ZAE BAYERN

The Future of VIPs – Challenges and Opportunities

Jochen Fricke
Bavarian Center for Applied Energy Research (ZAE Bayern)
Am Hubland, 97074 Wuerzburg, Germany
fricke@zae.uni-wuerzburg.de

Brundtland-Kommission* in 1987:

ZAE BAYERN

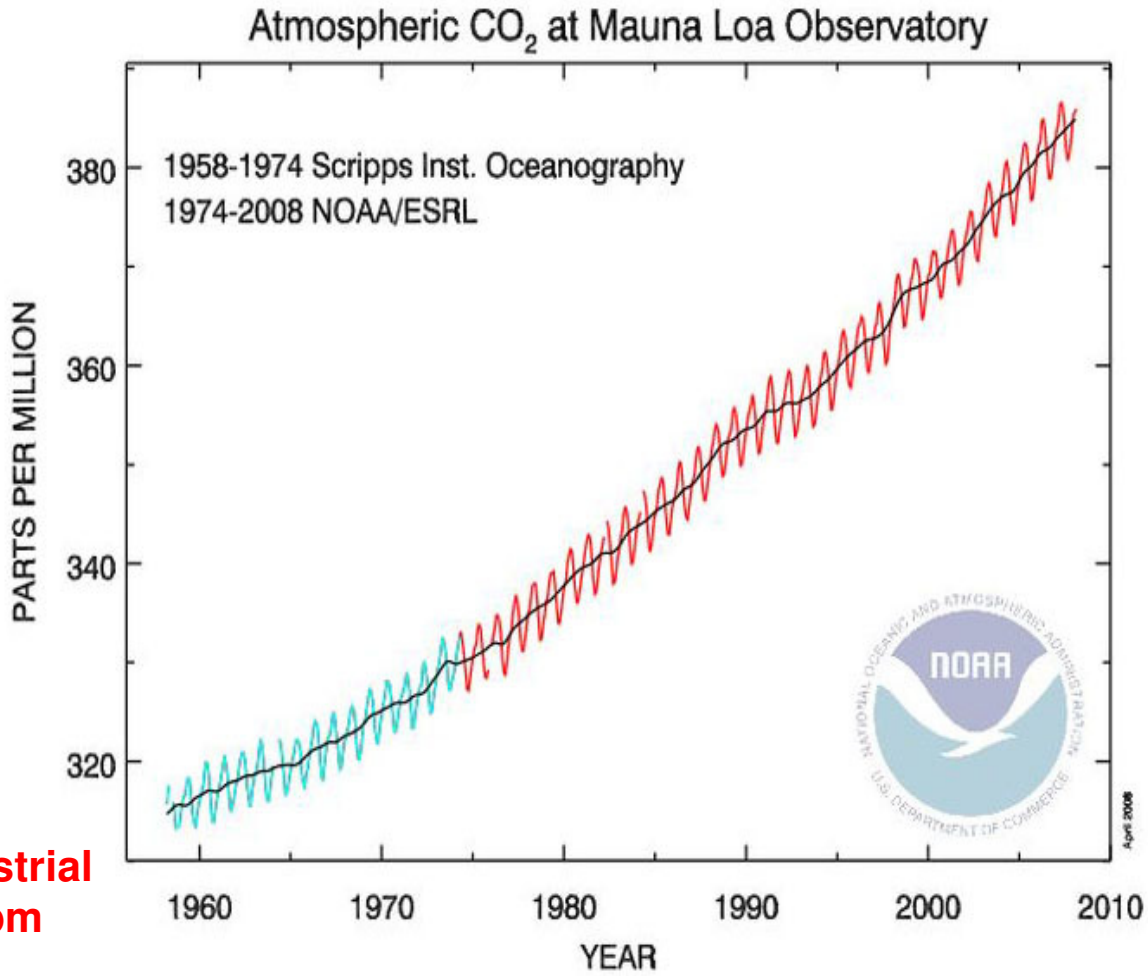
„Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.“

Seems a great dream, if one considers ….

* Chairwoman Gro Harlem Brundtland
Norwegian Primeminister

.. the CO_2 Increase From 280 to >380 ppm

ZAE BAYERN



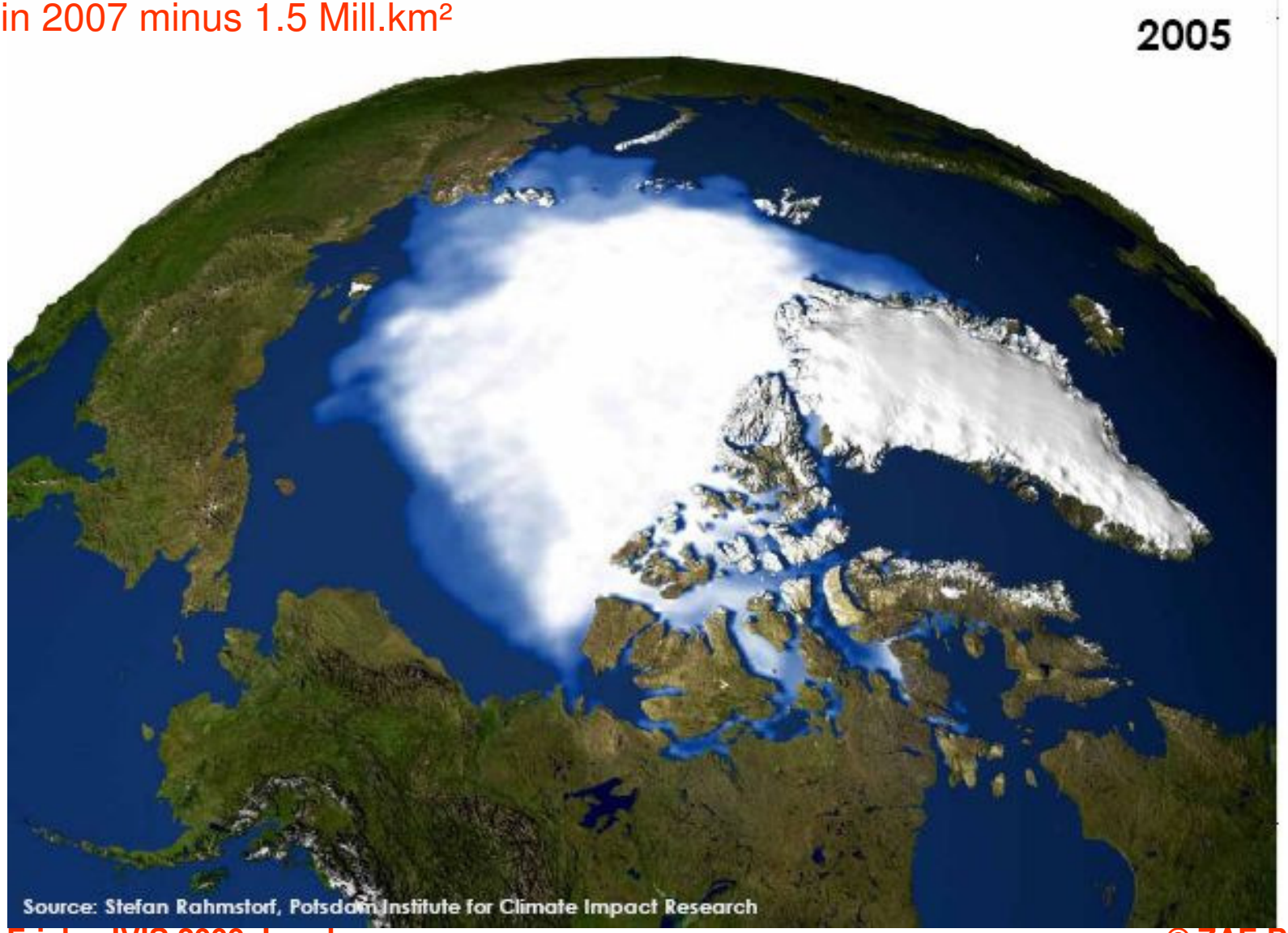
pre-industrial 280 ppm

The North Pole Sea Ice ….

...is Melting Faster Than Predicted.

