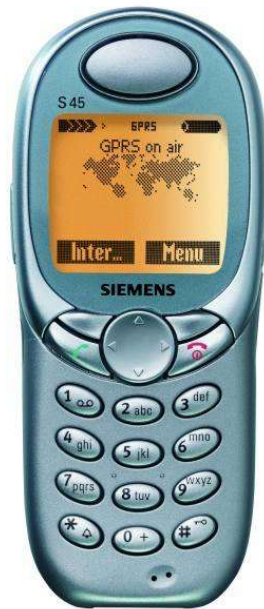


# Insulation and Systems



2000

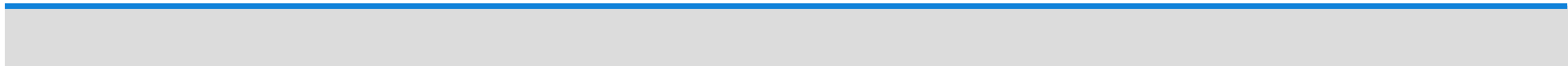


[www.siemens.de](http://www.siemens.de)

2016



[www.apple.de](http://www.apple.de)





**Battery life**

1 week

max. 1 day

**Impact limit**

Third floor (asphalt)

½ m (hardwood floor)

**Impact protection**

Built-in

Needs adds-one

**Software-updates**

unnecessary

Once a week

**Life span**

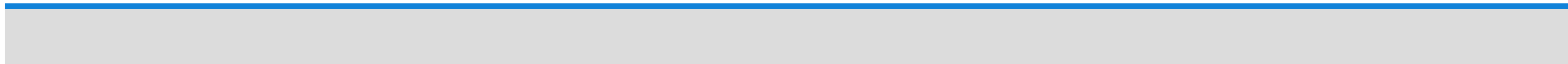
Still going

max. 2 years

**Typing speed SMS**

9 characters per sec

Damm autocorrection



Wall @ 3500 b.c  $U = 0,5 \text{ W}/(\text{m}^2\text{K})$





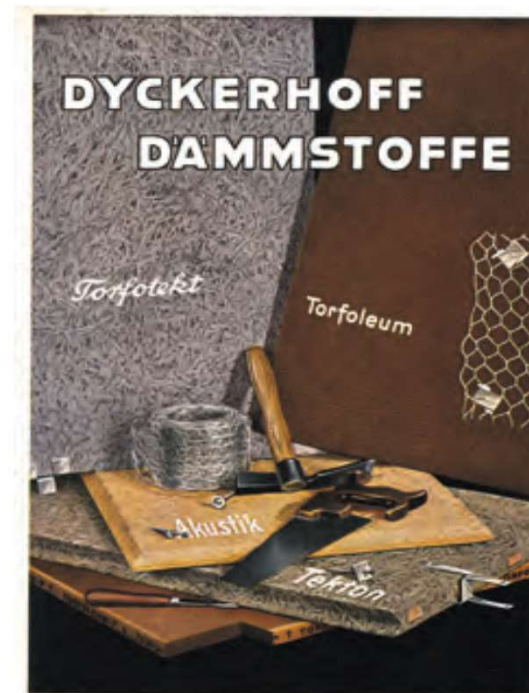
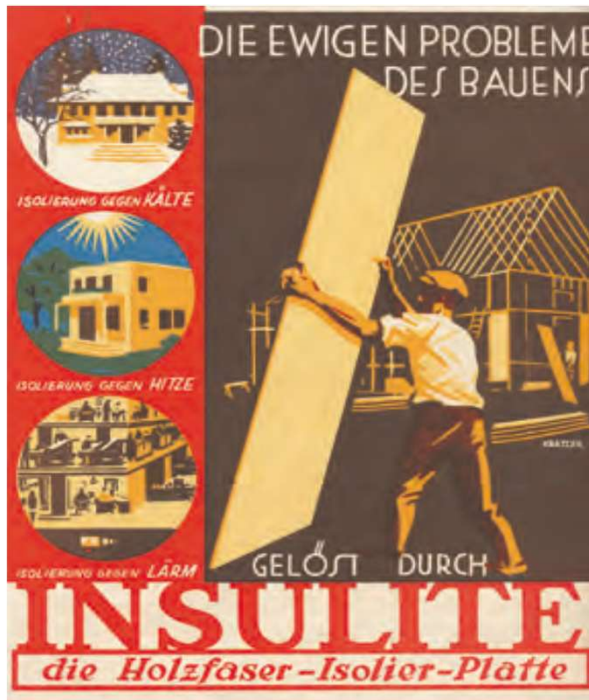
# Historical materials



Quelle: Kleine Geschichte der Dämmstoffe von W.E. Hennig in wksb 65/2011

Quelle: Kleine Geschichte der Dämmstoffe von W.E. Hennig in wksb 65/2011

# Historical materials



Quelle: Kleine Geschichte der Dämmstoffe von W.E. Hennig in wksb 65/2011

Quelle: Kleine Geschichte der Dämmstoffe von W.E. Hennig in wksb 65/2011

## Historical materials (1900)



Quelle: Kleine  
Geschichte der  
Dämmstoffe von  
W.F. Hennia in

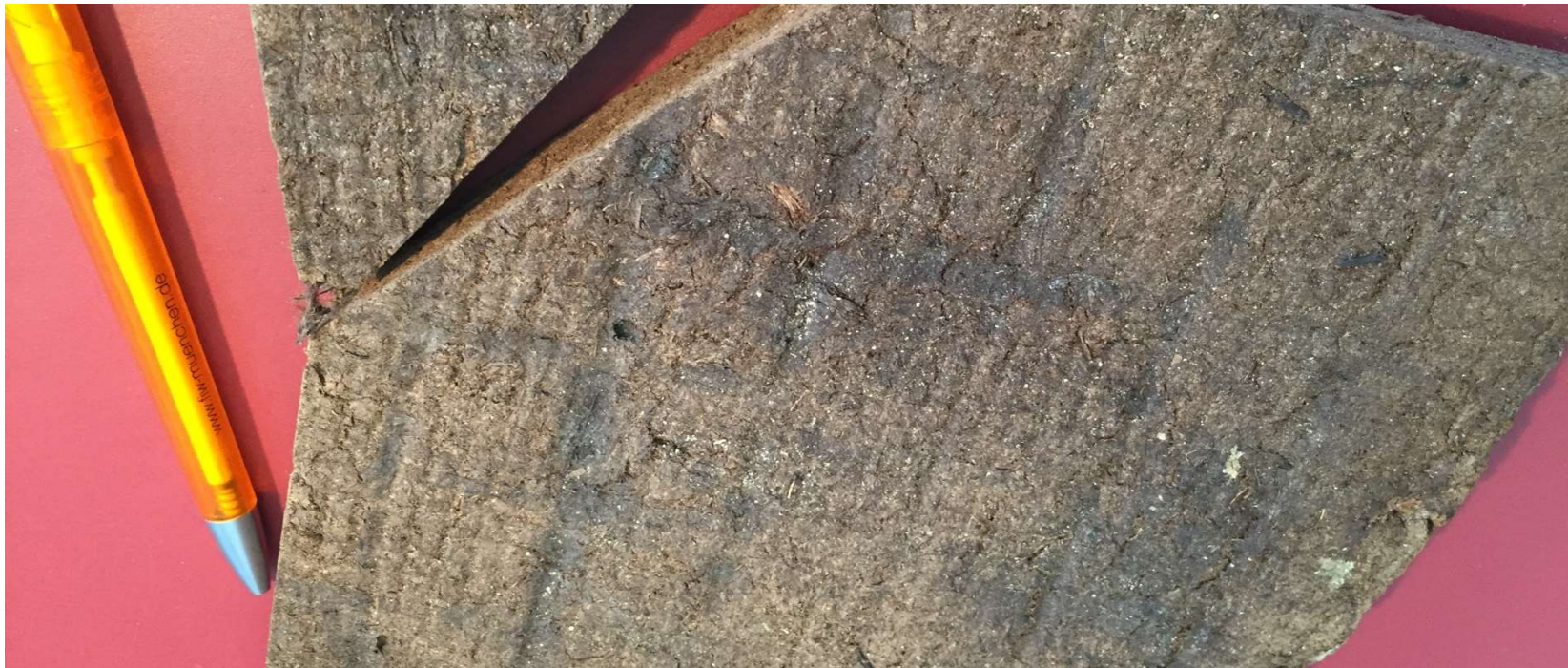
# Historical materials



Gebundene Torfdämmplatte „Torfoleum“ ca. 1927 – Foto: FIW München

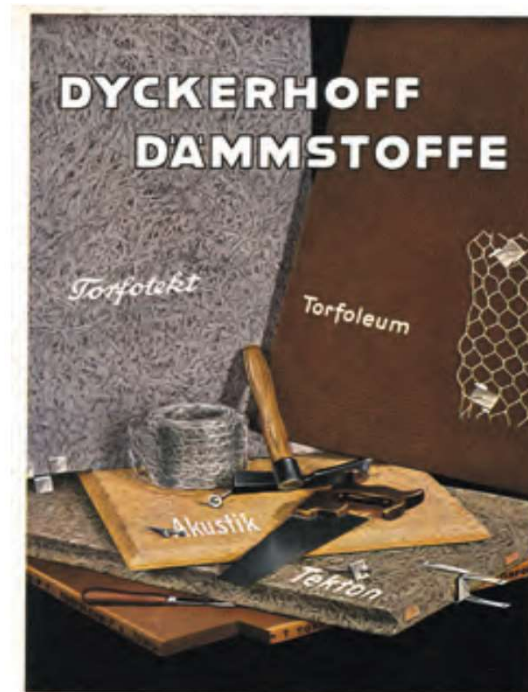


# Historical materials



Gebundene Torfdämmplatte „Torfoleum“ ca. 1927 – Foto: FIW München

# Historical materials



Quelle: FIW

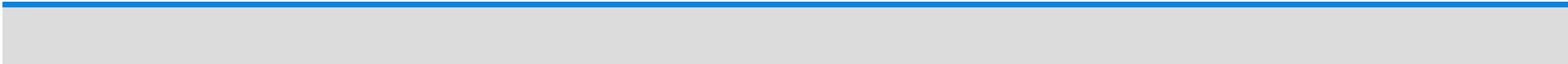
Quelle: Kleine Geschichte der Dämmstoffe von W.E. Hennig in wksb 65/2011



# Building stock



■ [www.bbt-gmbh.net](http://www.bbt-gmbh.net)









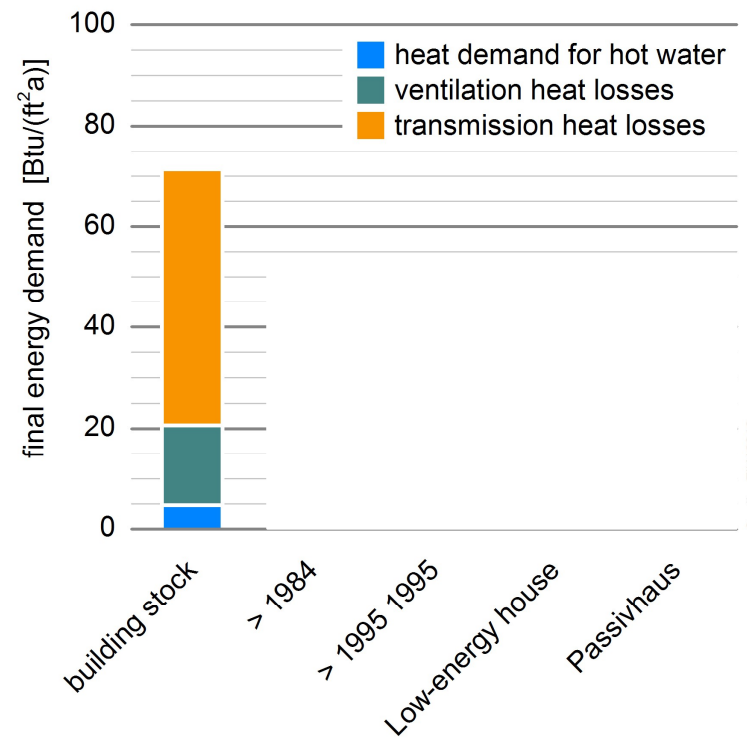




**construction industry is not innovative !**

[http://www.appel-autofit.de/media/img/altes\\_auto\\_low.jpg](http://www.appel-autofit.de/media/img/altes_auto_low.jpg)

# From "no-tech" to "high-tech"





## From "no-tech" to "high-tech"

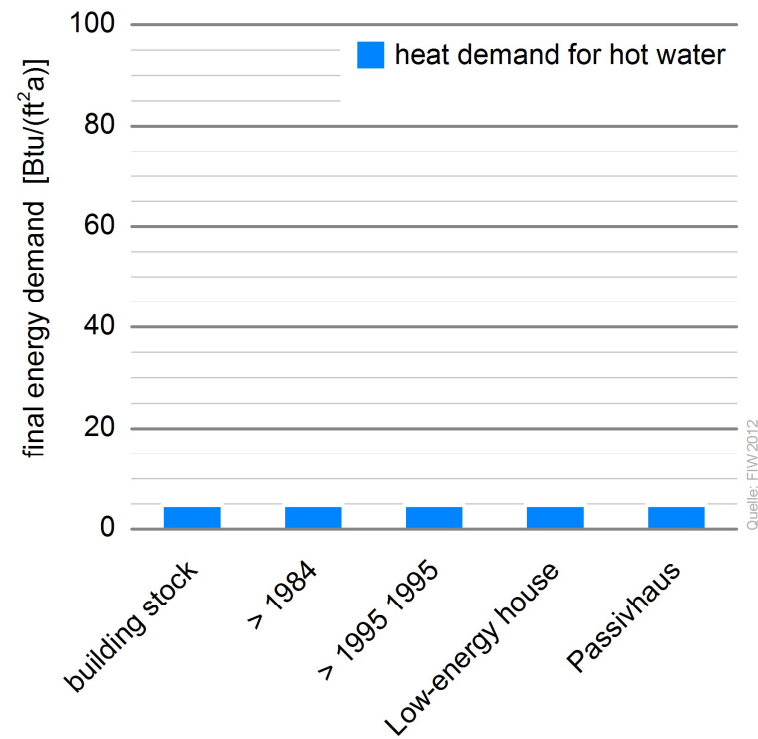


[www.paultaylorplumbingservices.co.uk/](http://www.paultaylorplumbingservices.co.uk/)

