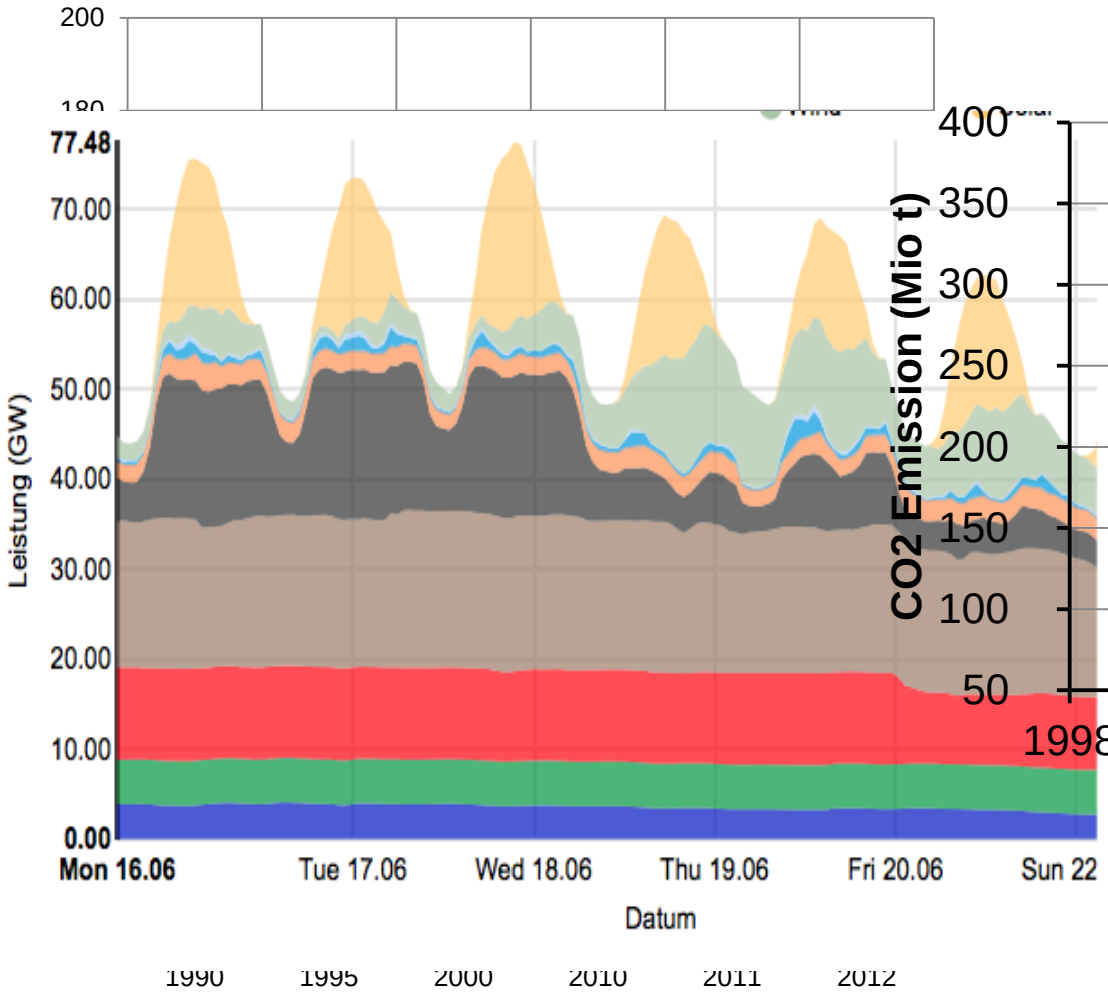
How Gas and Renewable

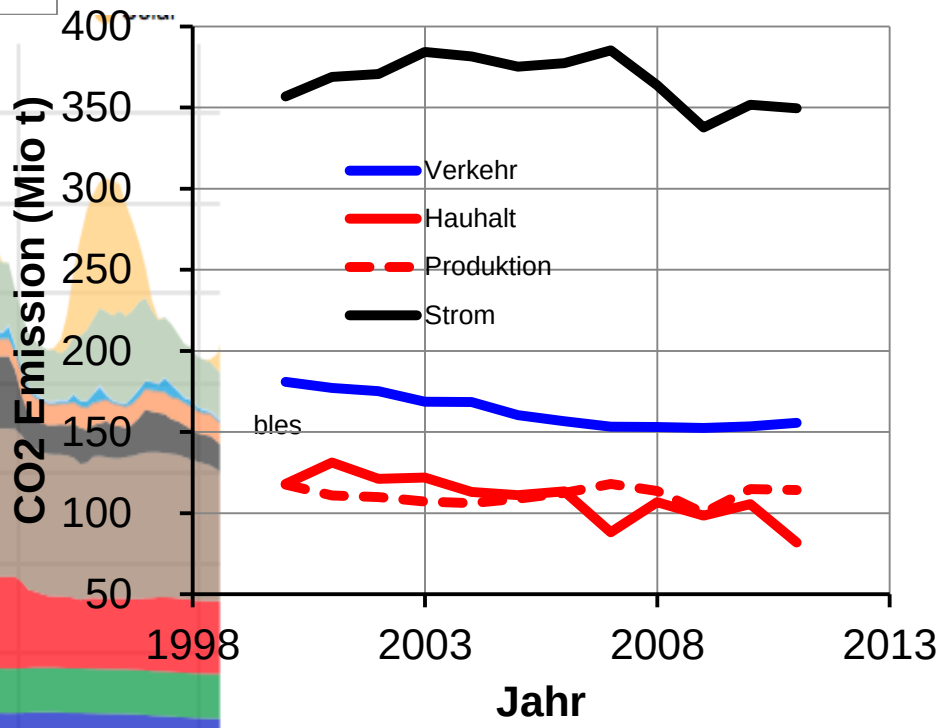
Energy turnaround (?)

- We strife for a conversion of energy systems into sustainable states.
- Energy is a system involving technical and human factors: it is holistic and non-rational.
- “Sustainable” means simultaneous optimization in several dimensions.
  - Closed cycle material streams under human control
  - Minimal restrictions in access to all resources required (energy and mineral)
  - Socio-economic accessibility for all stakeholders
- At present CO_2 seems the largest burden: fragmented regulatory approaches (electrical vs. mobility sectors).
- Strong regional differences presently critical for gas (fracking).