ZAE BAYERN

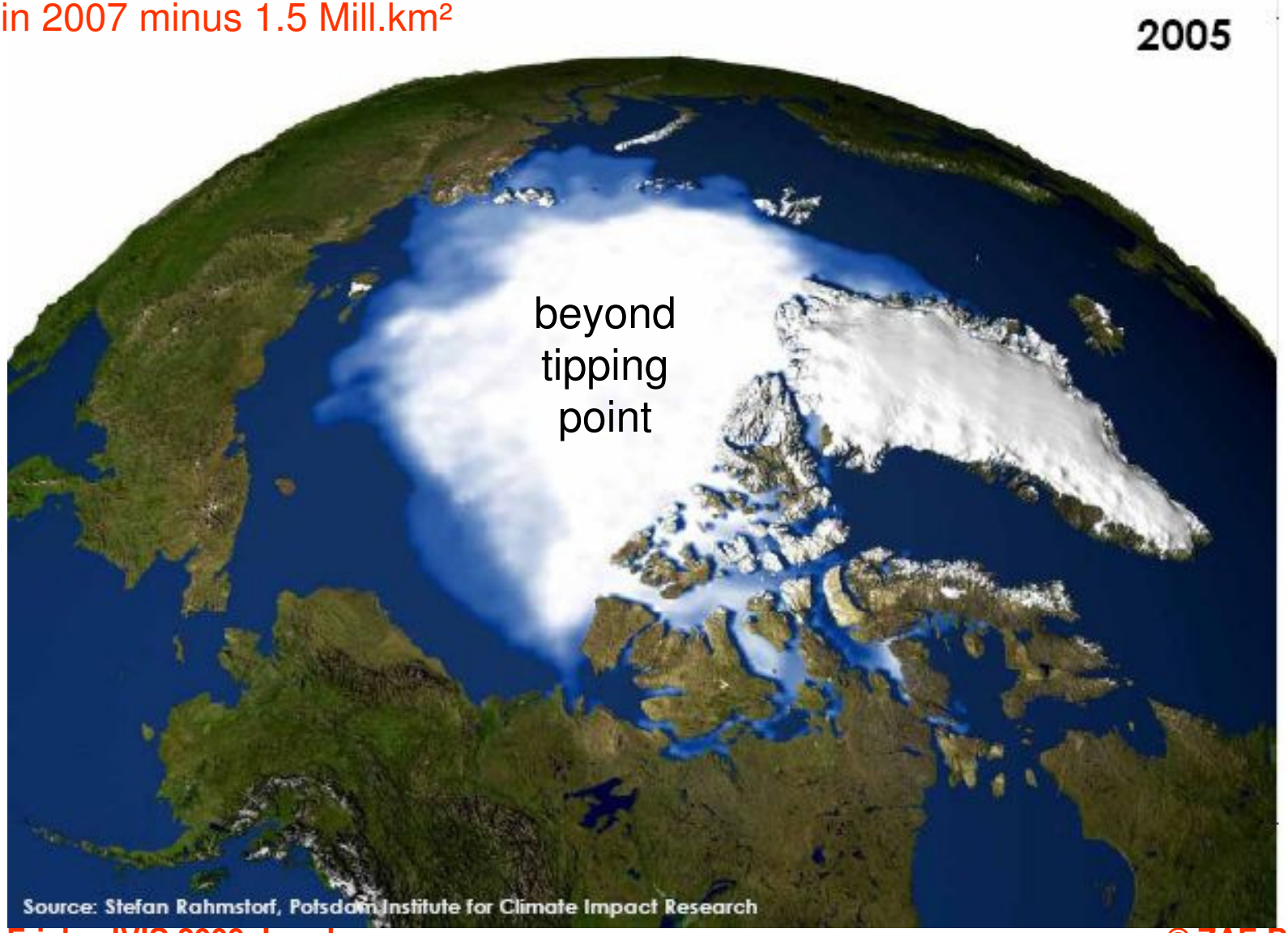
…in 2007 minus 1.5 Mill.km²



...is Melting Faster Than Predicted.

ZAE BAYERN

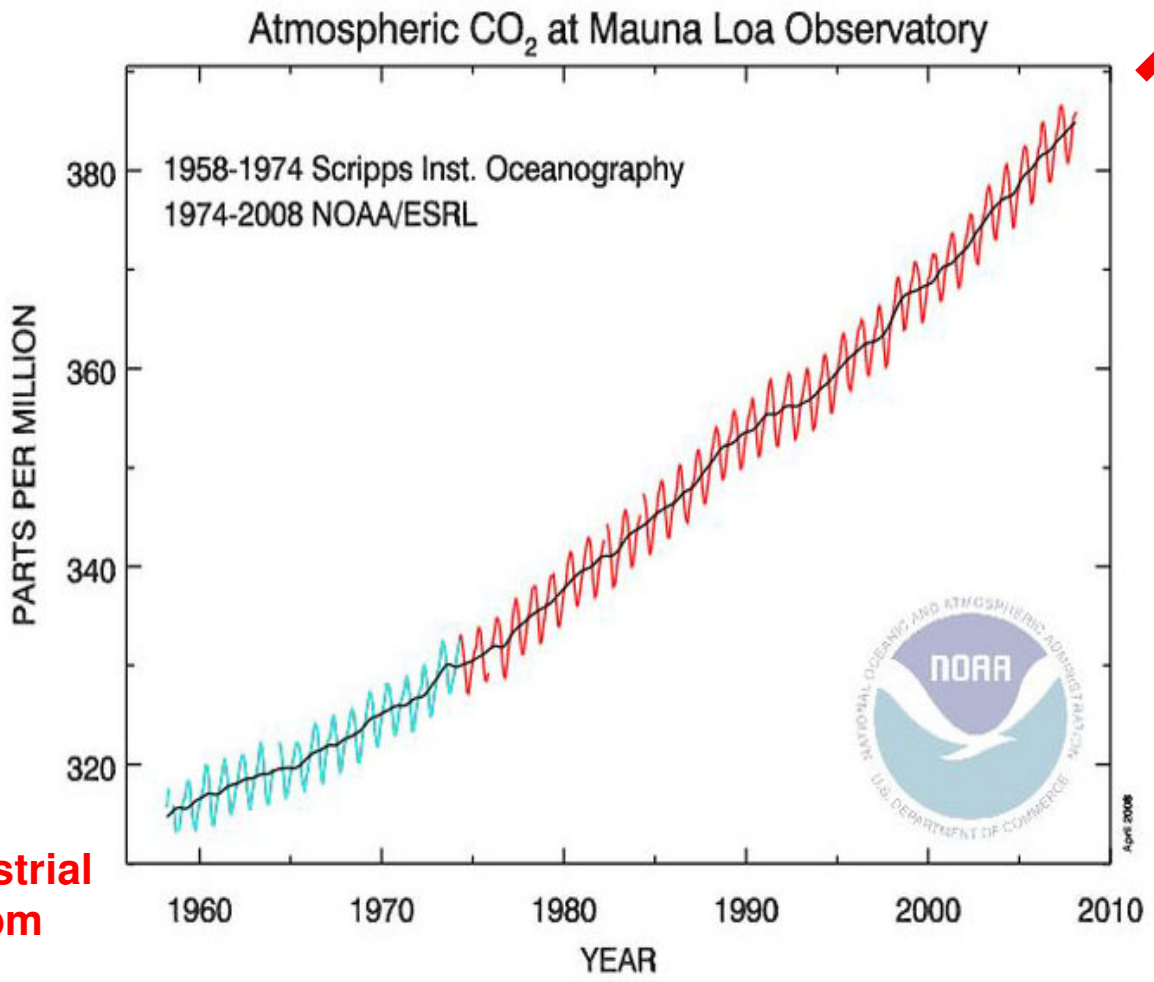
…in 2007 minus 1.5 Mill.km²



.. the CO_2 Increase From 280 to >380 ppm

ZAE BAYERN

How far up ?



pre-industrial 280 ppm

How Much Time t_{max} Do We Have, if We Limit the CO_2-Content at 560 ppm ?

ZAE BAYERN

Per 4 Gt burned fossil C the CO_2–content
of the atmosphere increases by about 1 ppm; thus we can burn globally

$4(Gt/ppm) \cdot (560 - 380)ppm = 4 \cdot 180\ Gt = 720\ Gt$ fossil C,

which transforms into $720 \bullet (44/12)\ Gt\ CO_2 = 2640\ Gt\ CO_2$.

Fraction for United Kingdom with
a CO_2 emission of 560 Mill.t/a and a population of 59 Mio

$2640\ Gt \cdot (59Mio/6700Mio)\ CO_2 \approx 23\ Gt\ CO_2$

$t_{max} = 23000/560 = 41$ years….
…and then **zero** emission.