<http://robertsonwindowwashing.com/>

FIW München

# From "no-tech" to "high-tech"





## From "no-tech" to "high-tech"



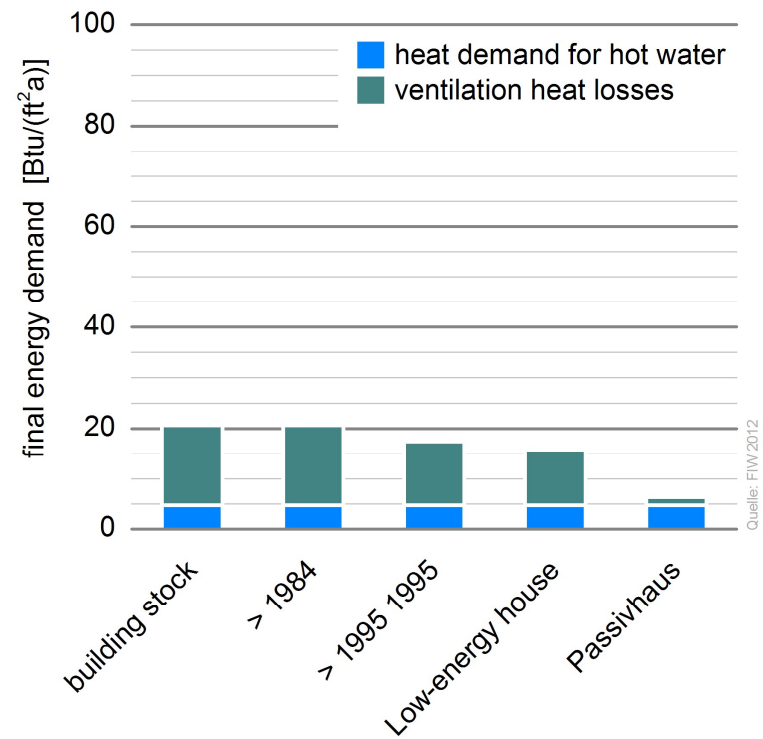
[www.paultaylorplumbingservices.co.uk/](http://www.paultaylorplumbingservices.co.uk/)



<http://robertsonwindowwashing.com/>

FIW München

# From "no-tech" to "high-tech"



# From "no-tech" to "high-tech"



[www.paultaylorplumbingservices.co.uk/](http://www.paultaylorplumbingservices.co.uk/)

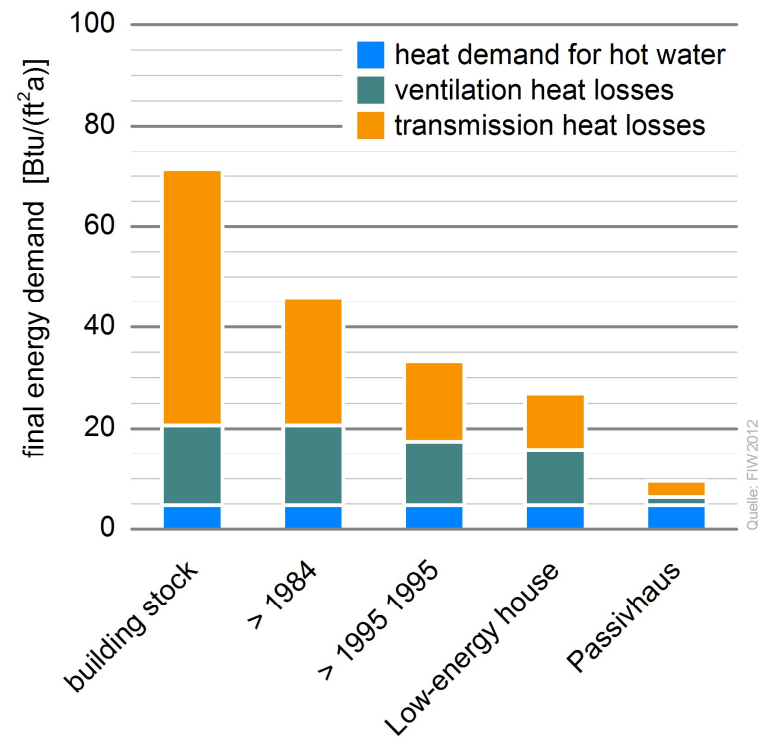


<http://robertsonwindowwashing.com/>



FIW München

# From "no-tech" to "high-tech"



90%

# Energy Saving Ordinance




Maximum values of the u-Value for envelope component retrofit

|                    | WSVO '95 | EnEV 2002 | EnEV 2009 |
|--------------------|----------|-----------|-----------|
| Walls<br>- general | R 14     | R 16      | R 24      |


# Energy Saving Ordinance



Maximum values of the u-Value for envelope component retrofit



|                    | WSVO '95 | EnEV 2002 | EnEV 2009 |
|--------------------|----------|-----------|-----------|
| Walls<br>- general | R 14     | R 16      | R 24      |



