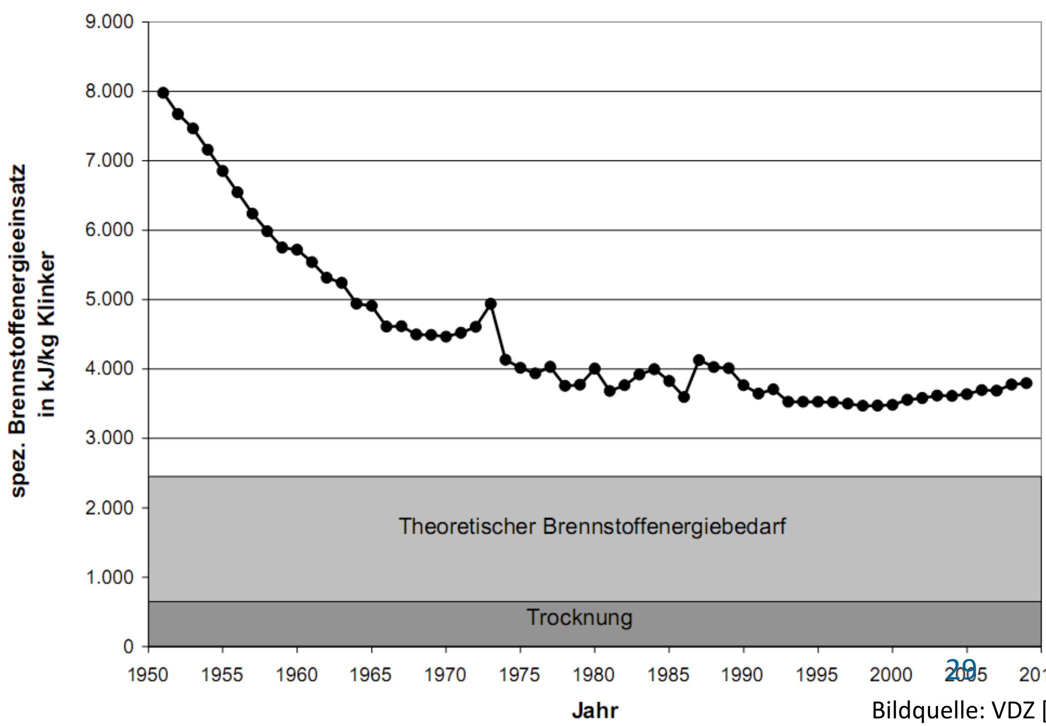
	2020	2030	2040	2050
BAU	1.35	1.38	1.41	1.44
Szenario 1	1.48	1.74	2.01	2.30
Szenario 2	4.83	4.42	4.59	4.75
Szenario 3a	3.94	3.56	3.76	6.80

Advanced production of cement



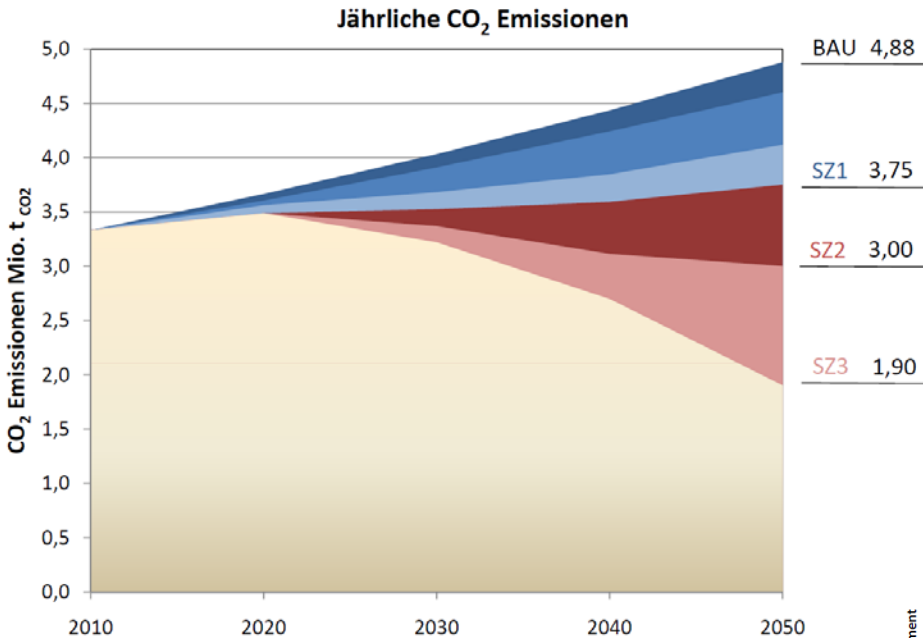
Bildquelle: KIT [2]

- **CO_2 – Sources:**
  fuel cause ~ $^1/_3$
- $C + O_2 \rightarrow CO_2$
- Process caused ~ $^2/_3$
- $CaCO_3 \rightarrow CaO + CO_2$