Some facts about gas in the German energy system



Source: AGEB 2013



Source: AGEB 2013

A few words on economics; The oil industry generates a turnover of 1 bn USD/d

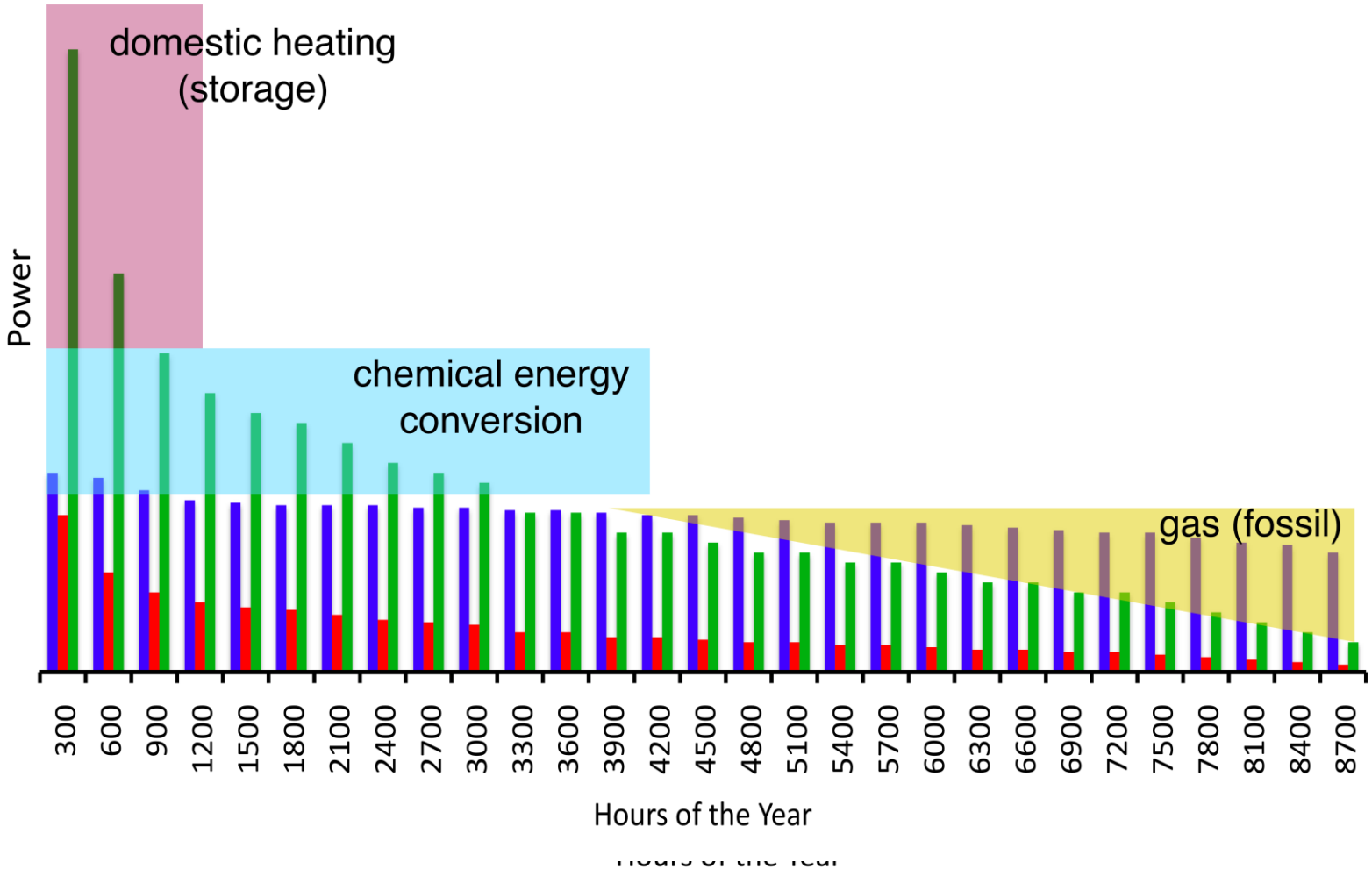
Chemical	**Prize per ton €**
H2 electrolysis	750 (projected), real ca. 2000
H2 reforming	200
CH2 (oil)	730 (1000 gasoline)
CH2 (gas)	675 europe, 135 US
CO2 (purified)	180
CH3OH	180
C (coal)	120
CH2 olefinic	200

VCI, BASF (2014)

At present no technology based on hydrogen ex electrolysis is economically viable even when all projected cost reduction is included.