Data for Other Countries/States:

ZAE BAYERN

Country	Population /Mill.	Annual CO2 emission /Mill.t	Annual CO2 emission per cap./Mill.t	Years to go
United Kingdom	59	560	9.5	41
US	307	6000	20	20
Germany	80	800	10	38
Bavaria	12.5	80	6.5	62

The „tolerable“ CO_2 emission will govern our energy usage more than the shortage of fossil energy resources.

Remedies to Achieve Sustainability

ZAE BAYERN

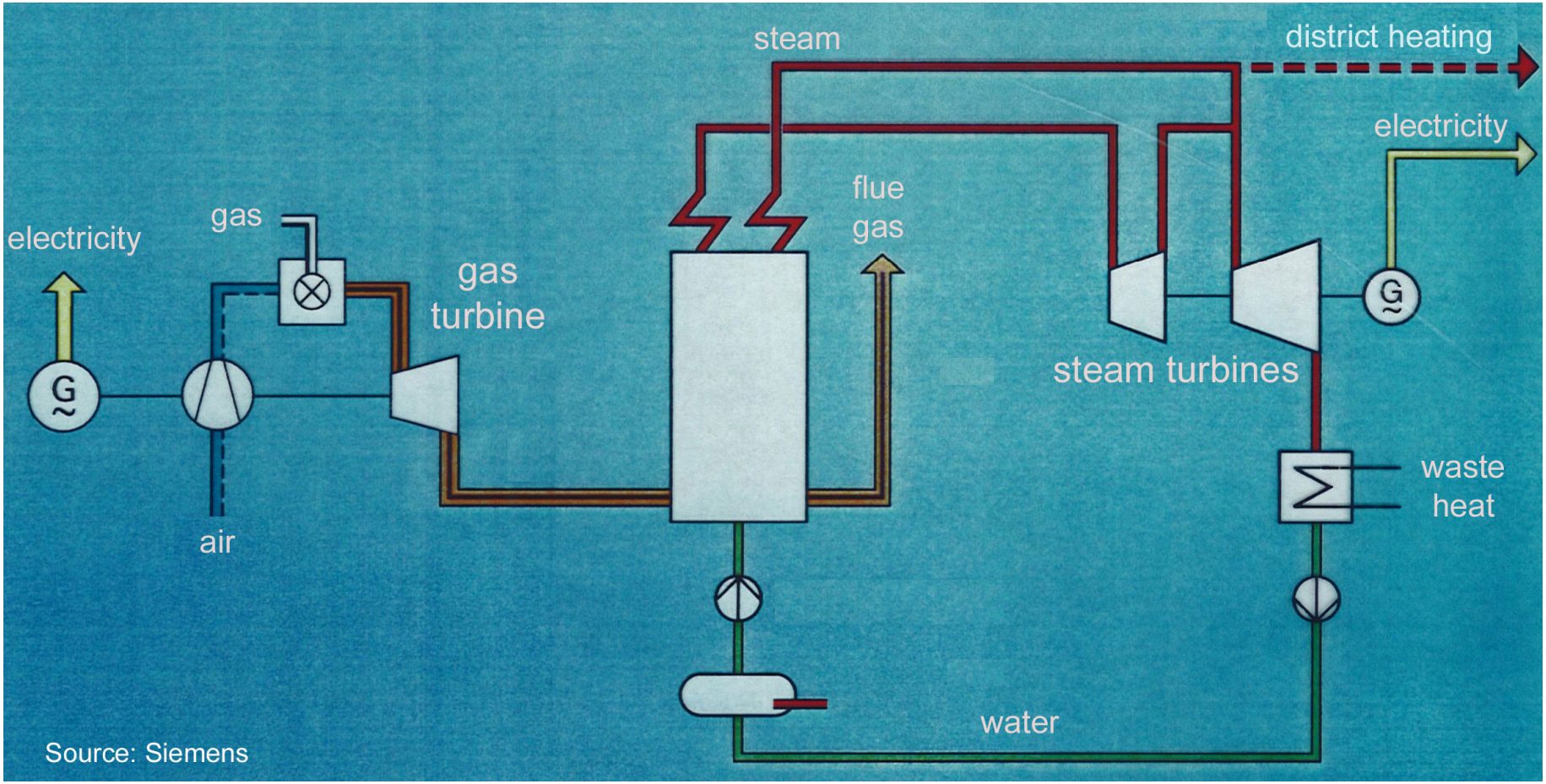
- **Energy conservation**
- **Rational energy usage**
- **Carbon capture and storage**
- **Prolonged use of nuclear energy**
- **Promote renewable energies**

Rational Energy Use

ZAE BAYERN

Co-generation for peak load electricity in Irsching/Bavaria with 60% efficiency from 340 MW gas +190 MW steam turbine…

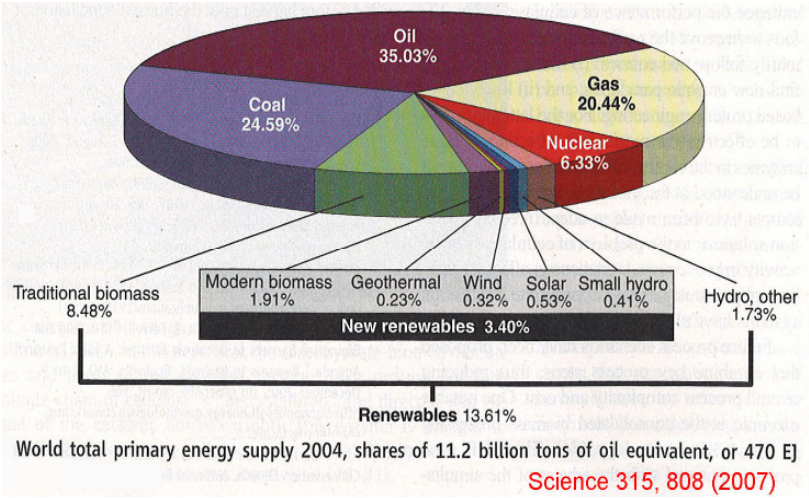
…or 80% efficiency for electricity production **and** district heating realized in Würzburg/Bavaria.



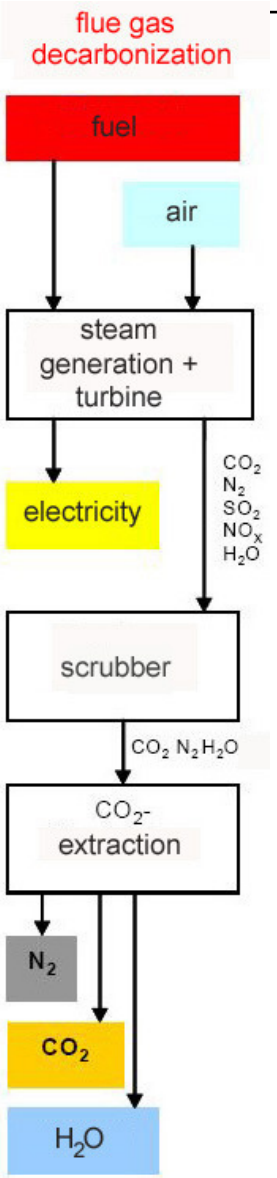
Fossil Fired Powerplants

ZAE BAYERN

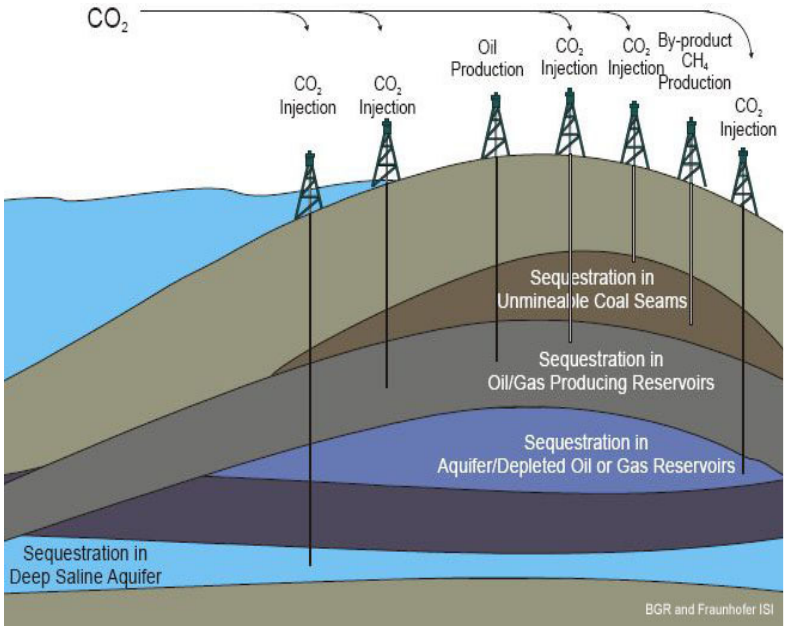
As 80% of the
global energy demand
today is supplied
by fossil resources…



World total primary energy supply 2004, shares of 11.2 billion tons of oil equivalent, or 470 EJ
Science 315, 808 (2007)



…Carbon Capture and
Storage (CCS)
is a MUST.