# Insulation Materials

organic

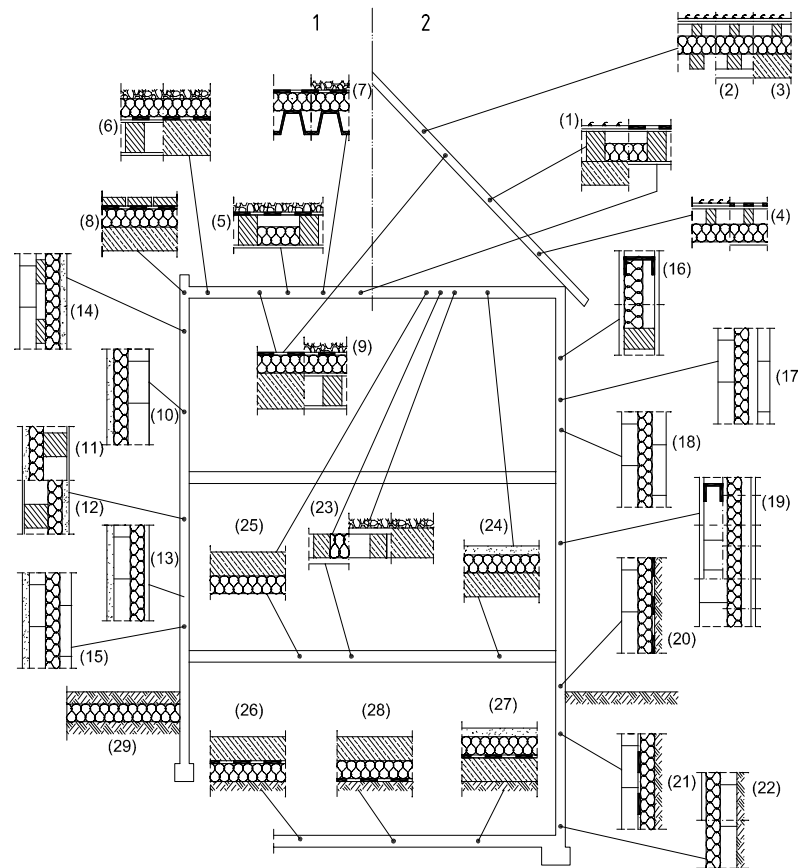
natural



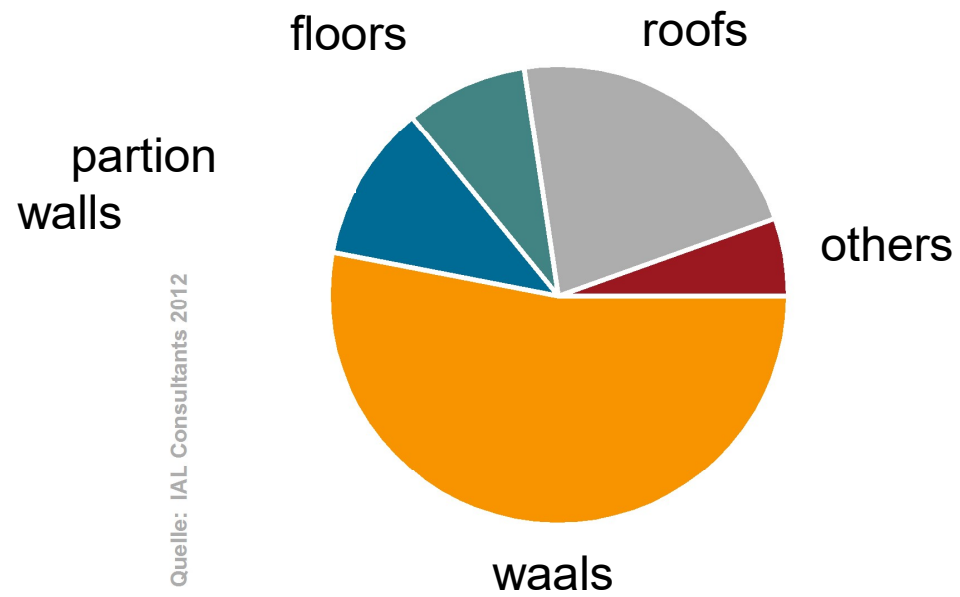
sheep wool



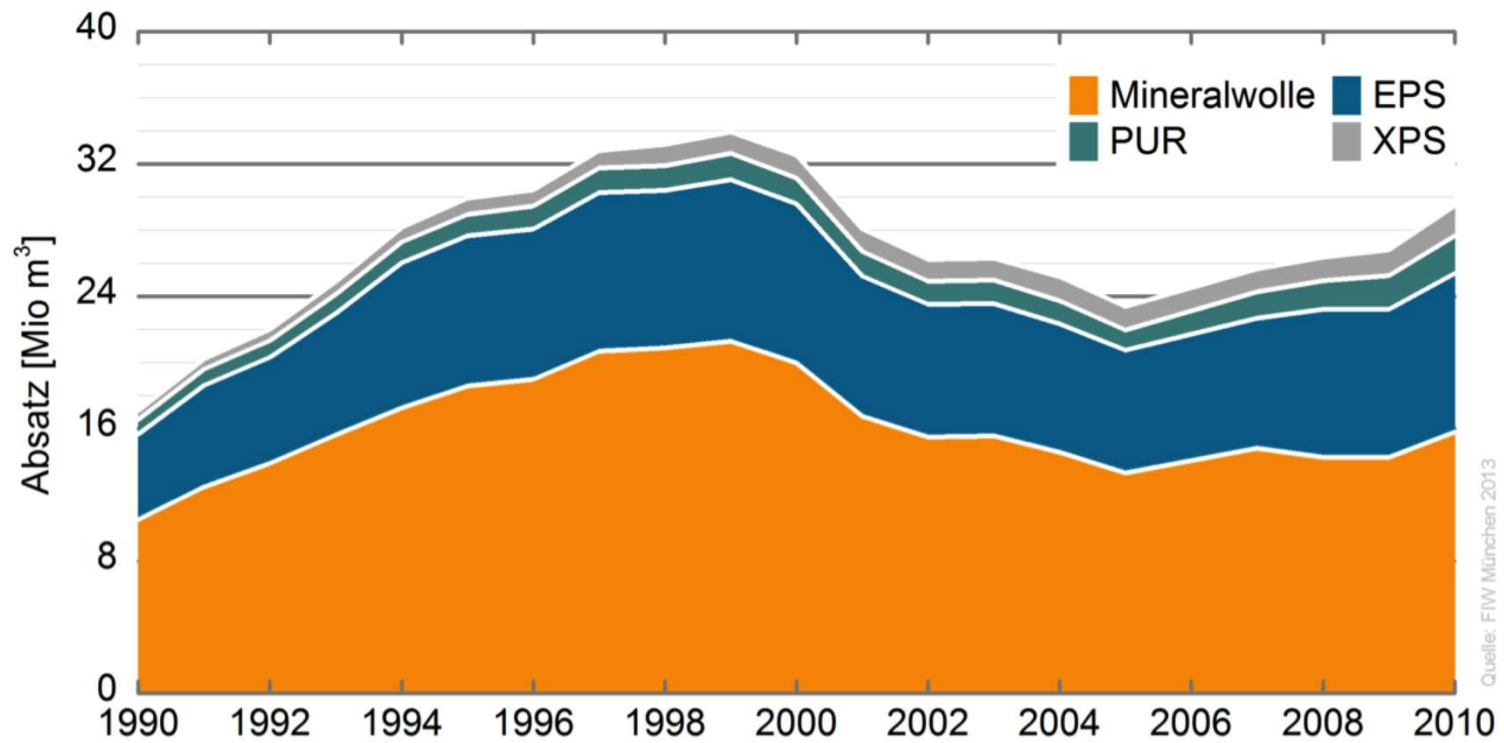
# Applications

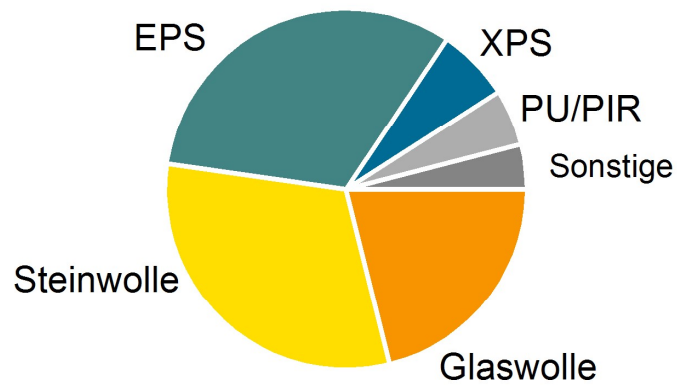


# Applications



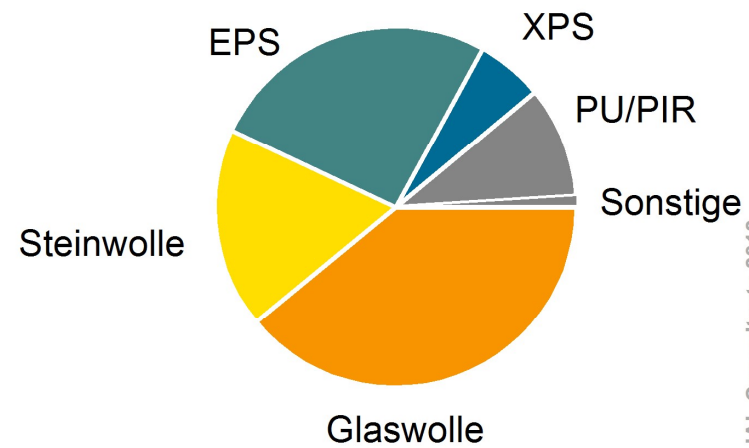
Quelle: IAL Consultants 2012





**Gesamtvolumen: ca. 28 Mio m<sup>3</sup>**

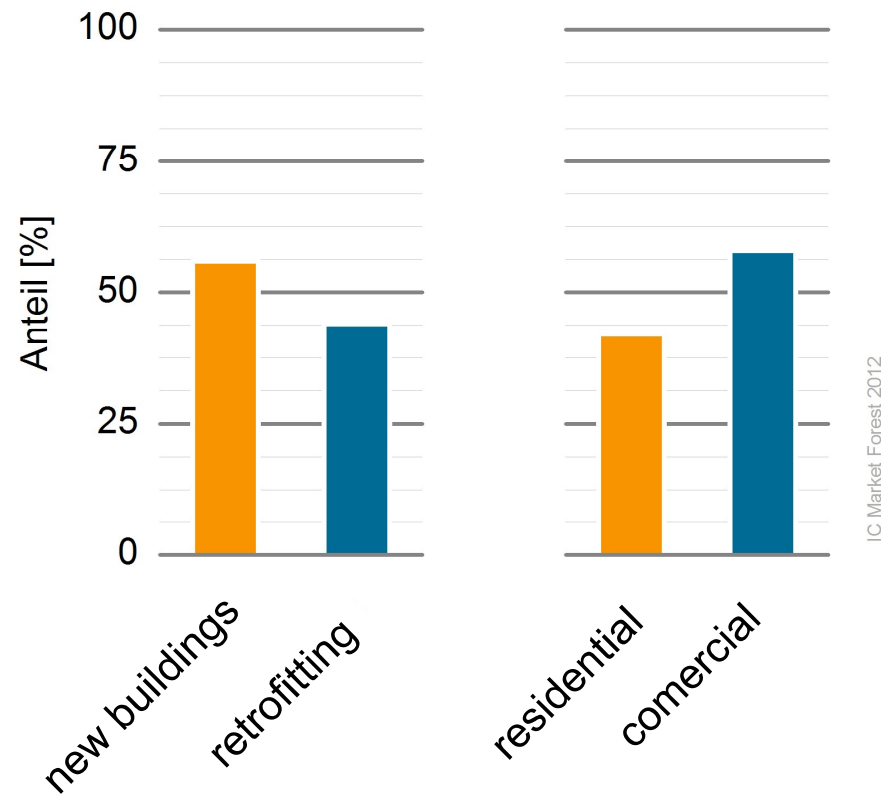
Quelle: GDI Baumarktstatistik 2010



**Gesamtvolumen: ca. 193 Mio m<sup>3</sup>**

Quelle: IAL Consultants 2012

# Where is insulation used ?



# Thermal Insulating Materials and Products



- thermal conductivity / thermal transmission resistance
- dimensions and tolerances
- mechanical characteristics
- behaviour in water (vapour)
- fire behaviour (Euro class)
- soundproofing characteristics e.g. dynamic stiffness or length-related air flow resistance

# Standardized insulating materials



## inorganic

|            |                             |
|------------|-----------------------------|
| <u>MW</u>  | Mineral Wool (EN 13162)     |
| <u>CG</u>  | Cellular Glass (EN13167)    |
| <u>EPB</u> | Expanded Perlite (EN 13169) |

## organic

|            |                                 |
|------------|---------------------------------|
| <u>EPS</u> | Expanded Polystyrene (EN 13163) |
| <u>XPS</u> | Extruded Polystyrene (EN 13164) |
| <u>PUR</u> | Polyurethane-Foam (EN 13165)    |
| <u>PF</u>  | Phenolic Foam (EN 13166)        |
| <u>WW</u>  | Wood Wool (EN 13168)            |
| <u>ICB</u> | Expanded Cork (EN 13170)        |
| <u>WF</u>  | Wood Fibre (EN 13171)           |

⇒ 10 hENs cover approx. 98 % of the market



# CE labeling



|               | DIN EN 13163  | <u>DIN</u>   |
|---------------|---|--|
| ICS 91.100.60 | <b>Thermal insulation products for buildings –<br/>Factory made products of expanded polystyrene (EPS) –<br/>Specification<br/>English version of DIN EN 13163:2009-02</b><br><br>Wärmedämmstoffe für Gebäude –<br>Werkmäßig hergestellte Produkte aus expandiertem Polystyrol (EPS) –<br>Spezifikation | Supersedes<br>DIN EN 13163:2001-10 and<br>DIN EN 13163<br>Corrigendum 1:2006-06<br>See start of validity |

# Structure of the 10 harmonized CEN- Standards:



- 1 Scope
- 2 Normative References
- 3 Terms, definitions, symbols
- 4 Requirements
  - for all applications
  - for specific applications
- 5 Test Methods
- 6 Designation code
- 7 Evaluation of conformity
- 8 Marking and labeling



Levels and Classes



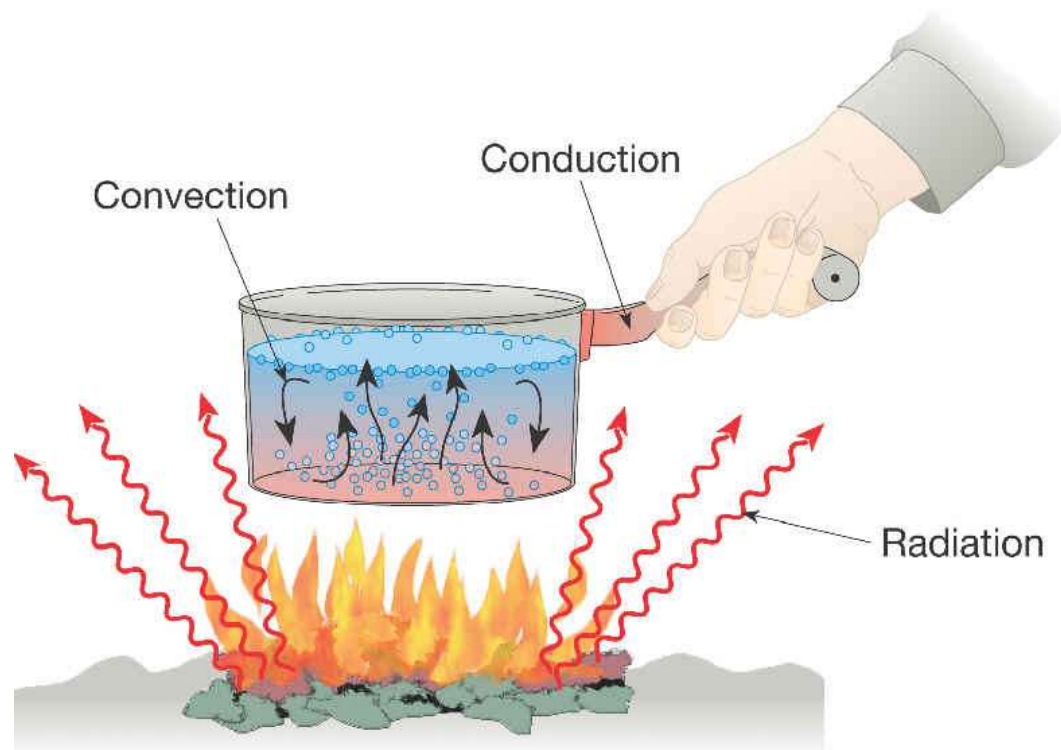
CE-mark



<http://www.planet-wissen.de/>

# How can we improve

# Heat Transfers by...



# What is an Insulator?



Insulators are materials that minimize the transfer

- of thermal energy,
- electric current, or
- sound.