If hydrogen becomes ca. 4 times cheaper then the production of solar transportation fuels becomes economically viable.

Integration of renewable electricity



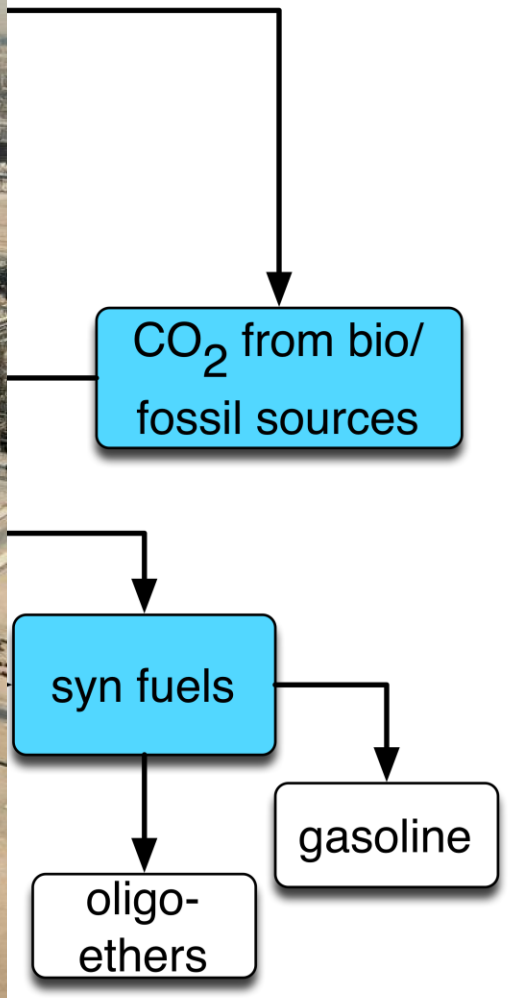
Structure of the gas consumption in Germany (2012)

- There contribute 4 main applications towards the primary gas consumption.
- In order to collect the CO_2 saving contribution from the gas consumption some replacement of gas by renewable electricity is politically required.
- Most easily achieved in domestic heating with central supply (thermal storage).