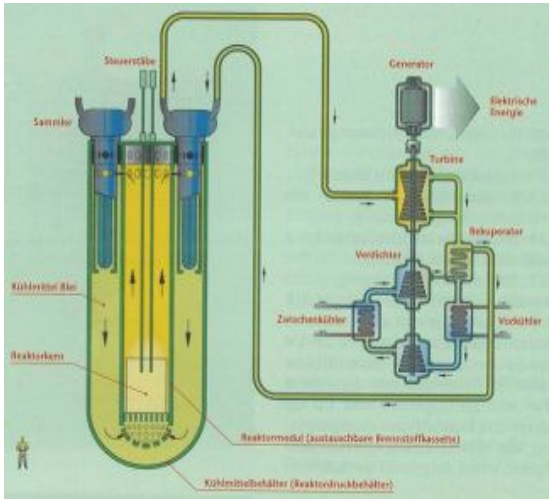
Nuclear Energy

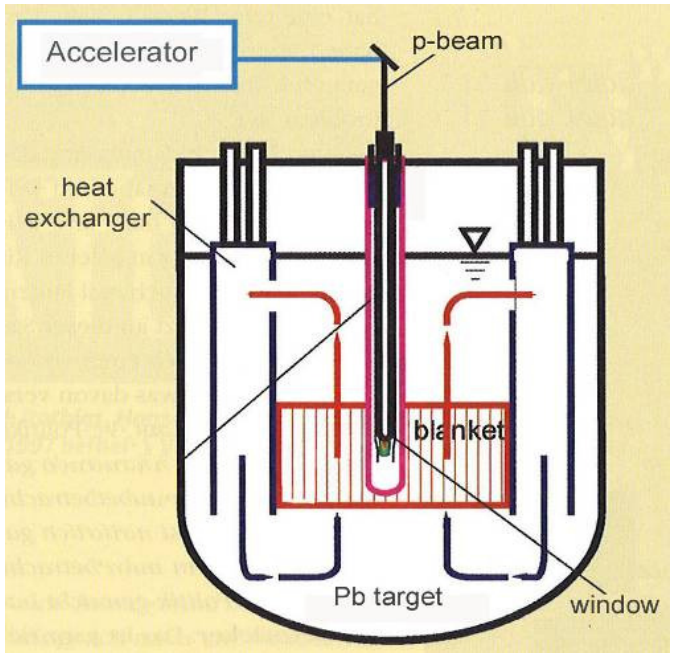
ZAE BAYERN

400 GW installed, cover base load;
440 reactors operating, 45 reactors under construction

Sustainability requires:
Partitioning of waste
+ transmutation
of long-lived isotopes

Gen IV Reactors





Renewables

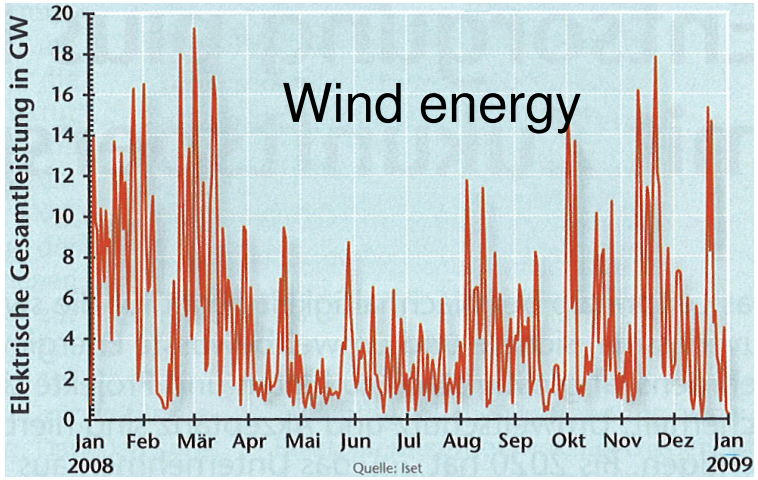
ZAE BAYERN

Base load capacity:

Hydro electricity 860 GW, 4000 h/year full load
Biomass, 60 GW, 5000 h/year
Geothermal, 10 GW, 6000 h/year
Solarthermal, 500 MW

Renewables with extreme fluctuations:

Wind, 120 GW, +2000 h/year
Photovoltaics, 15 GW, +1000 h/year



Remedies to Achieve Sustainability

ZAE BAYERN

- **Energy conservation: thermal insulation market – growing**
- **Rational energy usage**
- **Carbon capture and storage**
- **Prolonged use of nuclear energy**
- **Promote renewable energies**

Only the sum of these measures can provide the future energy demand sustainably, i.e. with low CO_2 output.

Remedies to Achieve Sustainability

ZAE BAYERN

- **Energy conservation: VIP market growing even more**
- **Rational energy usage**
- **Carbon capture and storage**
- **Prolonged use of nuclear energy**
- **Promote renewable energies**

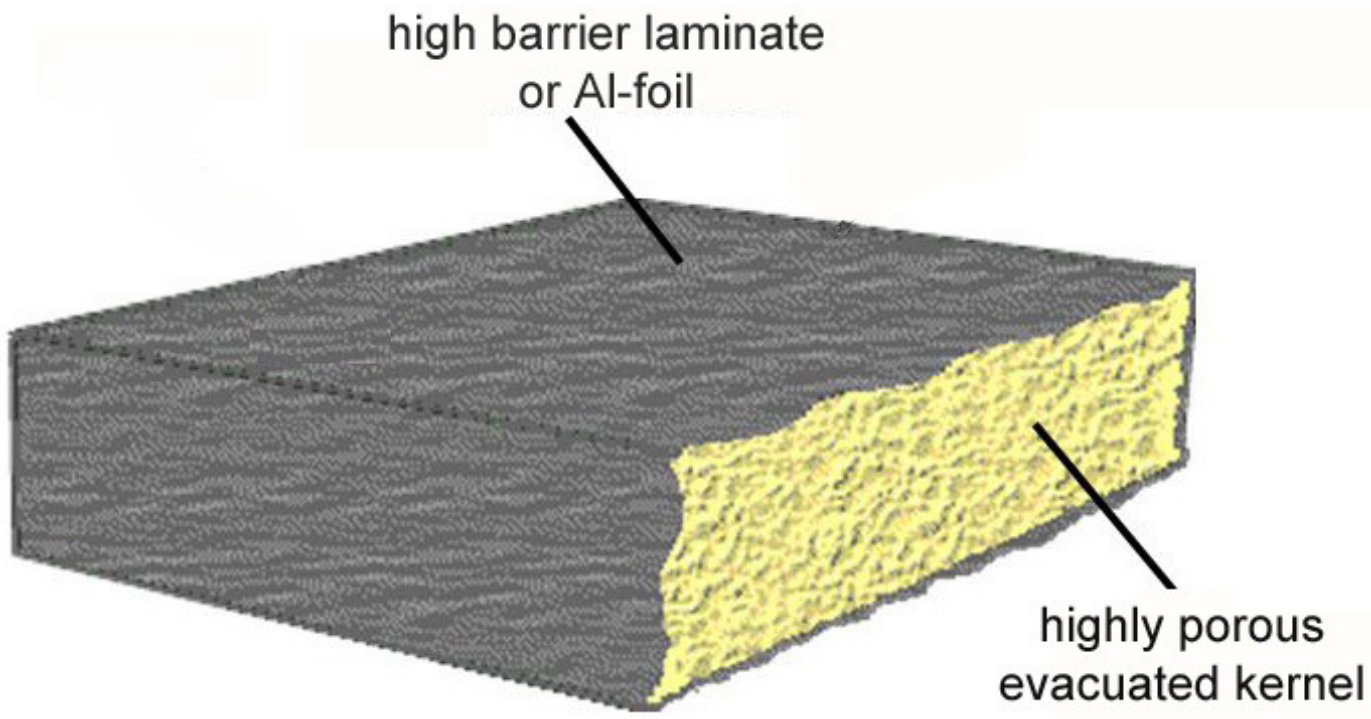
Only the sum of these measures can provide the future energy demand sustainably, i.e. with low CO_2 output.