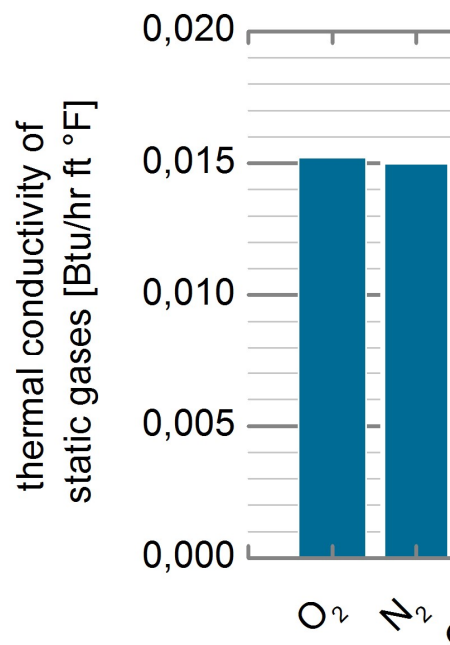
## Physical Background



\$ 1,50 online for 1 can

<http://www.steffen-persiel.de>

# Physical Background

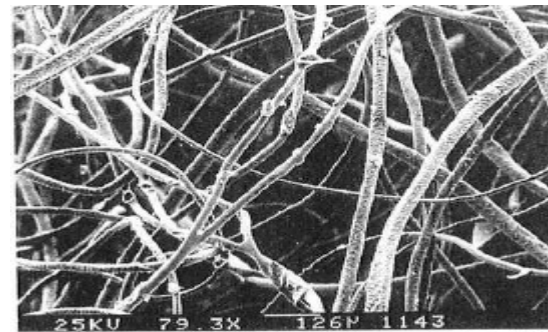


stagnant air

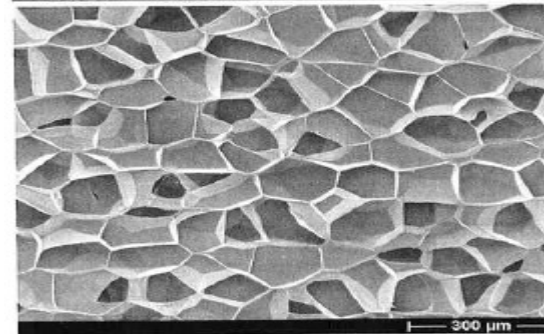
# Efficient Thermal Insulation



Fibrous Structure

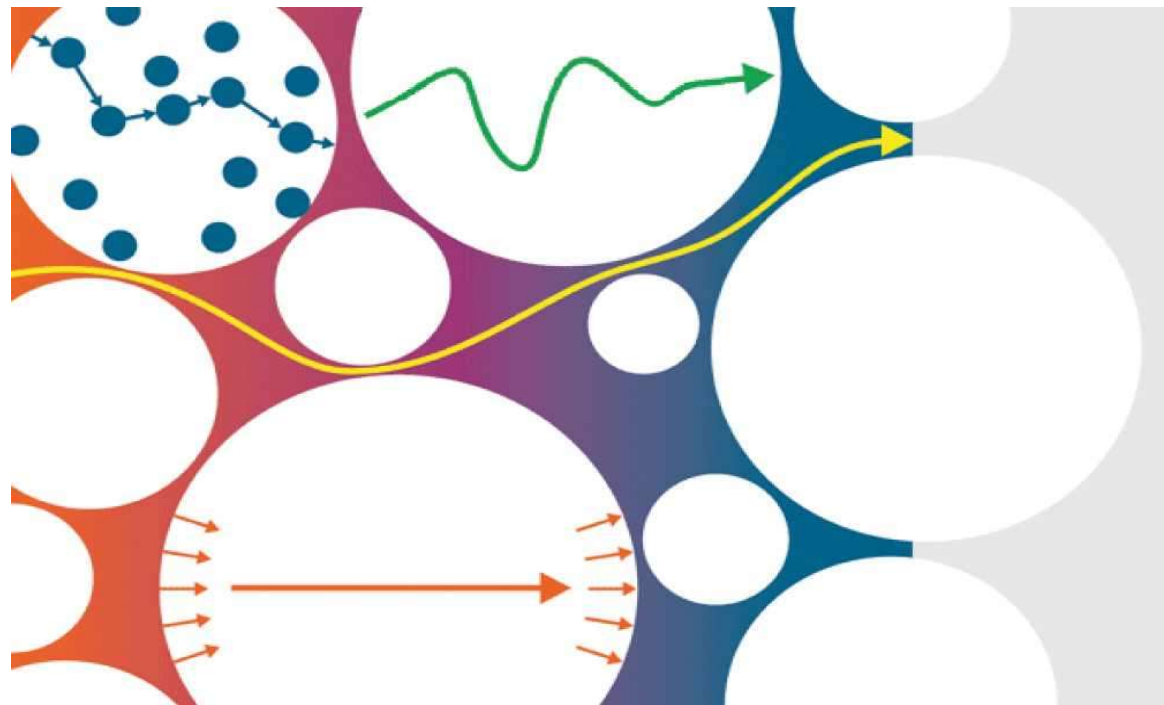


Microcellular Structure





# Physical Background



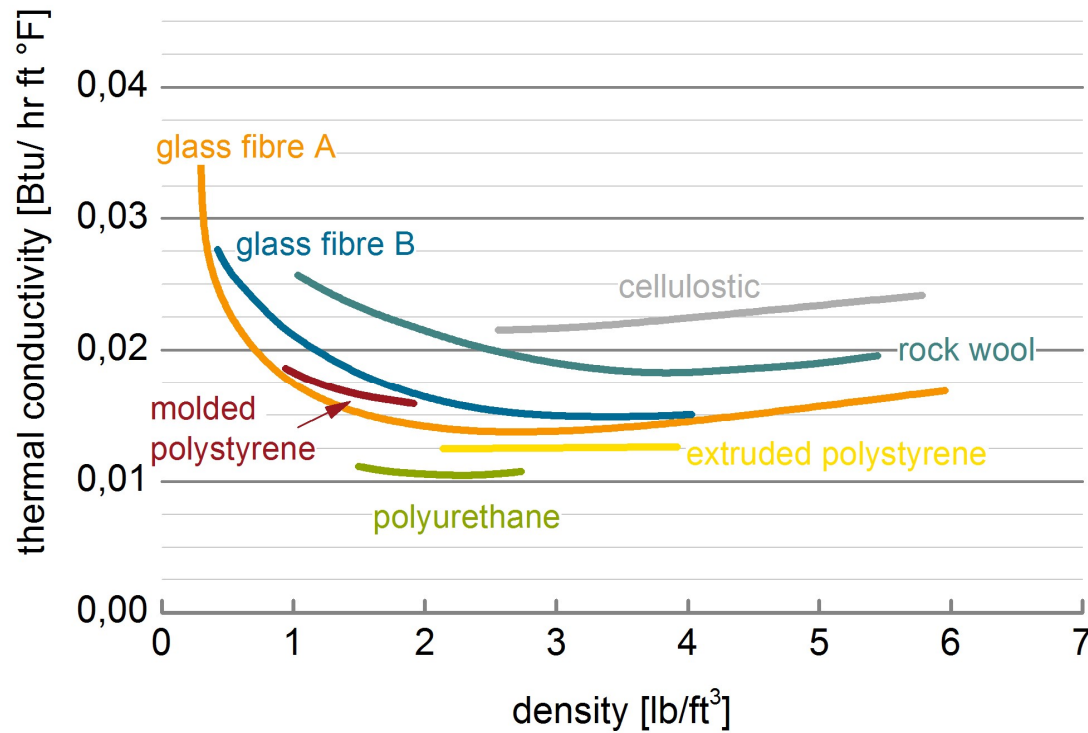
Quelle: <http://www.bine.info>

# Mechanism of thermal conductivity

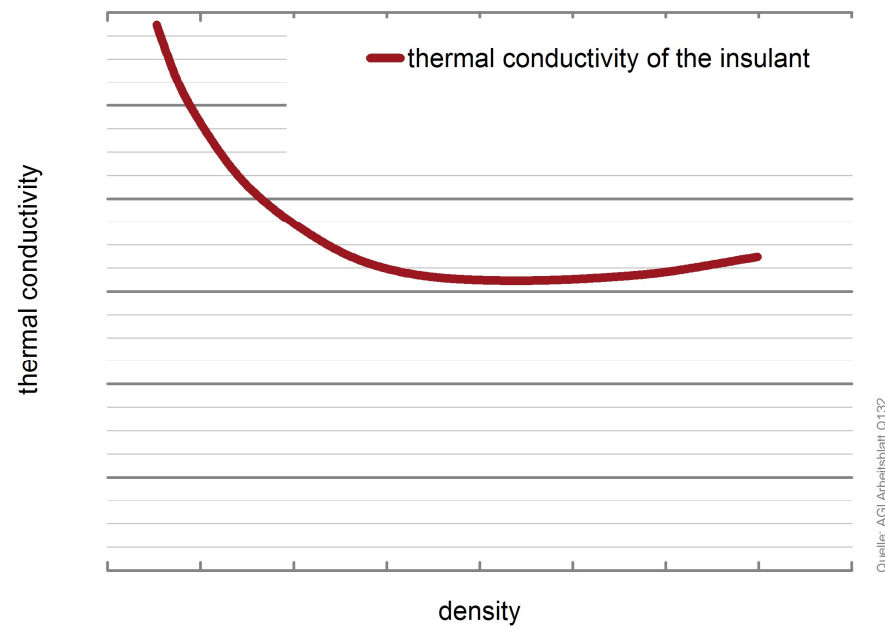


$$\lambda_{\text{Total}} = \lambda_{\text{convection}} + \lambda_{\text{solid}} + \lambda_{\text{cellgas}} + \lambda_{\text{radiation}}$$