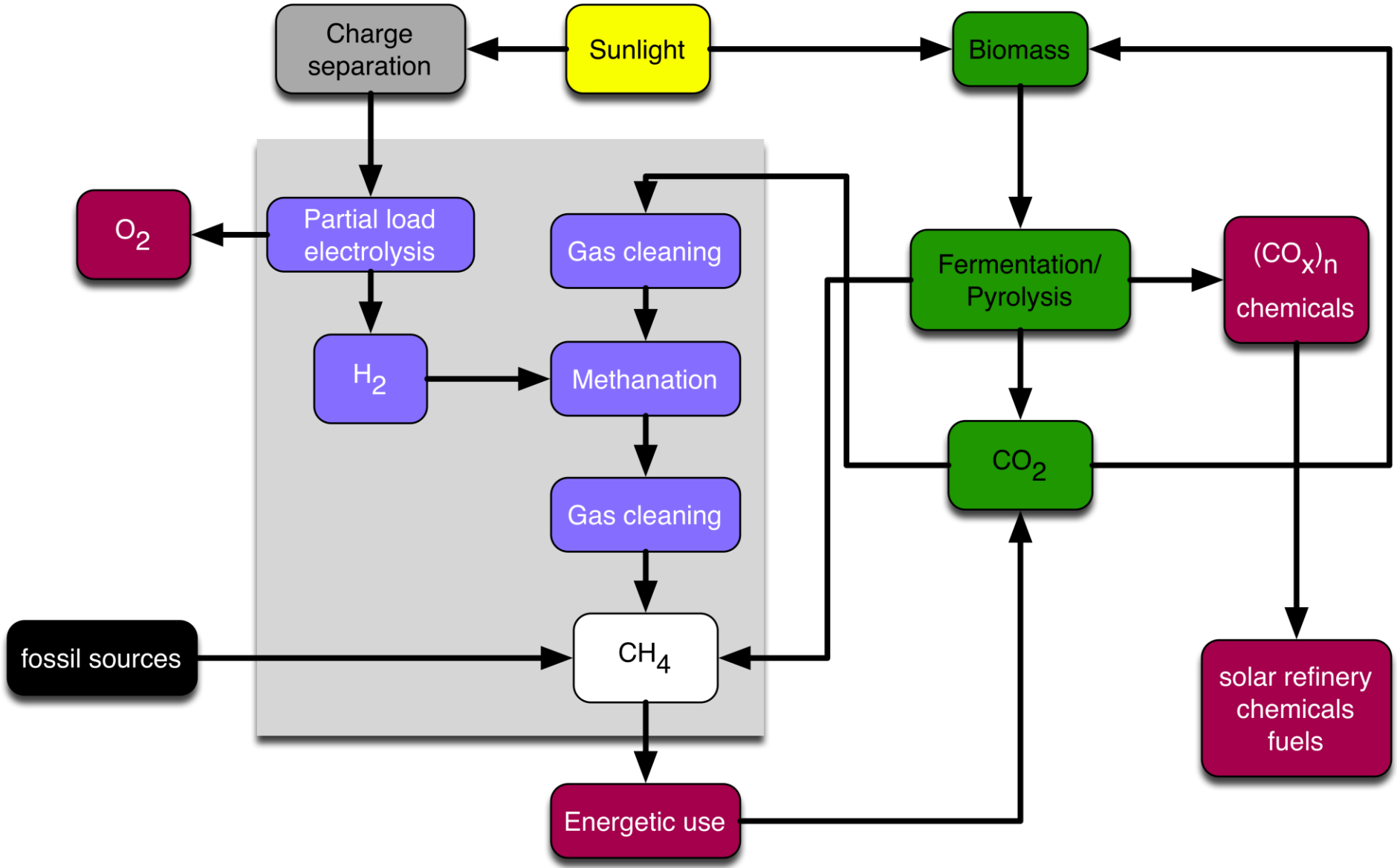
Industrial heating	Domestic heating	SME, services	Power generation
940	907	437	603