Vacuum Insulation Panels (VIPs)

ZAE BAYERN

$\lambda \approx (2\ldots10)\cdot10^{-3}$ W/(m•K)

which value is realized??



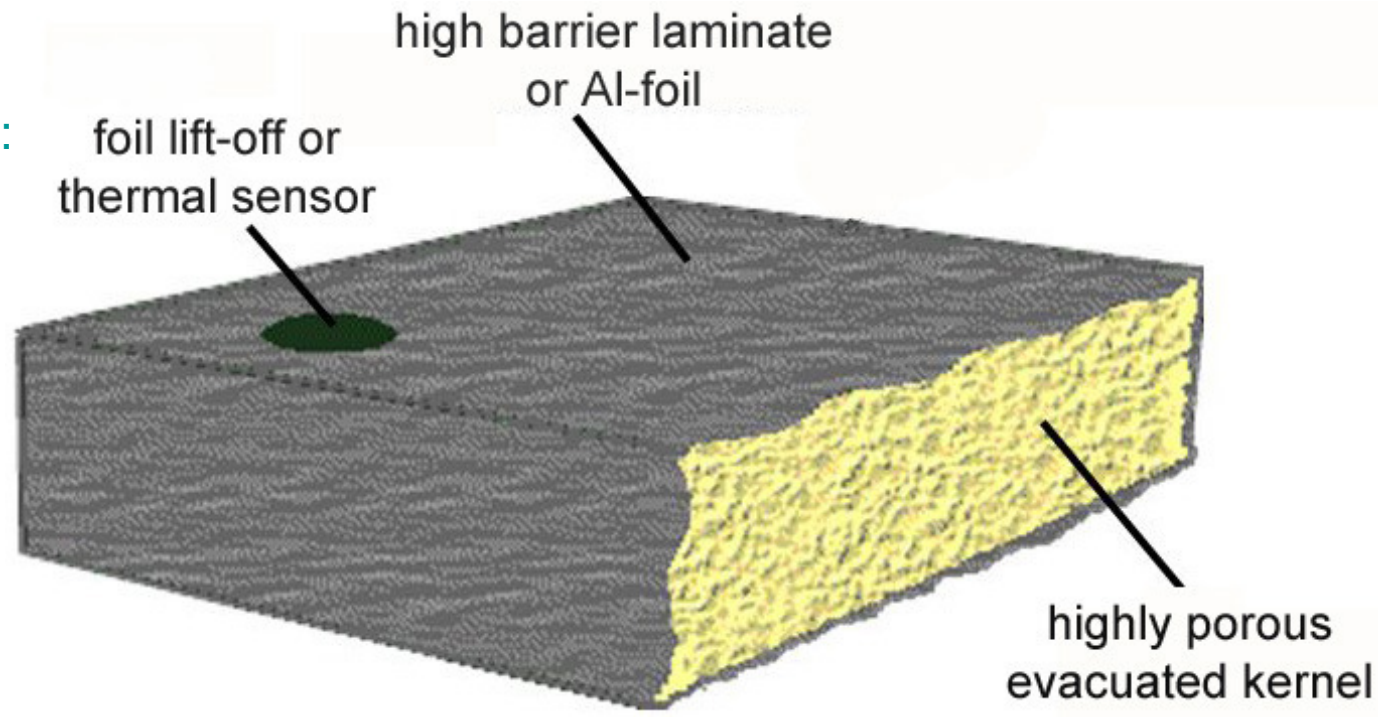
Vacuum Insulation Panels (VIPs)

ZAE BAYERN

$\lambda \approx (2\ldots10)\cdot10^{-3}$ W/(m•K)

which value is realized??

Sensitivity:
< 1 mbar
for both



Radiative Transport

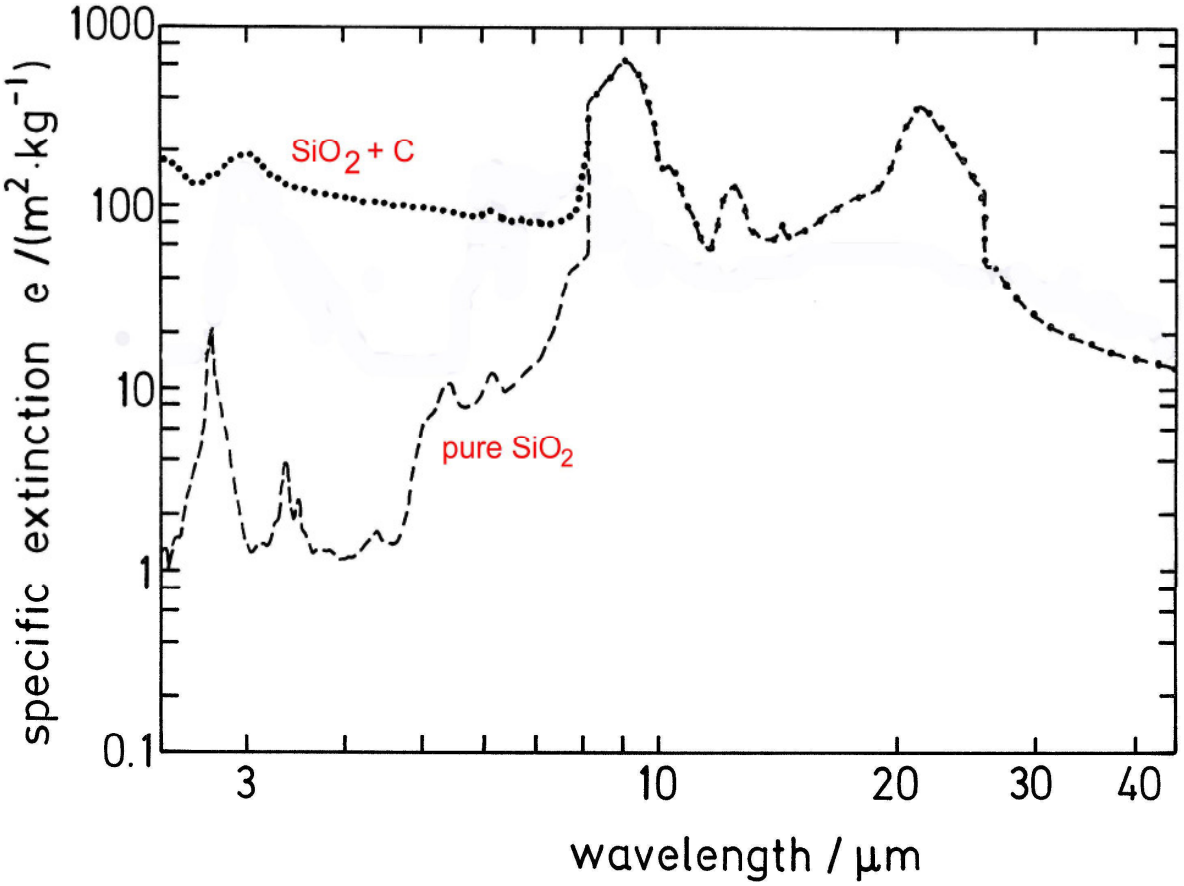
ZAE BAYERN

$\lambda_{rad} \sim T^3/(e \bullet \rho)$ for diffusion of IR-radiation

Integration of opazifiers
Into silica kernel
reduces
IR-optical mean
free length:

$L_{rad} = 1/(e \bullet \rho)$
$\approx (100 \bullet 200)^{-1}$ m
= 50 µm.

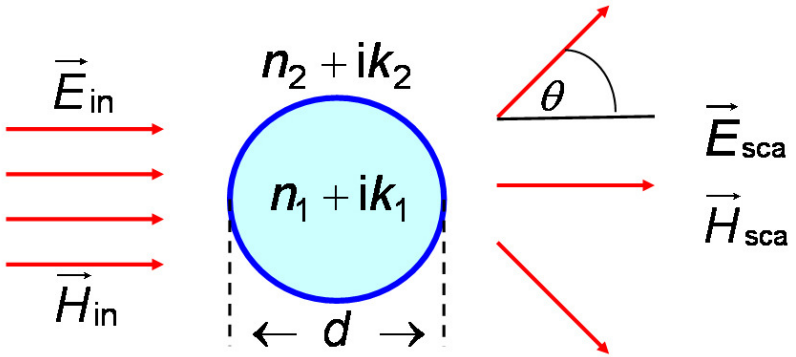
Consequently
radiative transport
is suppressed.