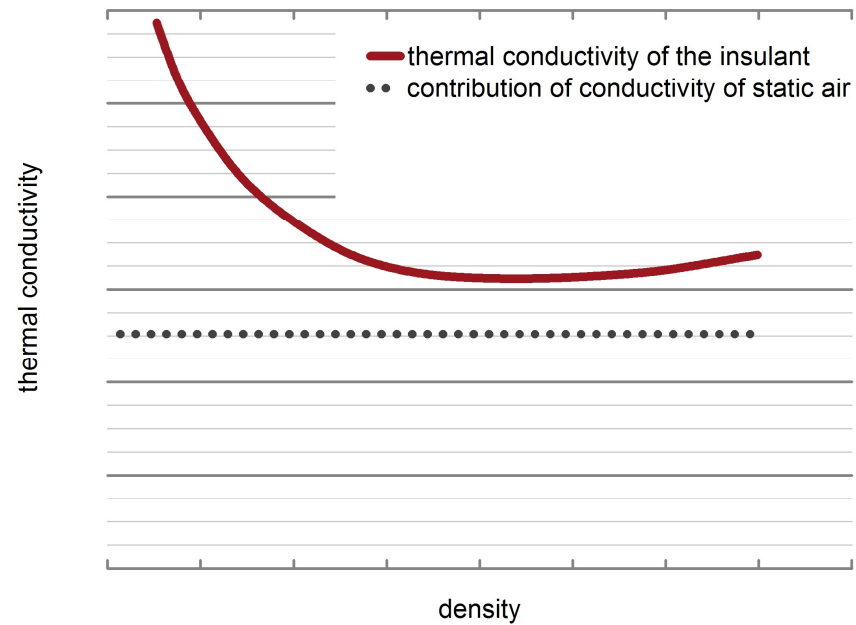
# Physical Background



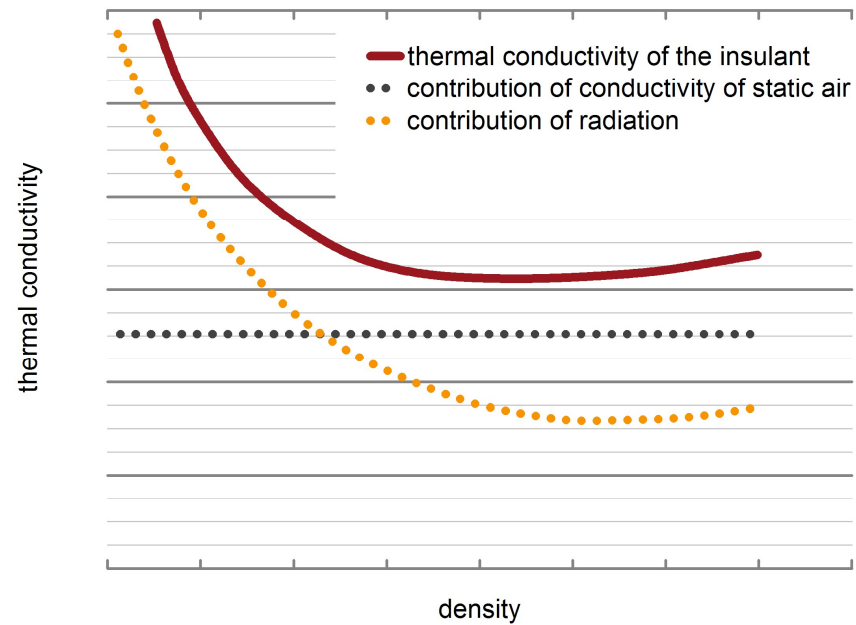
# Physical Background



# Physical Background

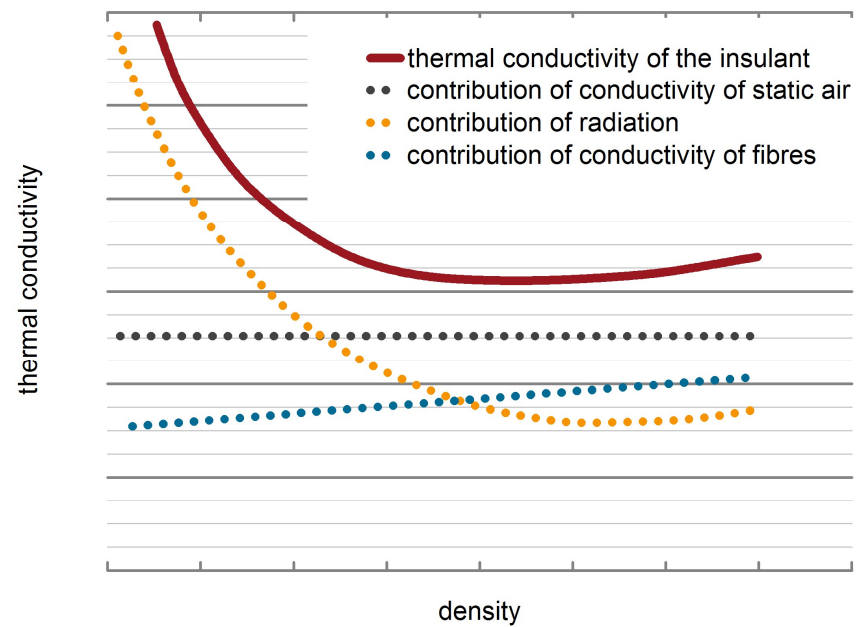


# Physical Background



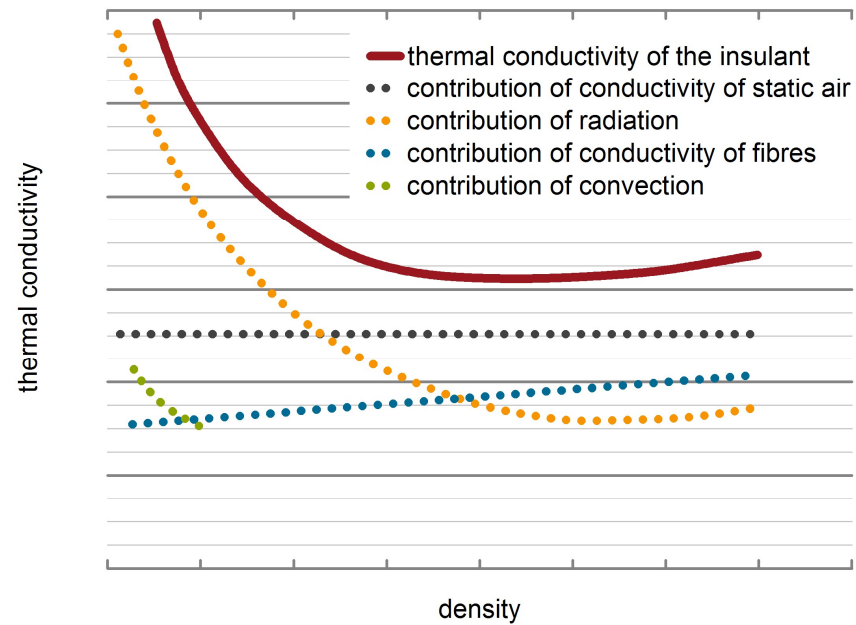
Quelle: AGI Arbeitsblatt Q132

# Physical Background



Quelle: AGI Arbeitsblatt Q132

# Physical Background





# Mineral wool

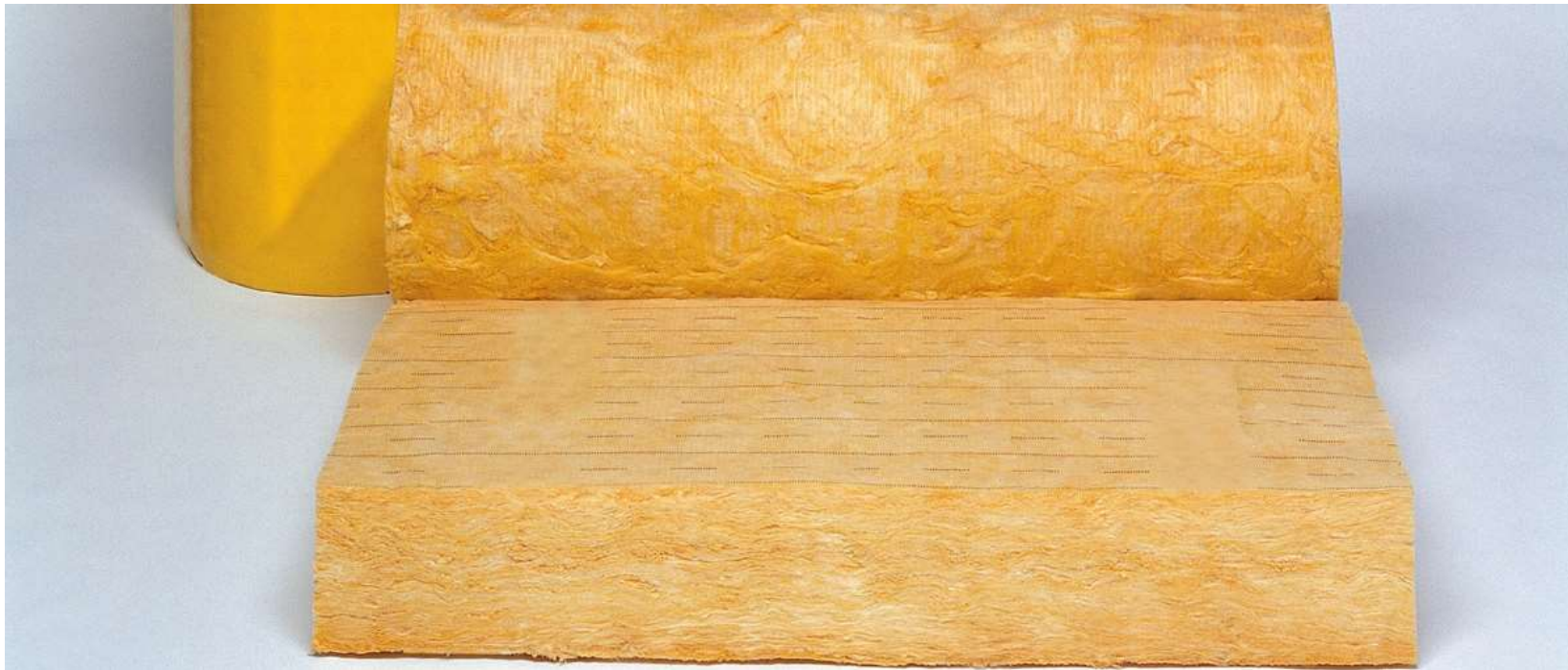
# Efficient Thermal Insulation



Fibrous Structure



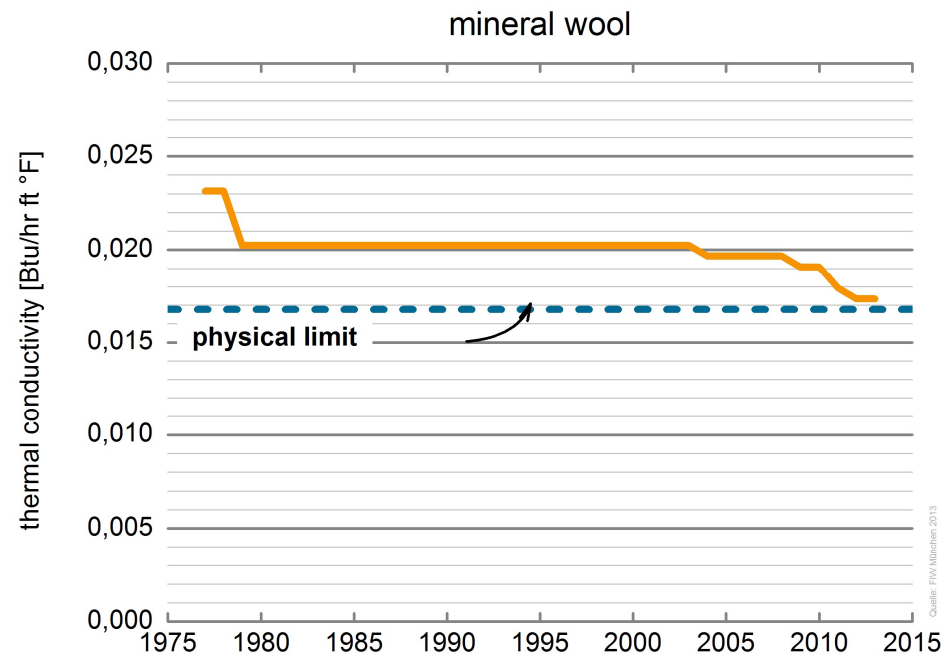
# Glas wool



# Stone wool



# Development of thermal conductivity



# Development of thermal conductivity



- BAU 2013
- 0,0173 Btu / hr ft °F



## Development of thermal conductivity



<http://www.outdoorfreunde.net/>

# Development of thermal conductivity



<http://img.archiexpo.de>



<http://www.baulinks.de/>

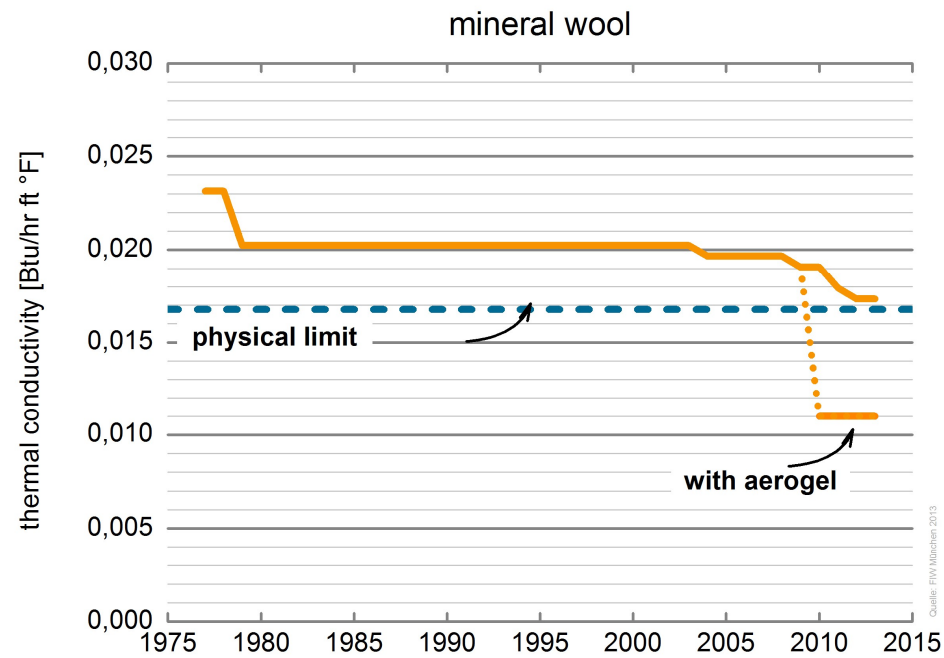


# Development of thermal conductivity



<http://daemmung.benz-baustoffe24.de>

# Development of thermal conductivity



## New areas of application



Source: Rockwool



Source: Rockwool

## New areas of application



Quelle: [www.presseportal.de](http://www.presseportal.de)



Quelle: [www.presseportal.de](http://www.presseportal.de)

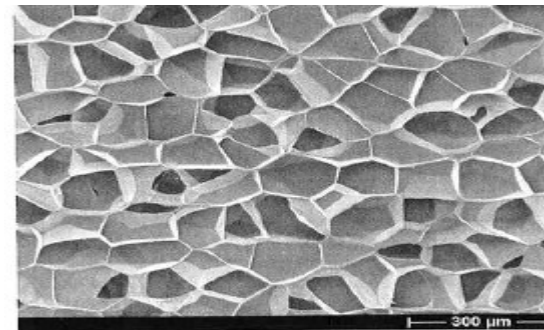
# EPS

polystyrene expanded

# Efficient Thermal Insulation



Microcellular Structure





# EPS



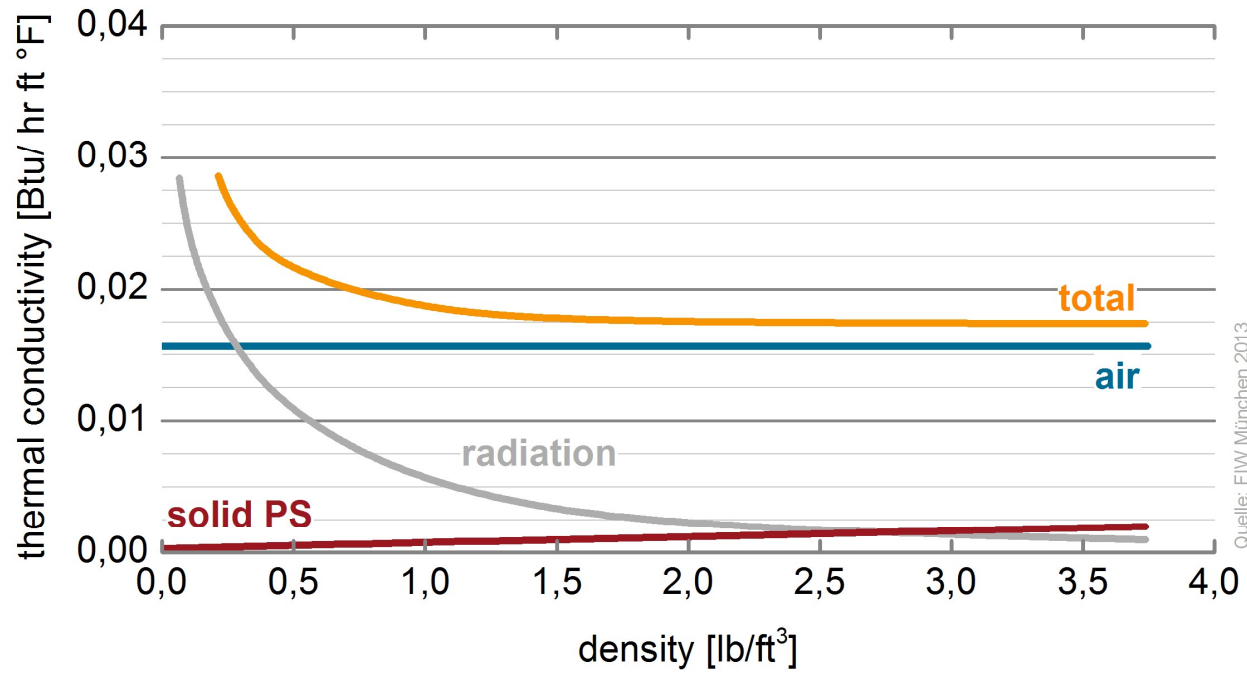
[http://www.detail.de/uploads/pics/Forschungsprojekt\\_zum\\_WDVS\\_Recycling\\_01\\_A\\_01.jpg](http://www.detail.de/uploads/pics/Forschungsprojekt_zum_WDVS_Recycling_01_A_01.jpg)

# EPS



Quelle: IBHolm

# EPS



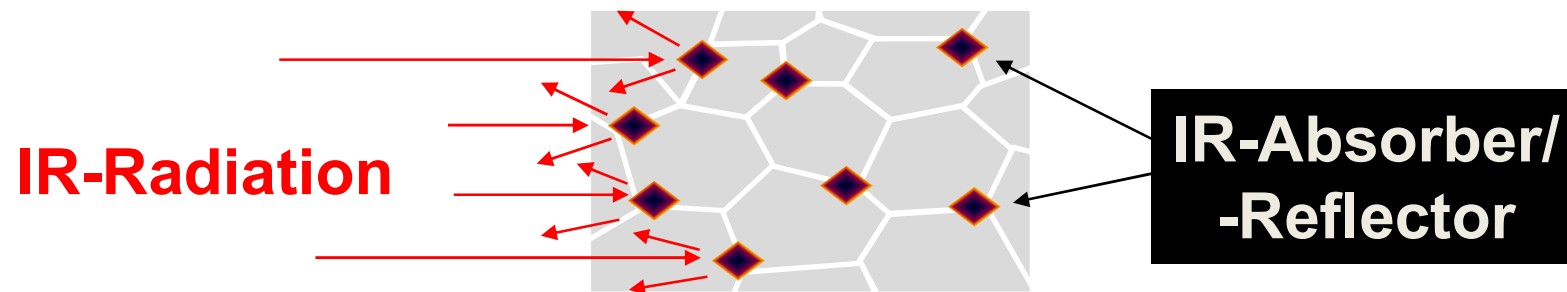
Quelle: FIW München 2013

# EPS



*Quelle: ZAE Bayern*

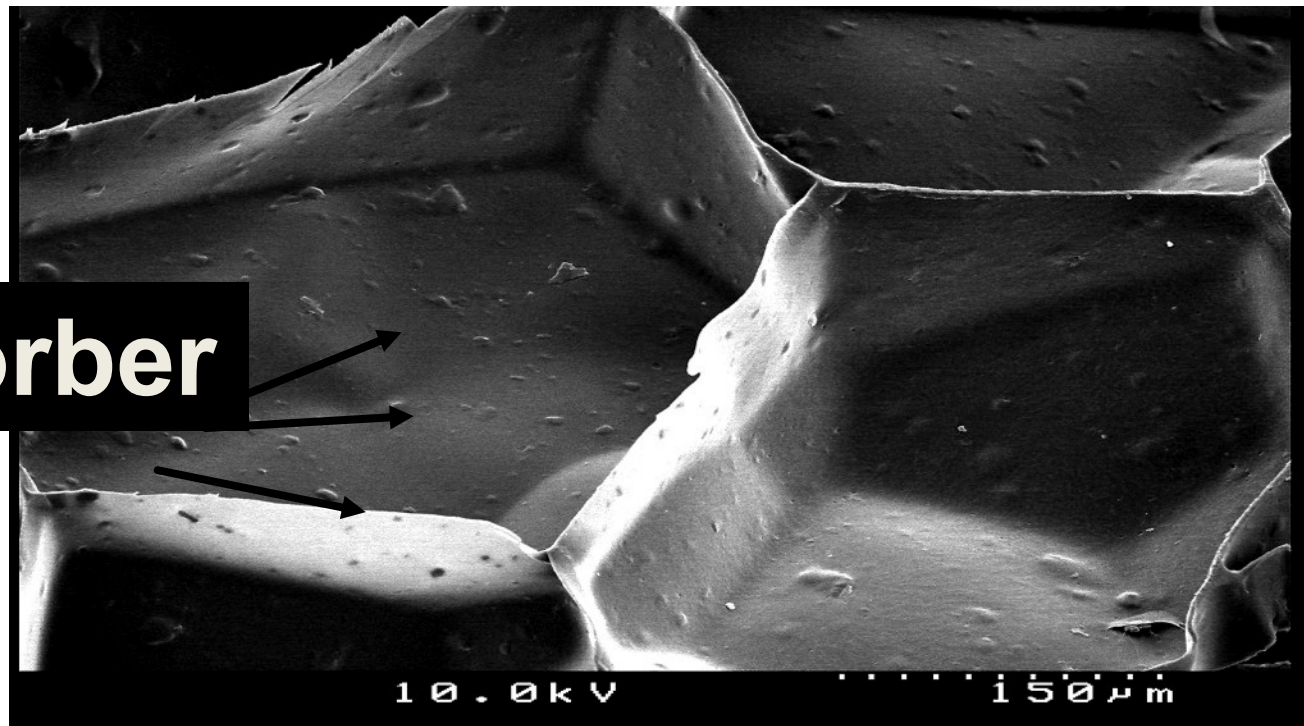
EPS





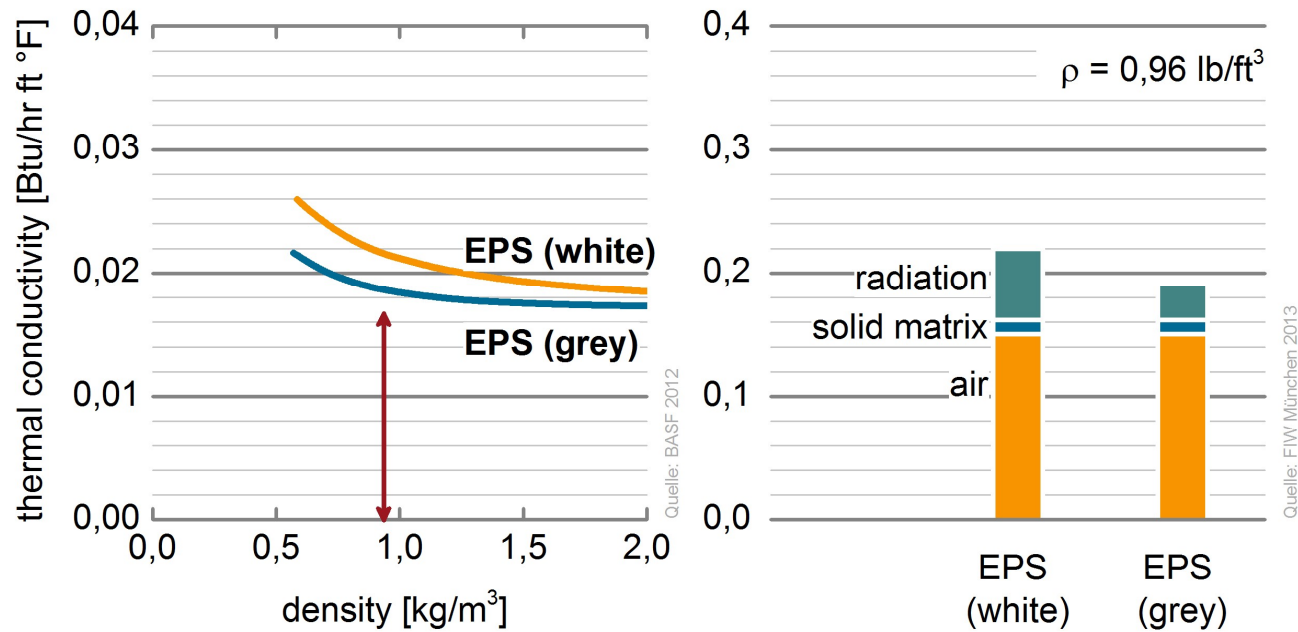
# EPS Neopor®

**IR-Absorber**



(Ref.: BASF AG, Ludwigshafen/Rh)