In PJ

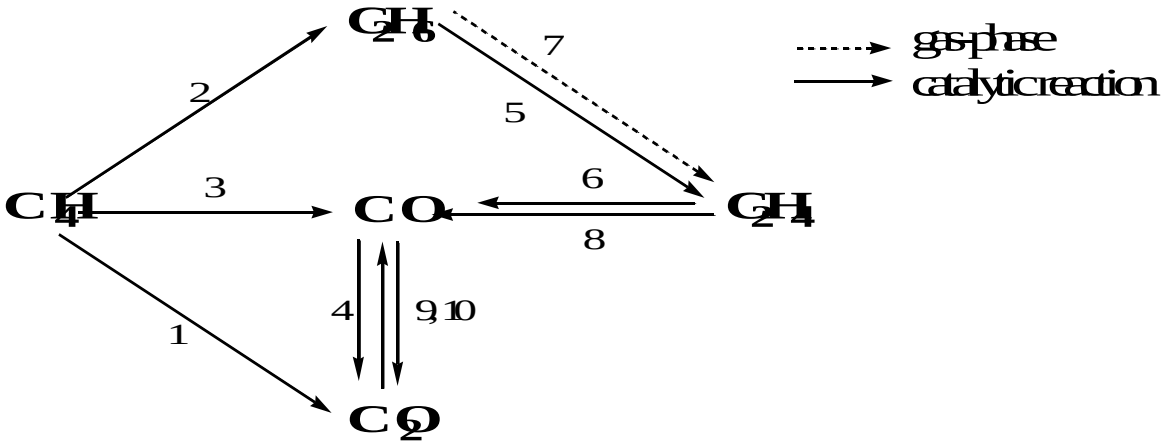
A practical realization of systemic energy supply: power from two independent systems!



The ultimate long-term solution



Science challenges



(1): $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
(2): $2CH_4 + 0{,}5O_2 \rightarrow C_2H_6 + H_2O$
(3): $CH_4 + O_2 \rightarrow CO + H_2O + H_2$
(4): $CO + 0{,}5O_2 \rightarrow CO_2$
(5): $C_2H_6 + 0{,}5O_2 \rightarrow C_2H_4 + H_2O$
(6): $C_2H_4 + 2O_2 \rightarrow 2CO + 2H_2O$
(7): $C_2H_6 \rightarrow C_2H_4 + H_2$
(8): $C_2H_4 + 2H_2O \rightarrow 2CO + 4H_2$
(9): $CO + H_2O \rightarrow CO_2 + H_2$
(10): $CO_2 + H_2 \rightarrow CO + H_2O$

Traditional activation of methane to syn gas or OCM:
A reaction network still poorly controlled.

During methanation the nature of a Ni catalysts changes dynamically limiting performance and selectivity: This requires incomplete conversion with non-noble metal catalysts.