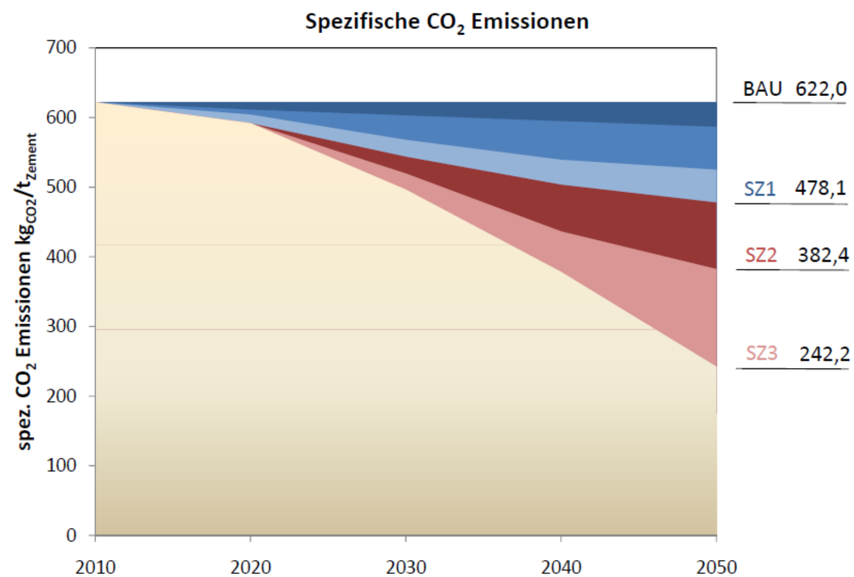


Bildquelle: VDZ [3]

Advanced production of cement

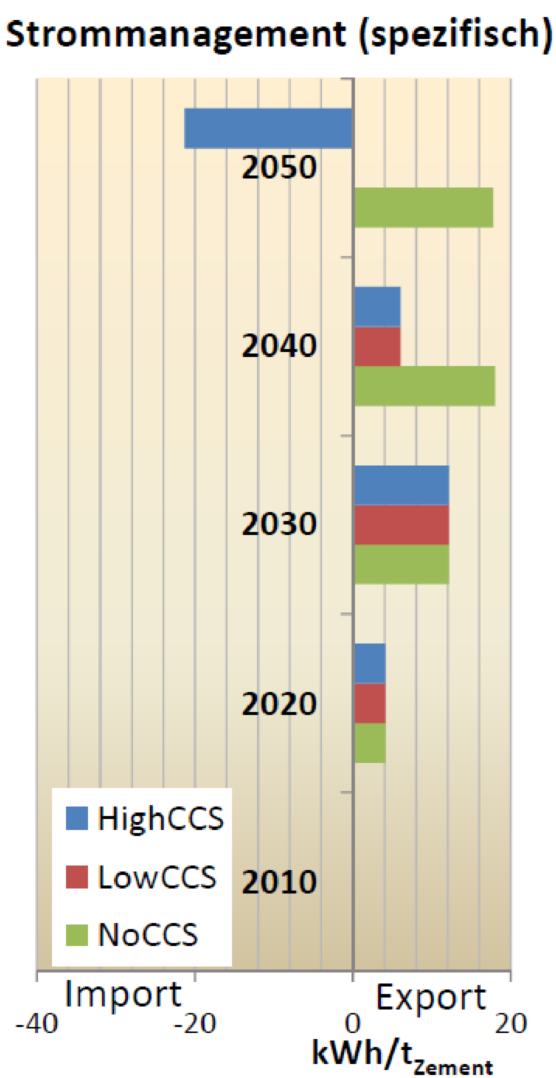


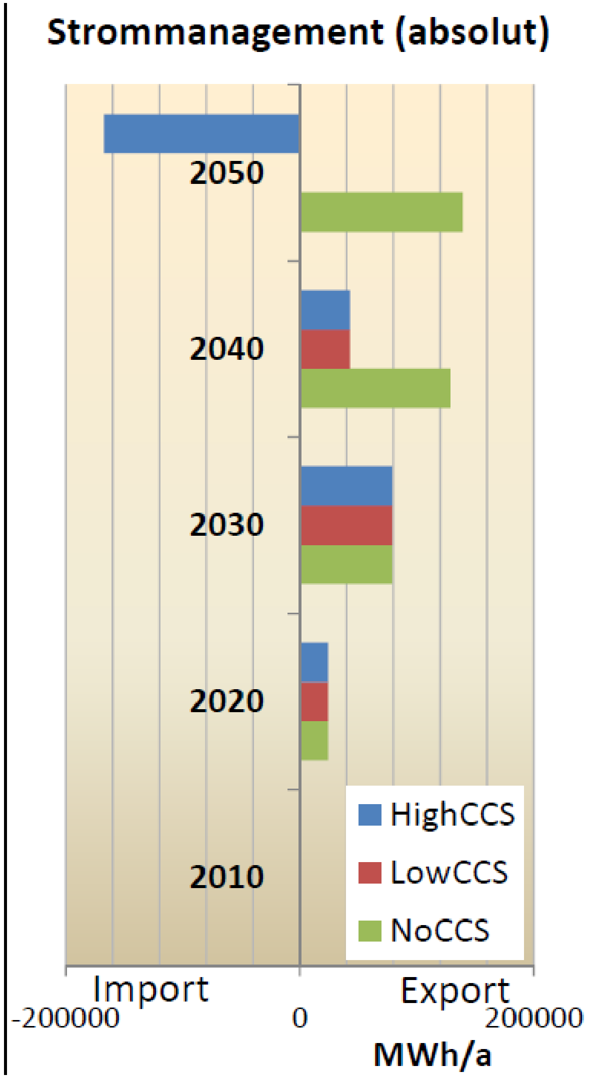
Scenario based assumptions:
Scenario 1: No CCS
Scenario 2: Low CCS
Scenario 3: High CCS



Bildquelle: VDZ [3]

Advanced production of cement





Bildquelle: VDZ [3]

Conclusions:

- Energy savings in industry can start immediately with simplest methods,
- Subdivide complex structures into systems which should be improved,
- Analyse measuring equipment within the system: What is available, what would be necessary, what can be got from the data available?
  How are the costs for additional data monitoring?
  How is the situation according to energy monitoring?
- Create a list of optimization measures: from simple to advanced (and cost intensive solutions)
- At heat recovery based power generation: Avoid standard errors like:
  Problematic fouling at heat exchangers, problems at condensers and air coolers...