# EPS with radiation control



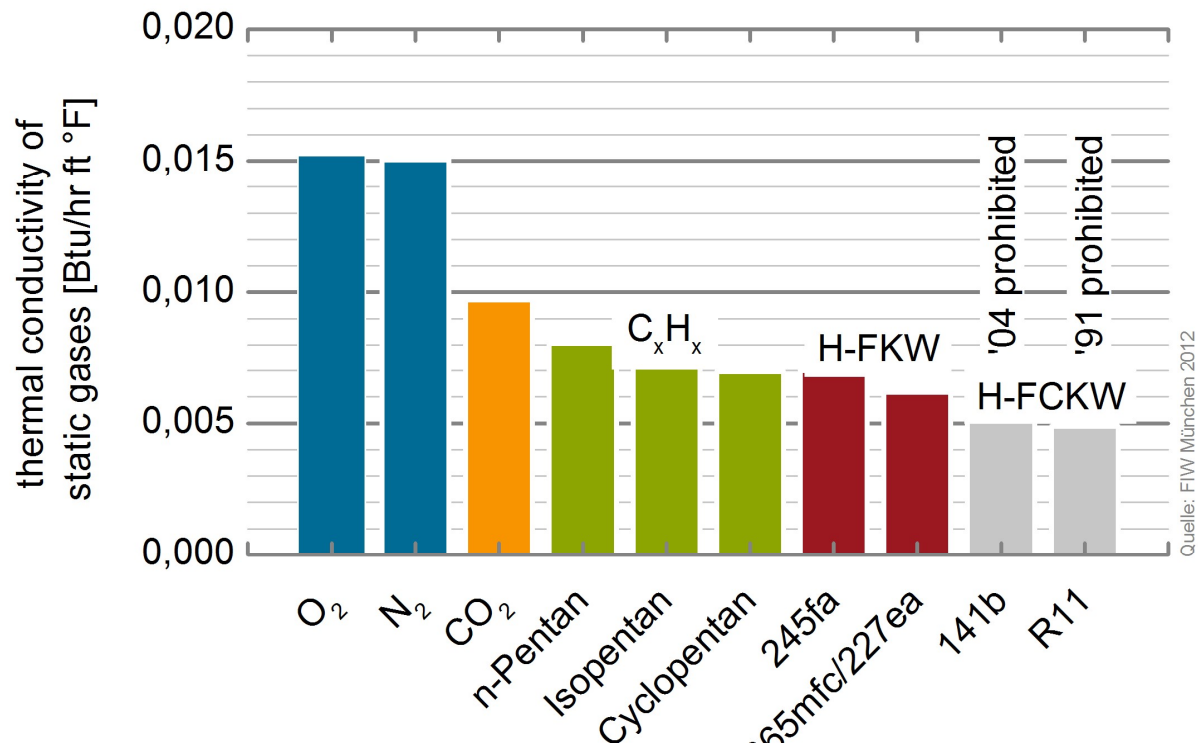
**improvement gained by adding graphite: 14%**



# PUR/PIR

## Polyurethan / Polyisocyanurat

# Physical Background



Quelle: FIW München 2012

# PUR/PIR



[http://www.ivpu.de/cms/upload/slider/pu\\_1.jpg](http://www.ivpu.de/cms/upload/slider/pu_1.jpg)

# PUR/PIR



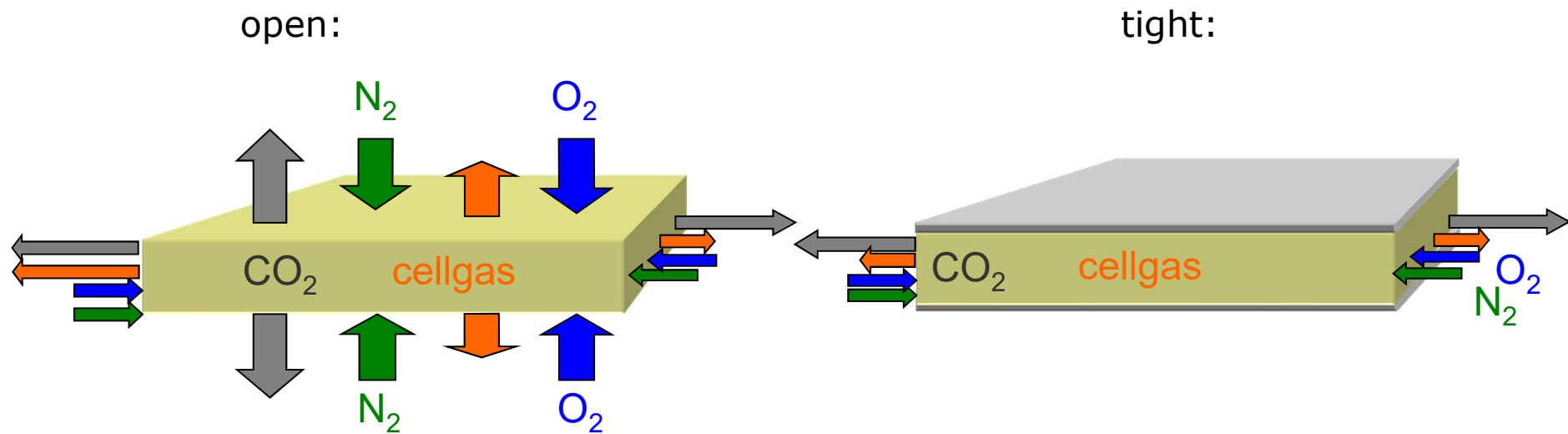
*Bild: FIW München*

# PUR/PIR



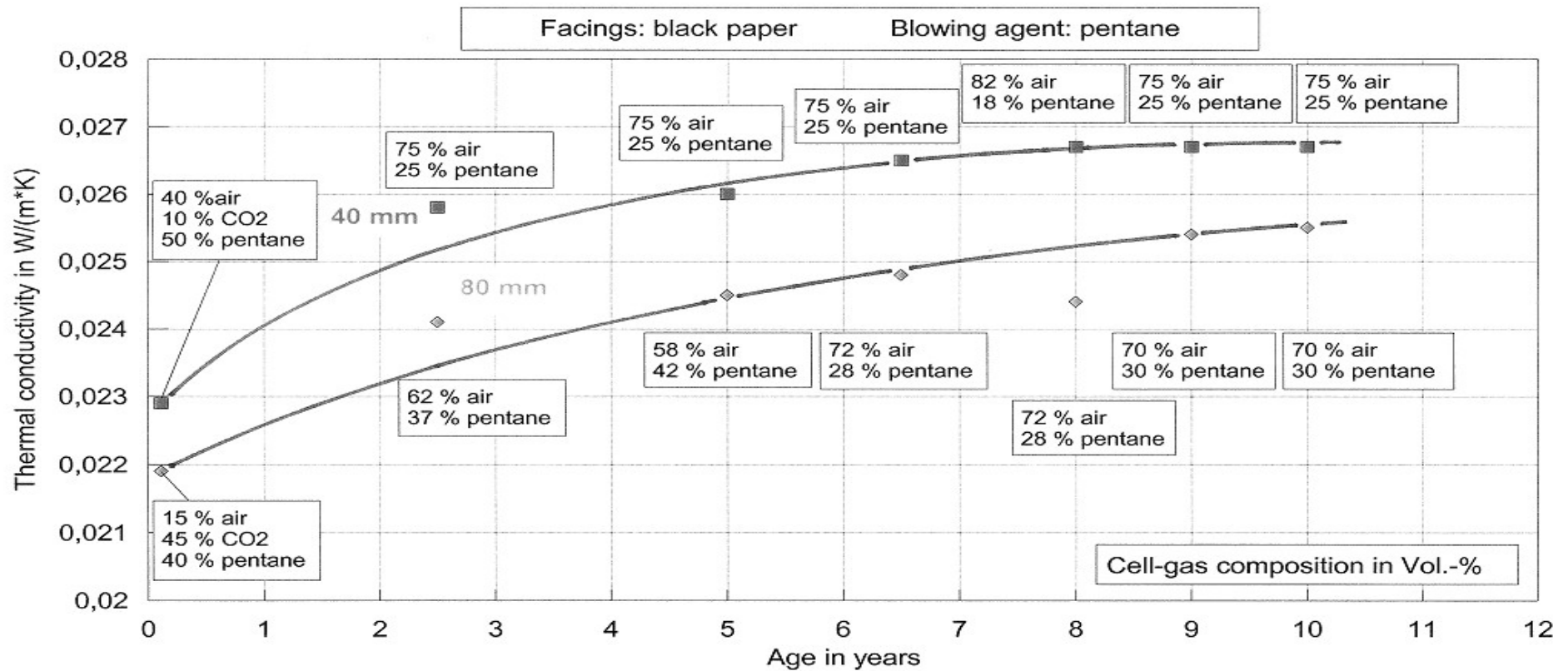
[http://www.ivpu.de/cms/upload/slider/pu\\_1.jpg](http://www.ivpu.de/cms/upload/slider/pu_1.jpg)