Discussion

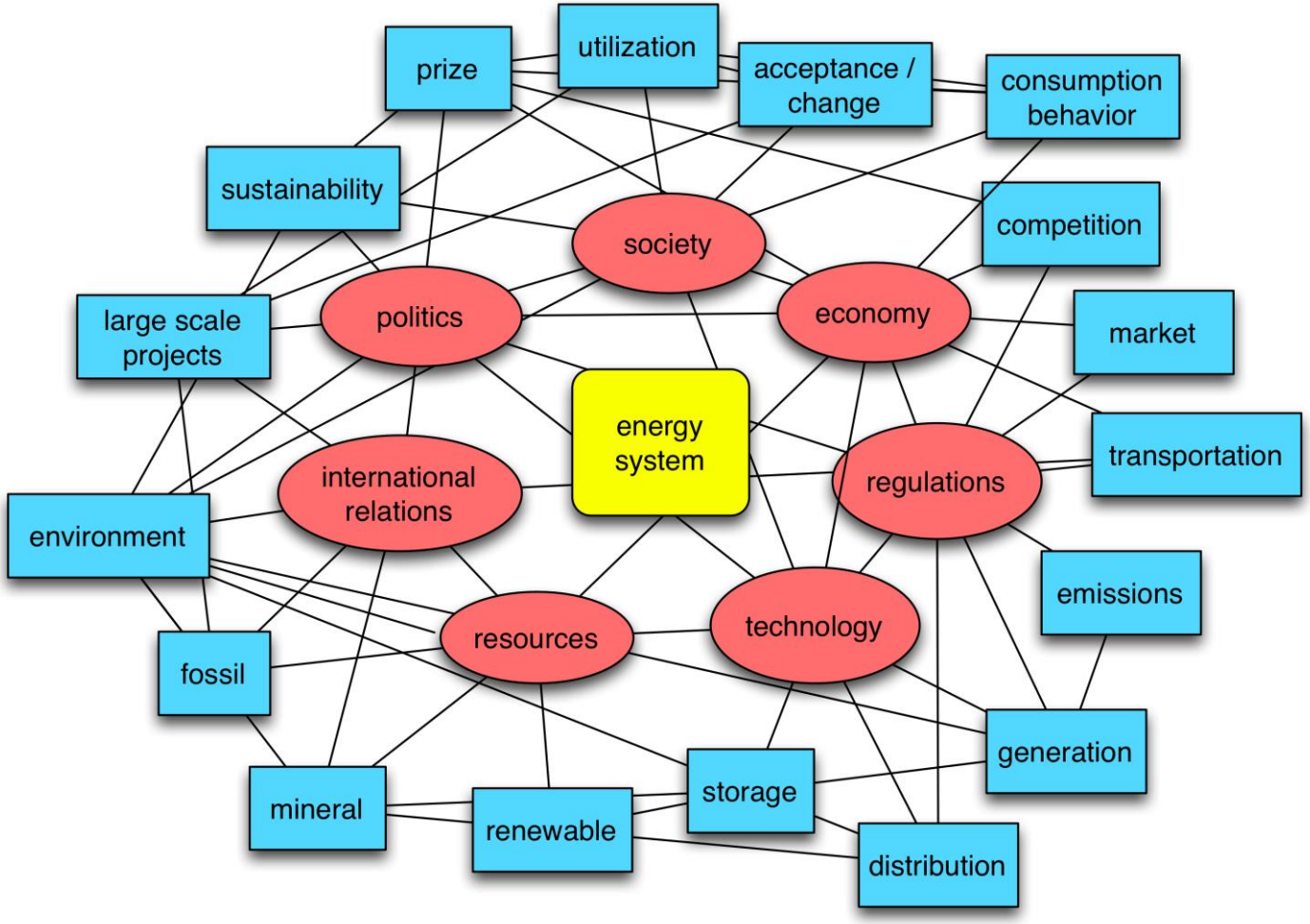
- Gas in Europe is hindered in its positive effects for energy systems.
- Regulatory and economic causes (could be resolved).
- Uses in transportation not activated (societal).
- Fossil (and Bio-)gas is a medium-to-long term ingredient in sustainable systems.
- Excess electricity should first go into power to X (material, transportation).
- Power-to-gas is the ultimate long term solution required when fossil gas is past peak production (or political).
- Massive deficits exist in fundamental and technological sciences for reliable economic grid scale CEC.