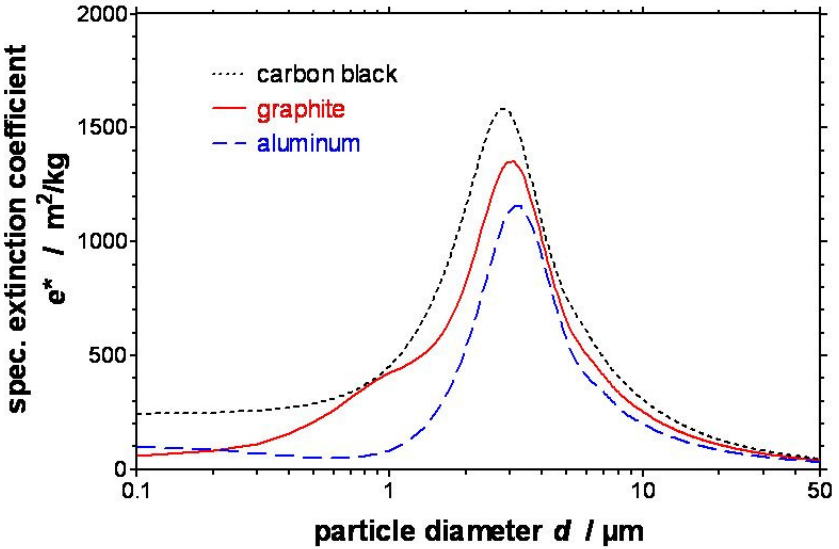


Mie Theory

ZAE BAYERN

Size optimization of opacifiers





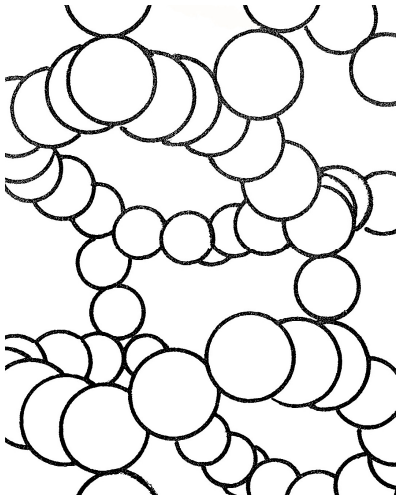
Gustav Mie solved the scattering from spherical objects in 1908

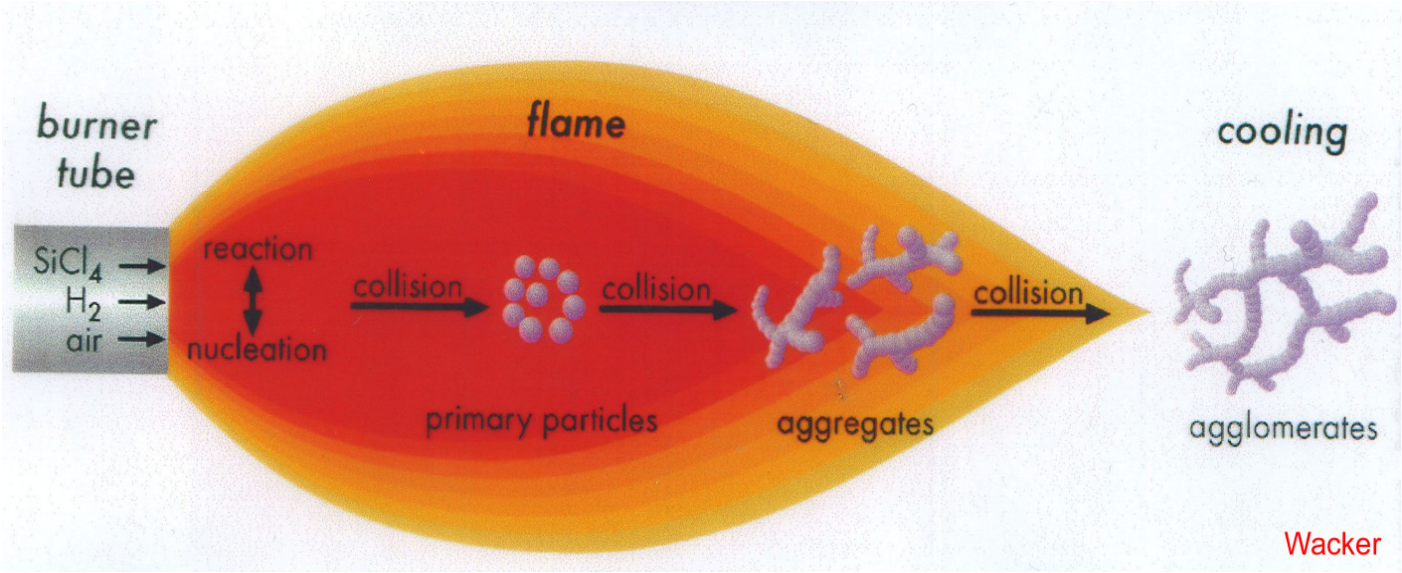
Solid Conductivity: Dominating in Optimized VIPs

ZAE BAYERN

$$\lambda_s \sim \rho^{\alpha}$$

Nano-powders





0.1 µm-sized pores

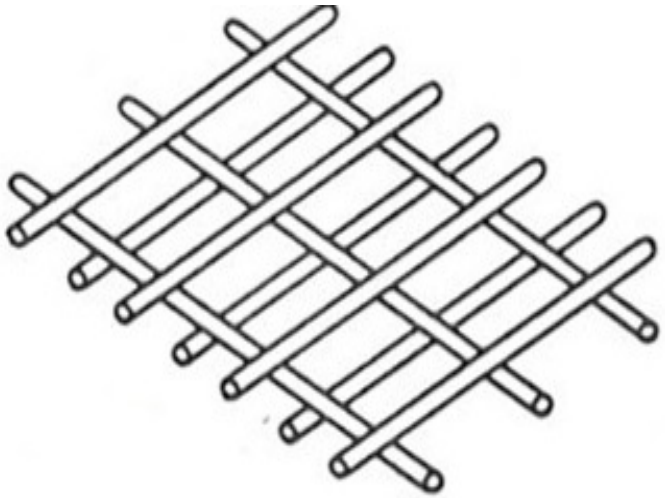
Fumed silica is not a waste product and thus
not a cheap kernel material,
but the least sensisitive against pressure increase.