# PUR/PIR

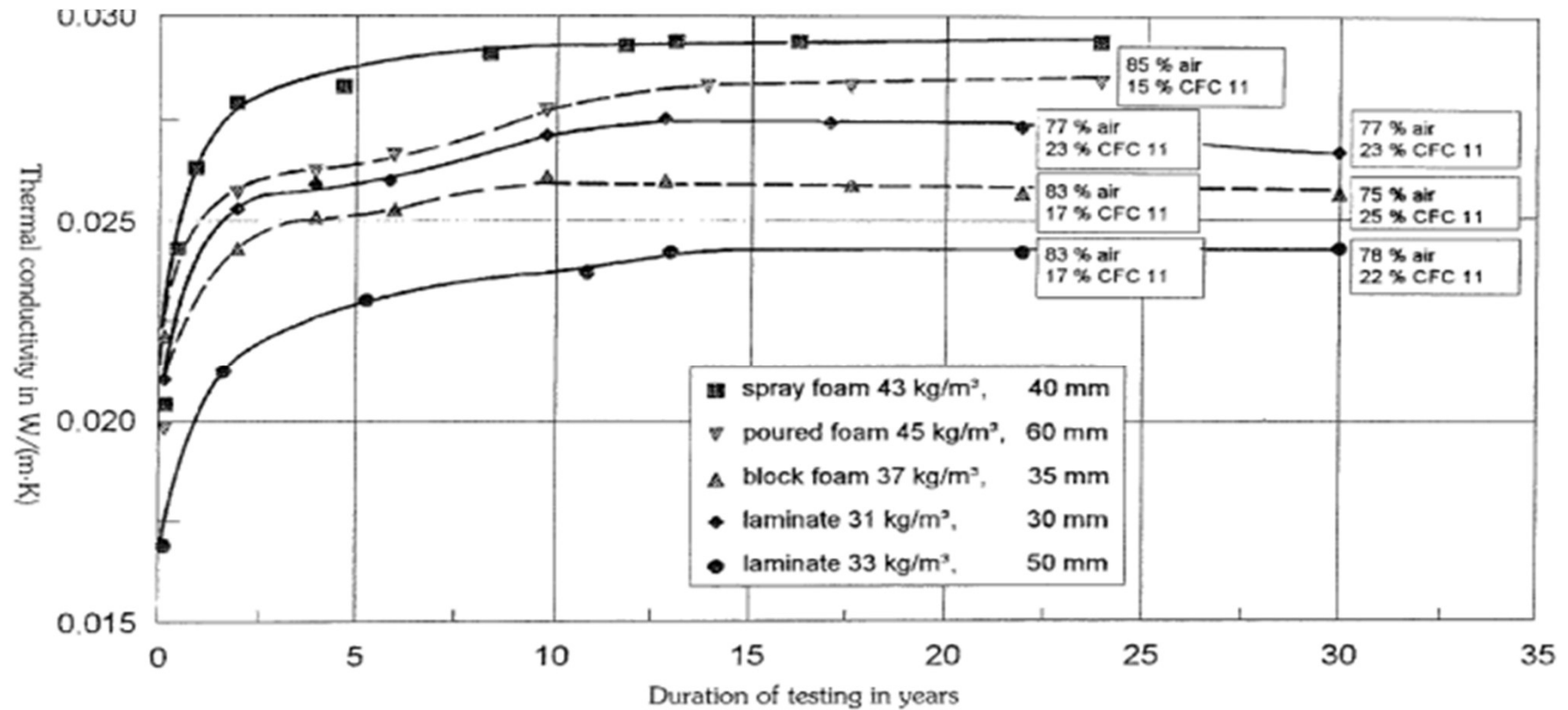


Change of thermal conductivity

# PUR: $\lambda$ depending on cell gas: Pentane



# PUR: $\lambda$ depending on cell gas: CFC 11





# PUR/PIR



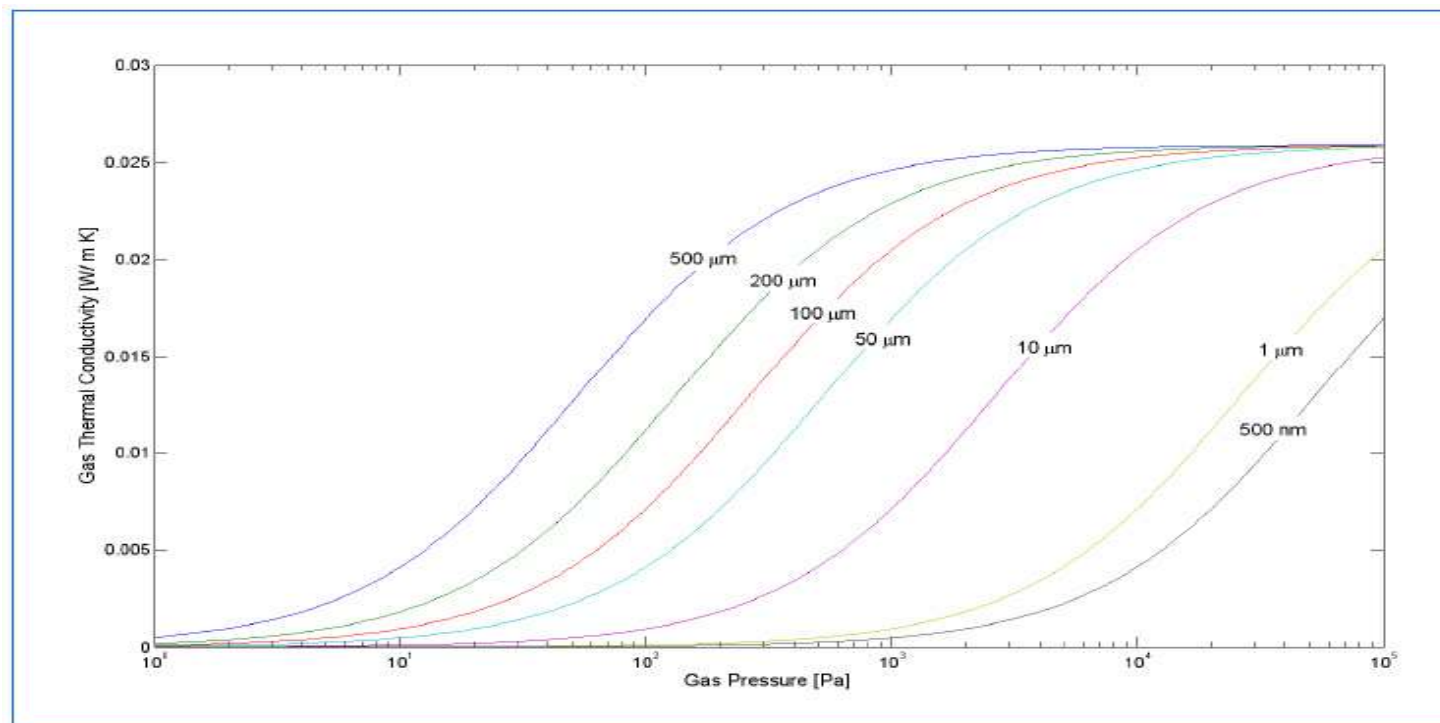
## ■ Ageing

- Material: strongly depending on cell gas content!
- Facings (metal or non-metal)
- Percentage of closed cells (>95% for industrial produced boards)
- System: shrinkage → Gaps in the system possible!!!

# Development Potential: Nanoporous



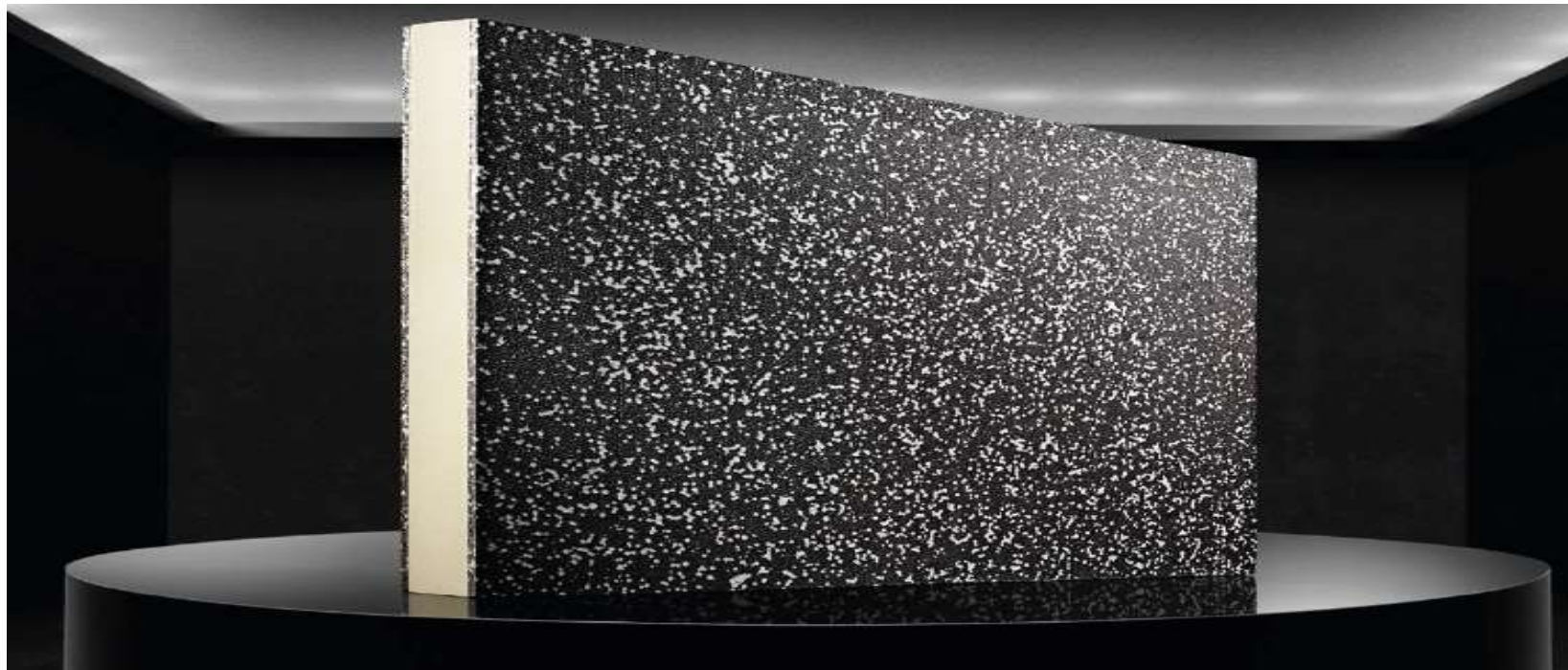
Scientific Background: Knudsen/Smoluchowski effect:



## Development Potential: Nanoporous



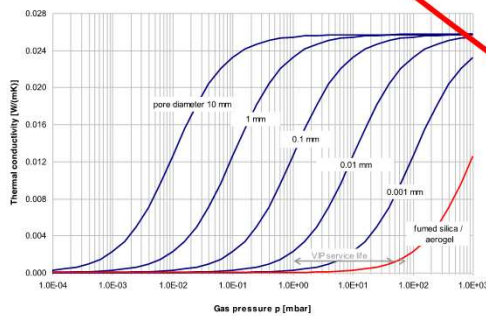
## Development Potential: combining 2 worlds





# Super Insulation Materials

# Super Insulation Materials – New IEA Annex



$$\lambda_g = \frac{\lambda_{g0}}{1 + C \cdot \frac{T}{\delta P}}$$

## Definition

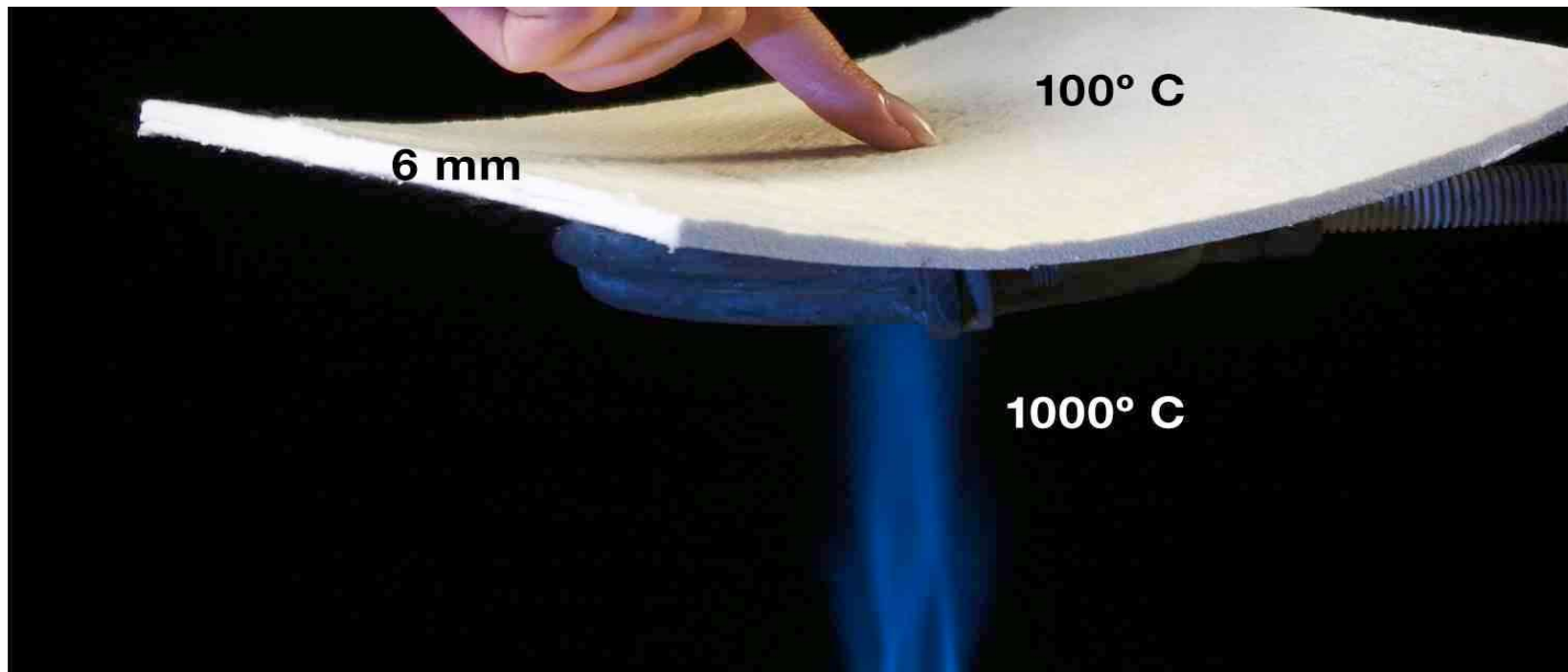


| Filling | Criteria                                  |
|---------|---|
| Air     | $< 25 \text{ mW}/(\text{m}\cdot\text{K})$ |
| Gases   | $< 20 \text{ mW}/(\text{m}\cdot\text{K})$ |
| Vacuum  | $< 15 \text{ mW}/(\text{m}\cdot\text{K})$ |

# Aerogels



## Aerogel based on Silica



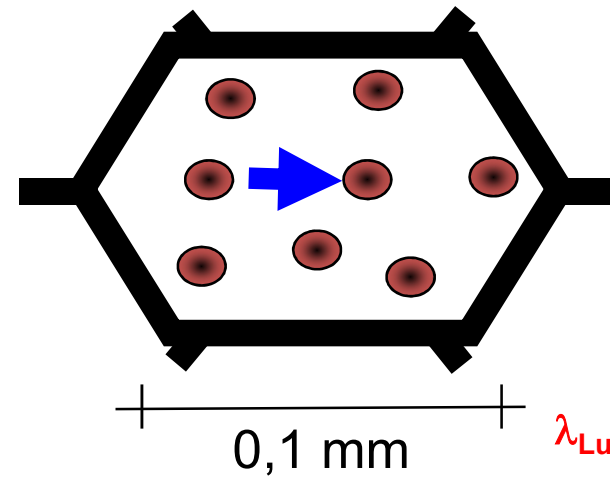
[http://press.aerogel.com/image/Aspen\\_Aerogels-Flame-n-Finger.jpg](http://press.aerogel.com/image/Aspen_Aerogels-Flame-n-Finger.jpg)

# Aerogels



Conventional cellstructure:

significant influence of cellgas



$$\lambda_{\text{Luft}} = 26 \text{ mW}/(\text{m}\cdot\text{K})$$

# Nanotechnology

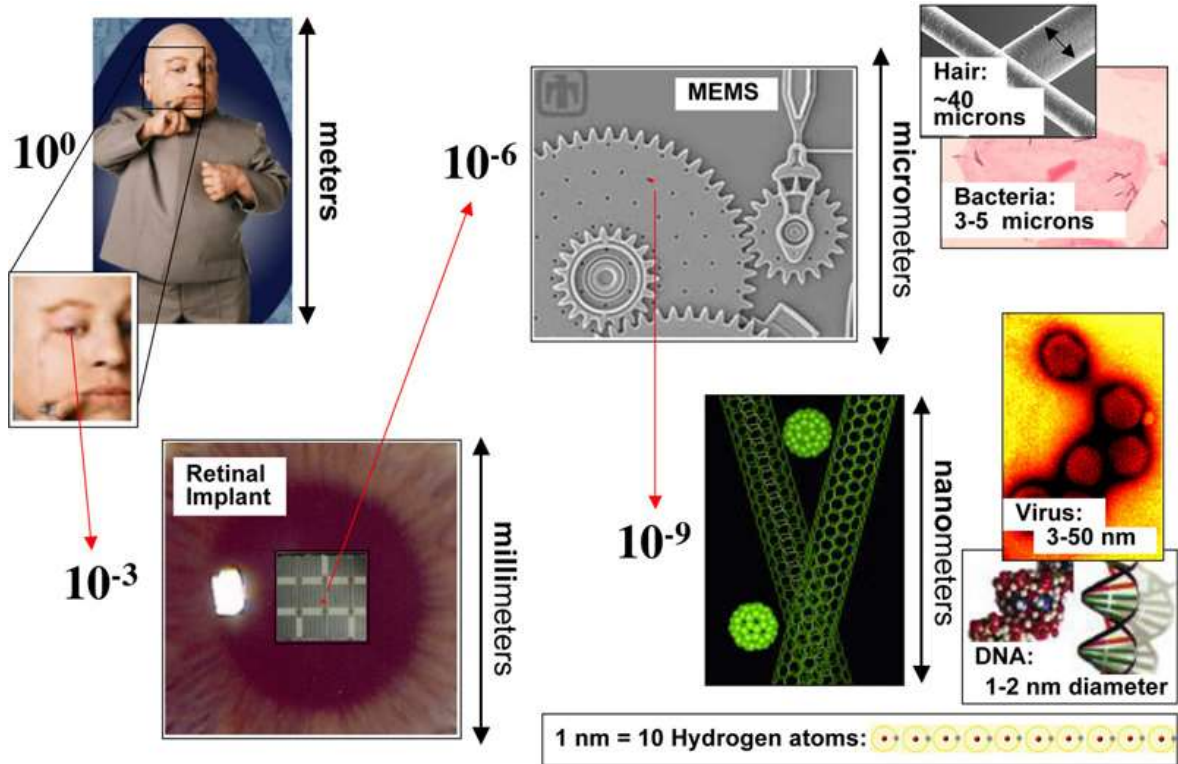
one billionth of a meter ( $10^{-9}$ )

## How many days are....



- 1 million seconds = about 11 days.
  