Dem Anwenden muss das Erkennen vorausgehen

Max Planck

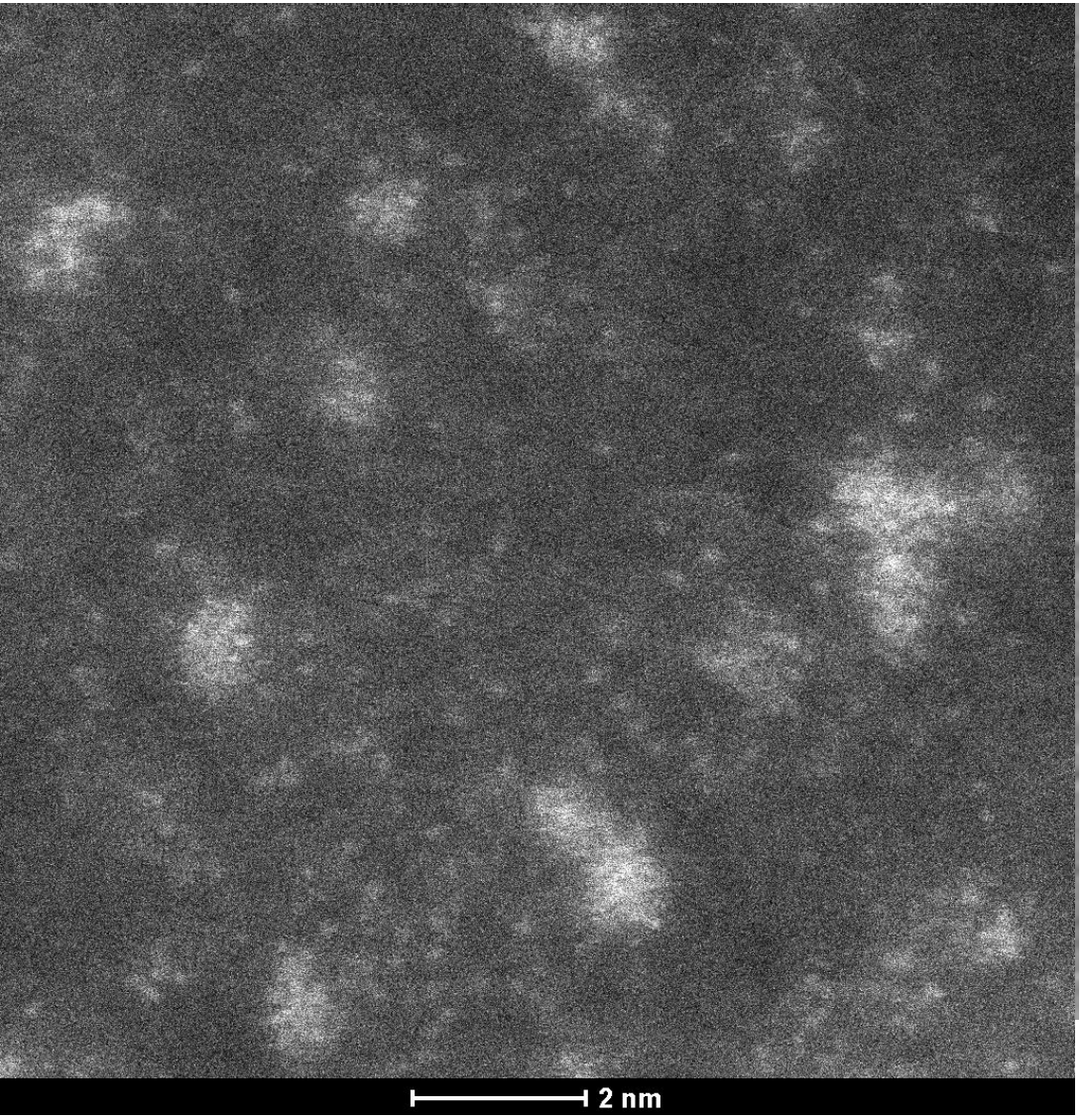
Thank You

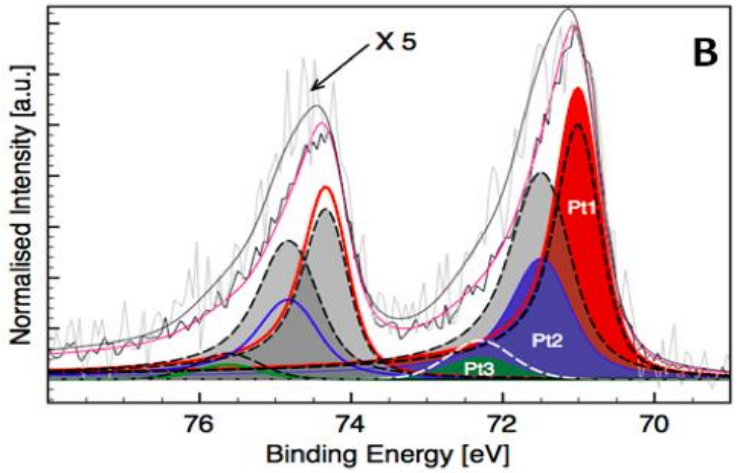
A holistic view of energy: energy conservation and human behaviour

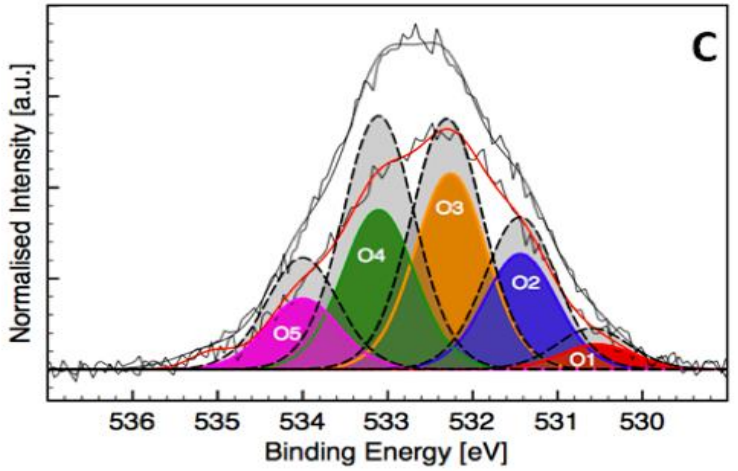


If the energy turnaround should be lost it will be outside of science!!!