Solid Conductivity: Dominating in Optimized VIPs

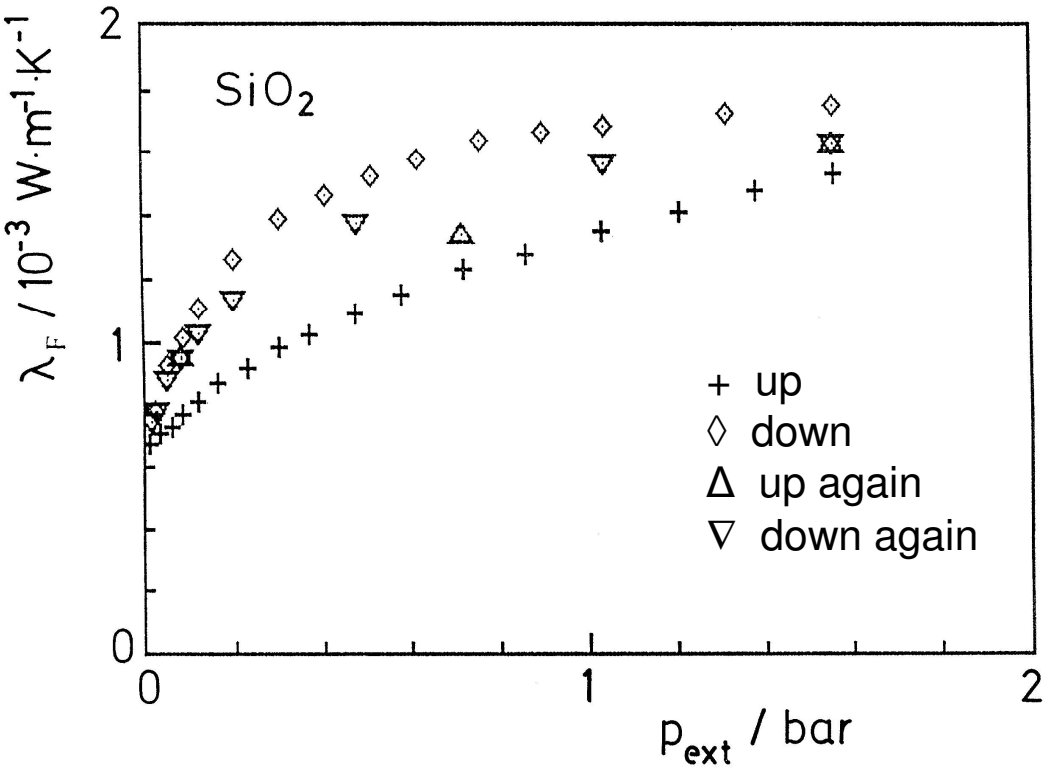
ZAE BAYERN

$\lambda_s \sim \rho^{\alpha}$

Fibers



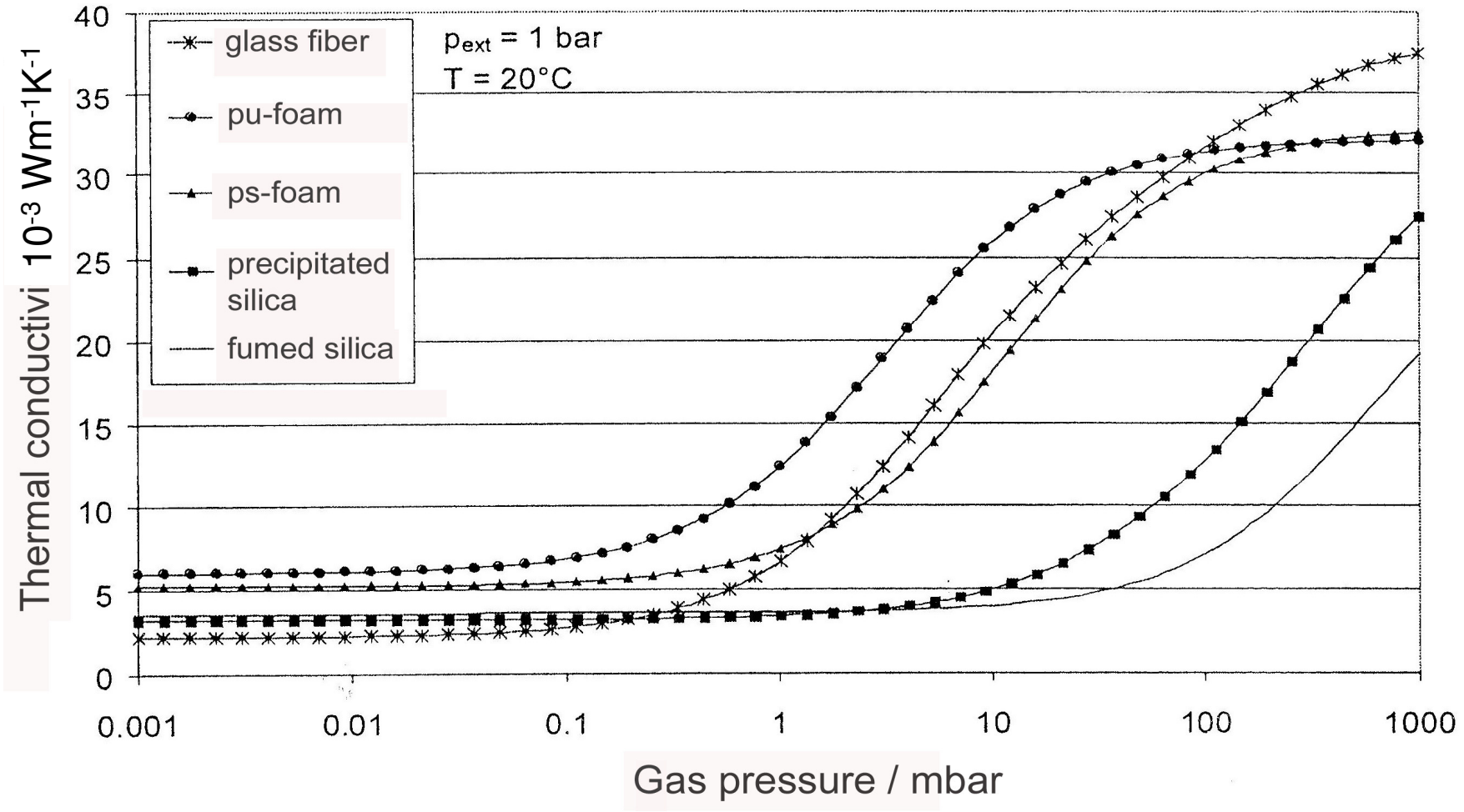
10 µm pores,
but higher thermal resistances
between contacts



With fiber kernels solid thermal conductivities of $1.5 \cdot 10^{-3}$ W/(m•K) are feasible.

Pressure Dependence of Thermal Conductivities:

ZAE BAYERN



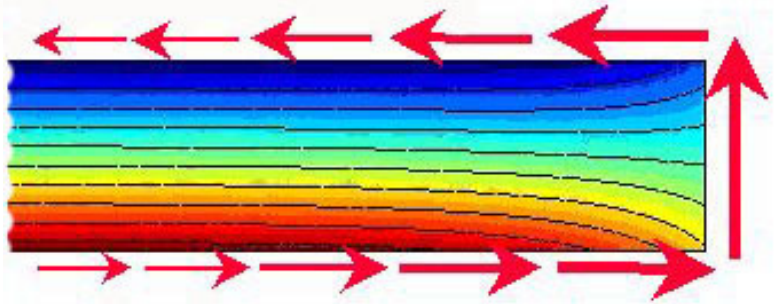
2 Types of Envelopes

ZAE BAYERN

Al-foil:

combination with fibers

Perfect seal but large lateral conductivity causes thermal bridges around edges



$\lambda_{center} \approx 0.002$ W/(m•K) but $\lambda_{eff} \approx 0.005$ W/(m•K)

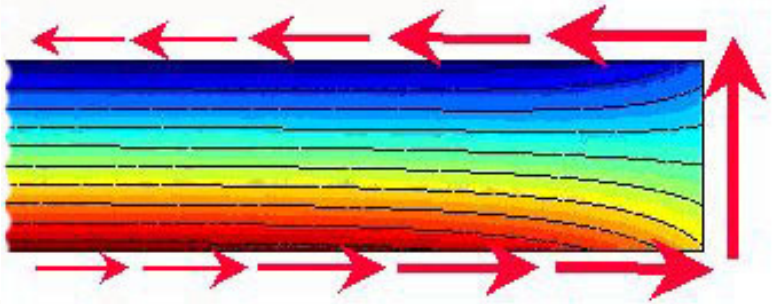
2 Types of Envelopes

ZAE BAYERN

Al-foil:

combination with fibers

Perfect seal but large lateral conductivity causes thermal bridges around edges



$\lambda_{center} \approx 0.002$ W/(m•K) but $\lambda_{eff} \approx 0.005$ W/(m•K)

Laminate:

combination with fumed silica

Very small lateral conductivity but some infusion of gases

$\lambda_{center} \approx \lambda_{eff} \approx 0.004$ W/(m•K)

Challenges: Lower Costs

ZAE BAYERN

VIP prices:

board 1 m²
2 cm thick

40 €

installation
by
trained workers

Sales prices

differ by factor 5

Prices
conventional
insulation:

polystyrene
50 €/m³,
board 1 m²
20 cm thick

8 €

installation
easy

Challenges: Lower Costs

ZAE BAYERN

VIP prices:

board 1 m²
2 cm thick

40 €

installation
by
trained workers

Sales prices

differ by factor 5

Find cheaper kernel materials.

Prices conventional insulation:

polystyrene
50 €/m³,
board 1 m²
20 cm thick

8 €

installation
easy

Challenges: Quality Control Requires:

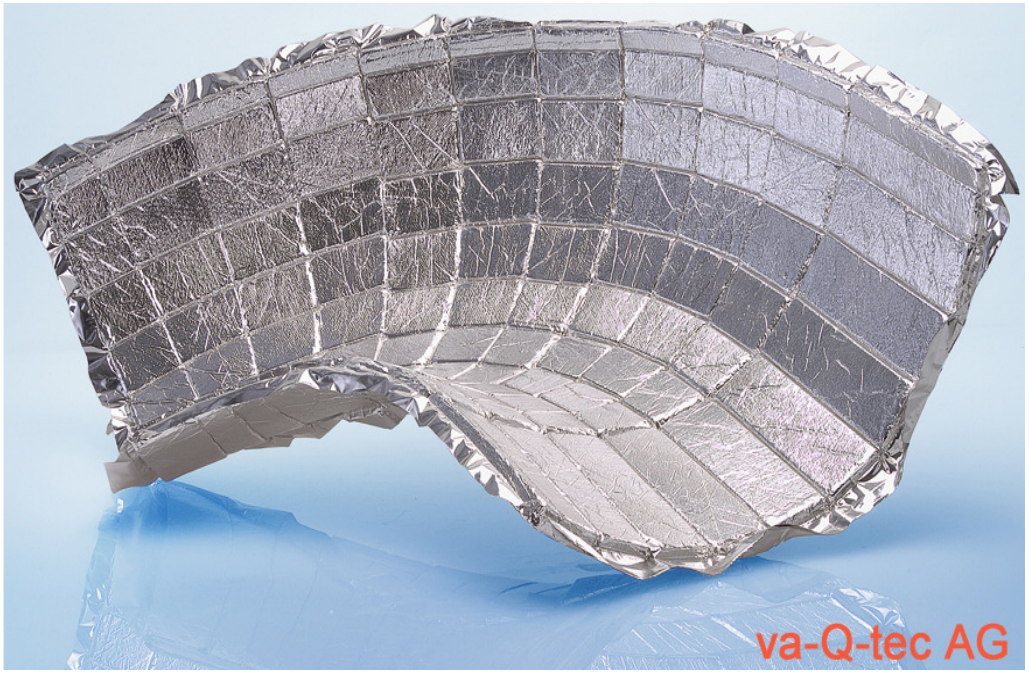
ZAE BAYERN

- Intake control of all materials
- Knowledge of structural + thermal kernel properties
- Knowledge of properties of bent or flexed laminate/foil
- Pressure measurement for every single VIP after production and just before application, in order to prevent integration of VIPs with micro-leaks.

Challenges: VIP Forms

ZAE BAYERN

Fascinating and encouraging



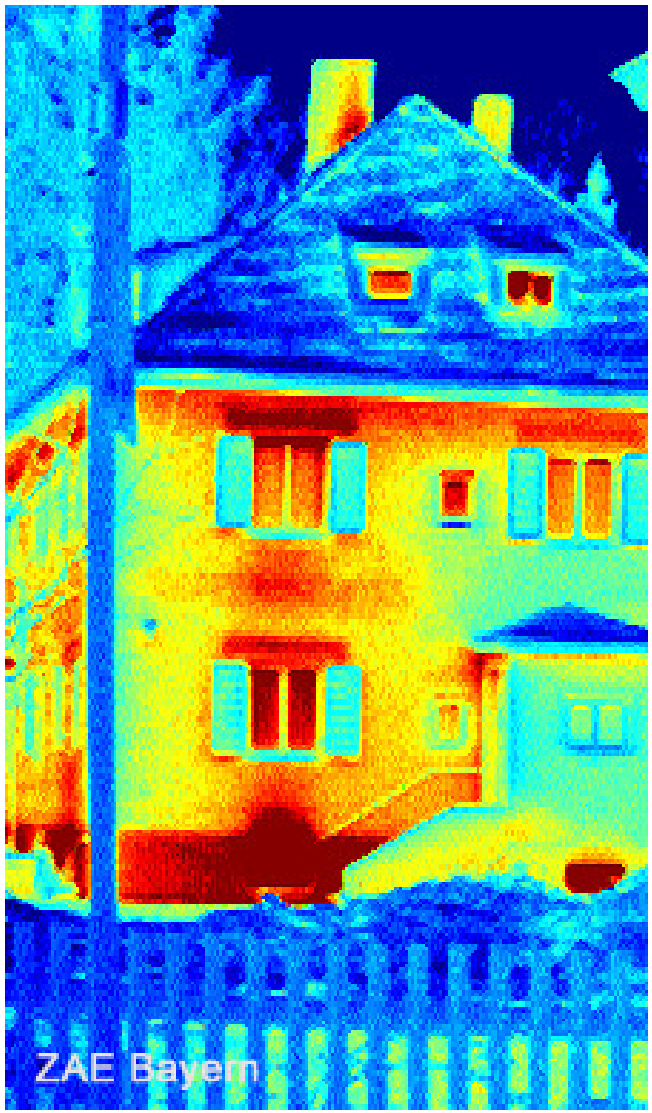
Challenges: Reduce Damages

ZAE BAYERN

A nice VIP-protection “library“

Energy Conservation: Thermal Insulation of Houses

ZAE BAYERN



Opportunities:

There are
≈ 20 Mill.
non-insulated
appartments/houses
in Germany
(and ≈ 9 Mill. in GB).
About 1.5% per year
are renovated in G.

If VIPs conquer 10%,
a demand builds up of
several Mill. m²/year in G.
and 10 Mill. m² worldwide.

Energy Conservation: VIP-Insulation for packaging

ZAE BAYERN

Opportunities:

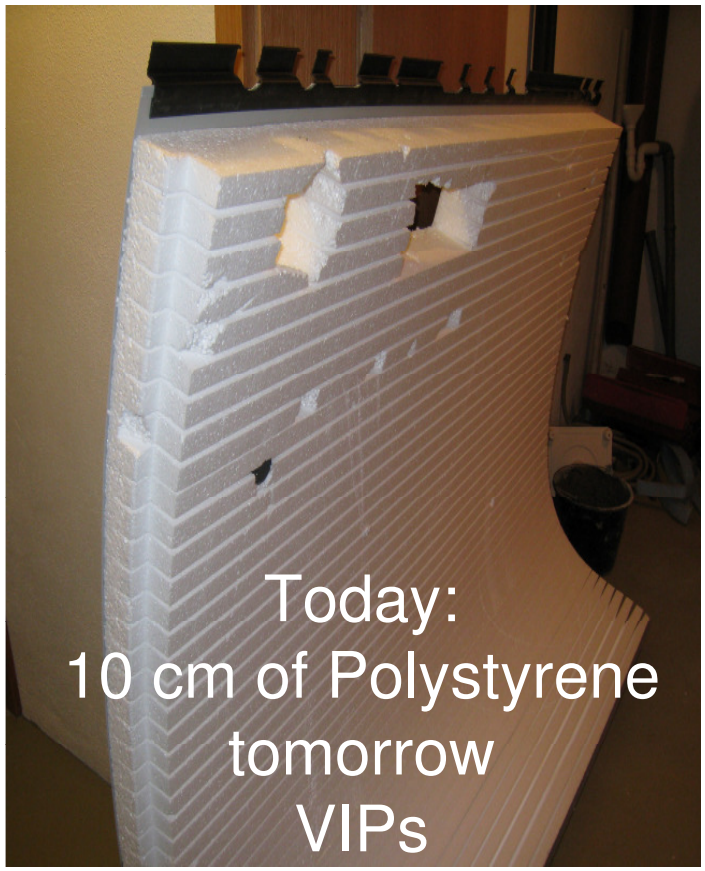
All-VIP-insulated
container
with
U = 0.18 W/(m²•K)
and
specific heat loss
2.15 W/K.

PCM packs
for improved
temperature stability.

Annually
1 Mill.
m² VIPs
worldwide ?

Energy Conservation: Thermal Insulation

ZAE BAYERN



Opportunities:

Millions of warm water buffer tanks, each with 8 m² of insulation.

Annually 3 million m² of VIPs in EU, 10 Mill.m² worldwide?

Energy Conservation: Thermal Insulation

ZAE BAYERN

Privileg/Quelle

When can
we
buy an
all-VIP-insulated
refrigerator?

Energy Conservation: VIP-Insulation

ZAE BAYERN

Now!

Yes we can.

A++
-40%
electricity
against
A

Energy Conservation: VIP-Insulation

ZAE BAYERN

Now!

Yes we can.

A++
-40%
electricity
against
A

Opportunities:

Worldwide
about 40 Mill.
refrigerators
are manufactured
per year.
With about 5 m²
per refrigerator
an annual
VIP-world-market of 200 Mill. m²
opens up.

The Future Market of VIPs ?

ZAE BAYERN

The Future Market of VIPs ?

ZAE BAYERN

.....VIPs world ≈ 50 Mill.€ in 2010??

The Future Market of VIPs ?

ZAE BAYERN

.....VIPs world ≈ 50 Mill.€ in 2010??

To get more reliable numbers, a **new VIA** or an attesting notary would help.

DISCUSSION

ZAE BAYERN

Which VIP-applications in buildings dominate?
Which types of VIP-protection are available?
Has research advanced enough?
Are there enough trained craftsmen for VIP-installation?
Has marketing to be improved?
Is there hope for cheaper VIPs?
Which is the energy amortisation time for VIPs?