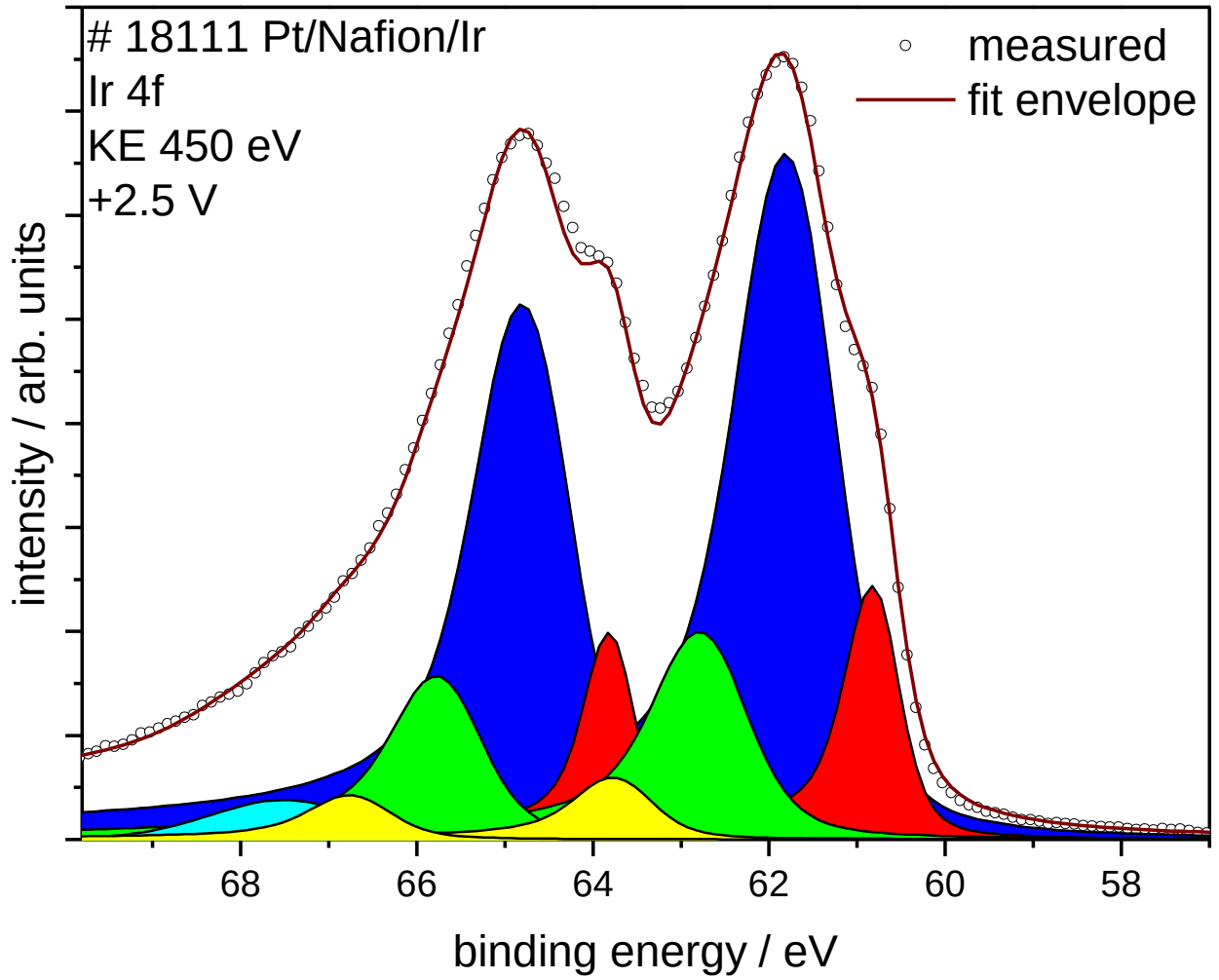
Water splitting is essential to minimize CO_2 emission a close-up into oxygen evolution reaction







Speciation at reaction conditions



General options for sustainable systems