  
  
  
  
  
  
  
  
  
- 1 billion seconds = about 30 years.

# Nano scale: Factors of 1000

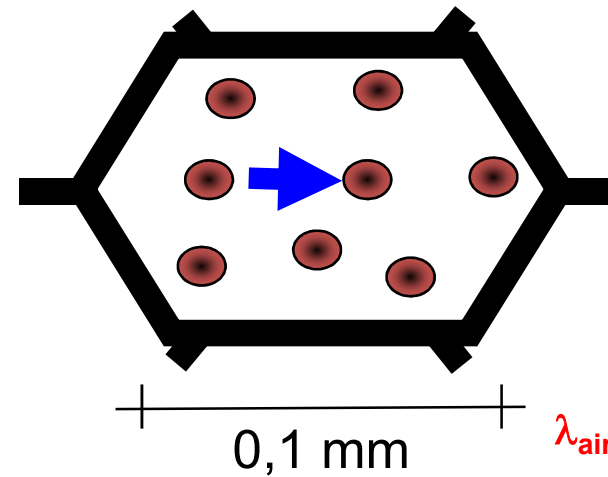


# Aerogels



Conventional cellstructure:

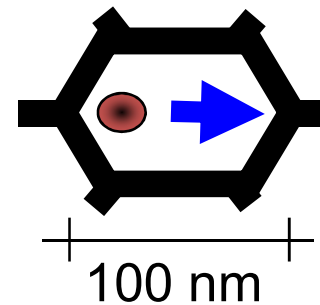
significant influence of cellgas



$$\lambda_{\text{air}} = 26 \text{ mW}/(\text{m}\cdot\text{K})$$

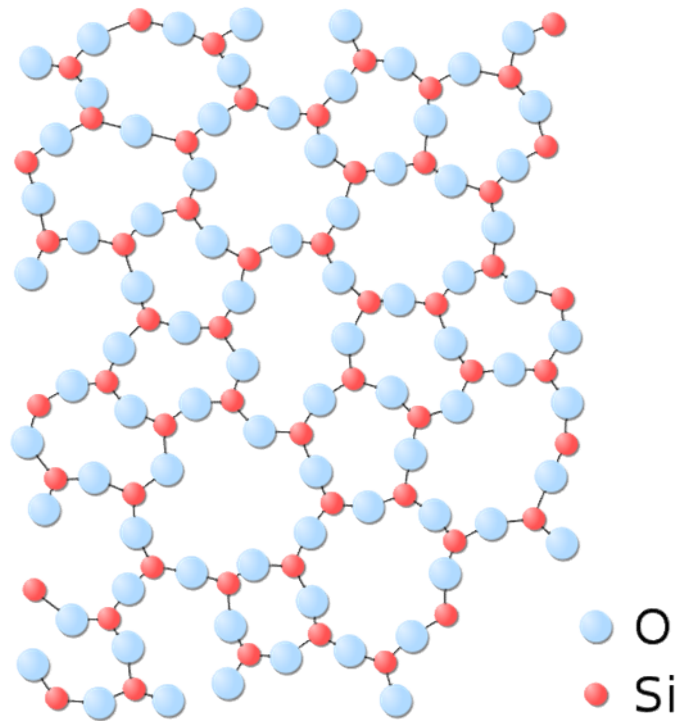
Nanocellular structure:

no influence of cellgas



$$\lambda_{\text{aerogel}} = 12 \text{ mW}/(\text{m}\cdot\text{K})$$

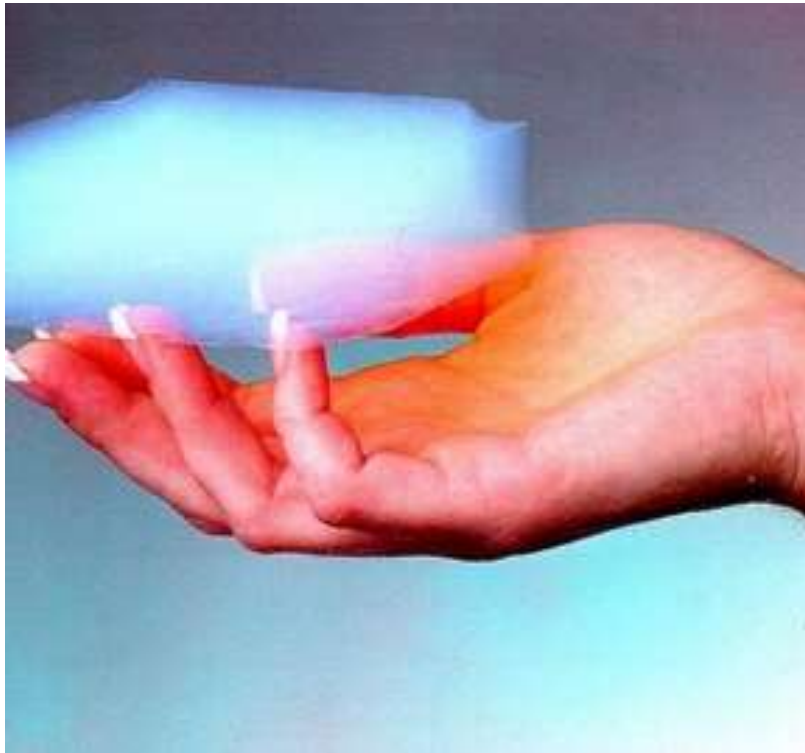
# Structure



- SiO<sub>2</sub> bonds
- Complex Lattice
- High porosit
- Extremely absorbent



## The trick: Surface Area/Volume



- Smaller and more pores increase internal surface area
- Reduce conduction and convection
- Trap air better

# Aerogel auf Silikatbasis



*loses Granulat:  
0,018-0,020 W/(m·K)*



*gebundene/gepackte Formen:  
0,014-0,016 W/(m·K)*

# Aerogel auf Silikatbasis



<http://img.archiexpo.de>



<http://www.baulinks.de/>

## Aerogel auf Silikatbasis



*Bild: EMPA*

## New areas of application



*Source: Rockwool*



*Source: Rockwool*



## New areas of application



Quelle: [www.presseportal.de](http://www.presseportal.de)



Quelle: [www.presseportal.de](http://www.presseportal.de)

# New areas of application

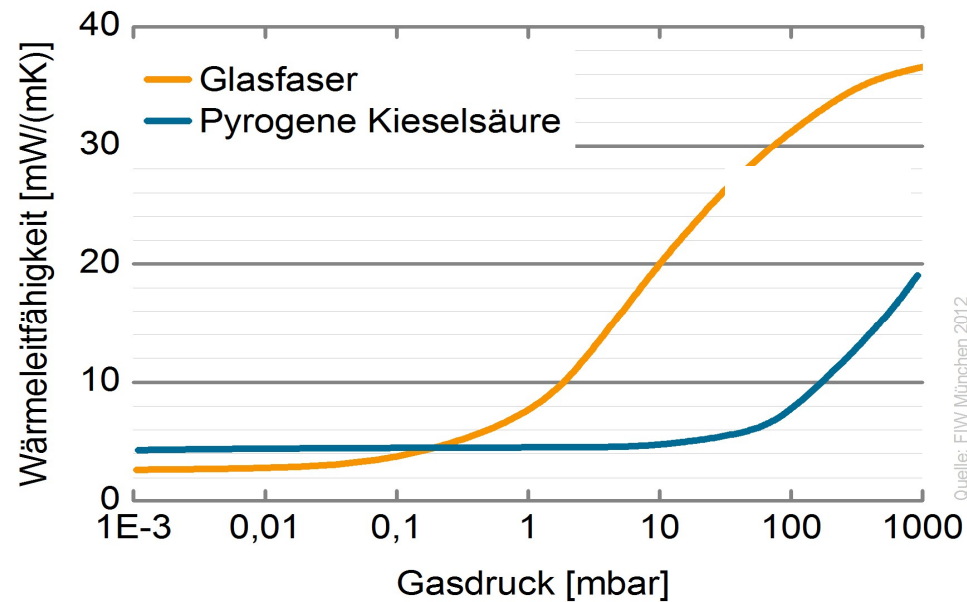


# VIP

## Vakuumisolationspaneele



# Vakuumisolationspaneele (VIP)



Quelle: FIW München 2012

<http://www.baupraxis-blog.de>

# Vakuumisolationspaneele (VIP)



# Vakuumisolationspaneele (VIP)



<http://www.baupraxis-blog.de>

# Vakuumisolationspaneele (VIP)



*EPS ummantelten VIPs*

# Vacuum insulation (VIP)



VIP protected by EPS

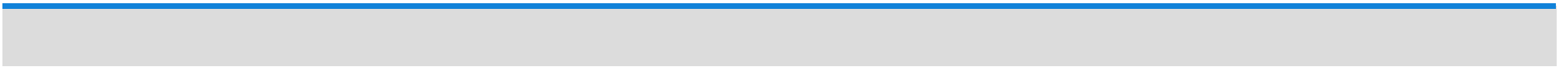


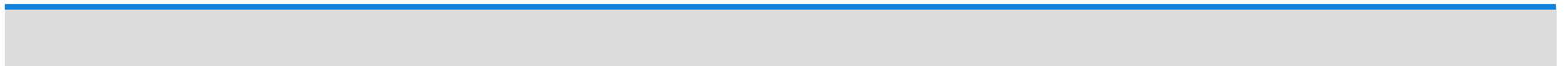
# Vakuumisolationspaneele (VIP)



*VIPs, überdeckt mit PUR-Dämmplatten mit diffusionsoffenen Deckschichten*

# Alternative Insulation Materials









■ Flickr / Ano Lobb



■ Typha Technik



# Paint



## als Öl tanken!

Aufgrund immer höher werdender Energiekosten mehr denn je der Einsatz innovativer Technologien Ansprüche. Seien es nun ökologische Aspekte wie z. Temperaturausgleich oder ganz einfach - aber wichtig

**Energiespar-Effekt**  
**Wärmeregulierung**  
**Geringe Verschmutzungsneigung**  
**Algen- und Pilzreduzierung**

### ► **Ausgangssituation**

- steigende Energiekosten

**Solar**  
**Solarfarbe**  
für Fassaden

Solaraktive Fassadenfarbe

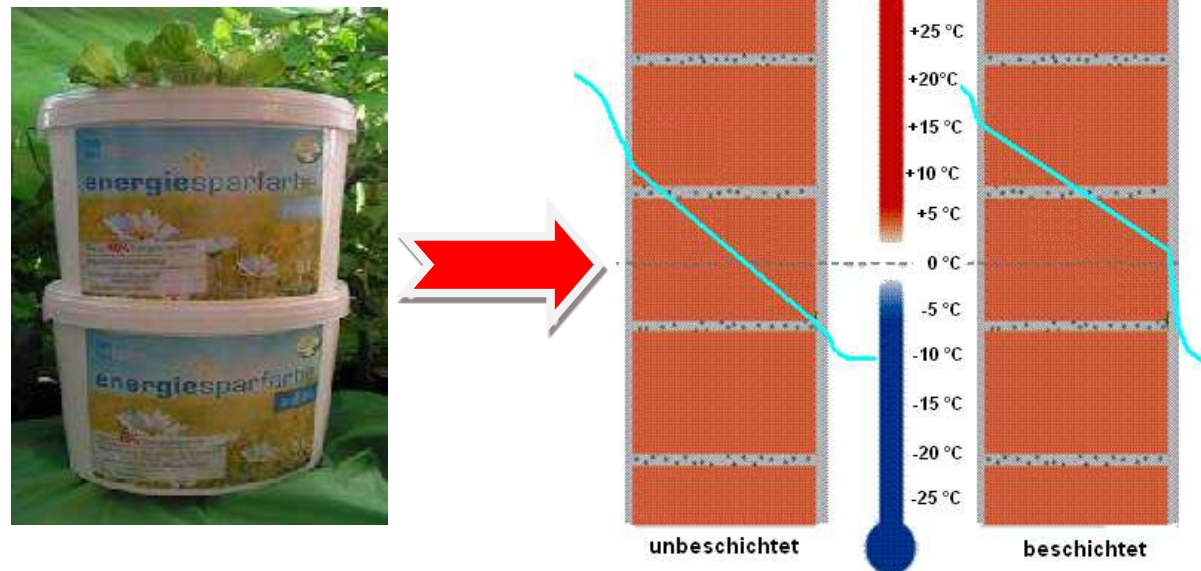


# Paint – liquid painting !!!!

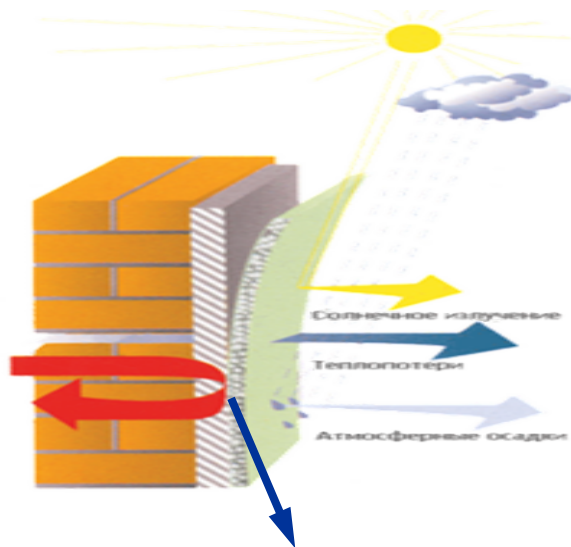


**energiesparfarbe**

# Paint – liquid painting !!!!



# Paint



Paint is not an insulation material !



**construction industry is not innovative !**

[http://www.appel-autofit.de/media/img/altres\\_auto\\_low.jpg](http://www.appel-autofit.de/media/img/altres_auto_low.jpg)



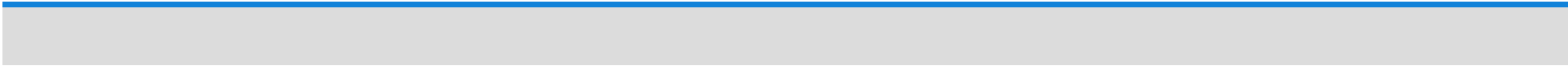
40 Jahre



www.auto-clever.de



www.commdiginews.com





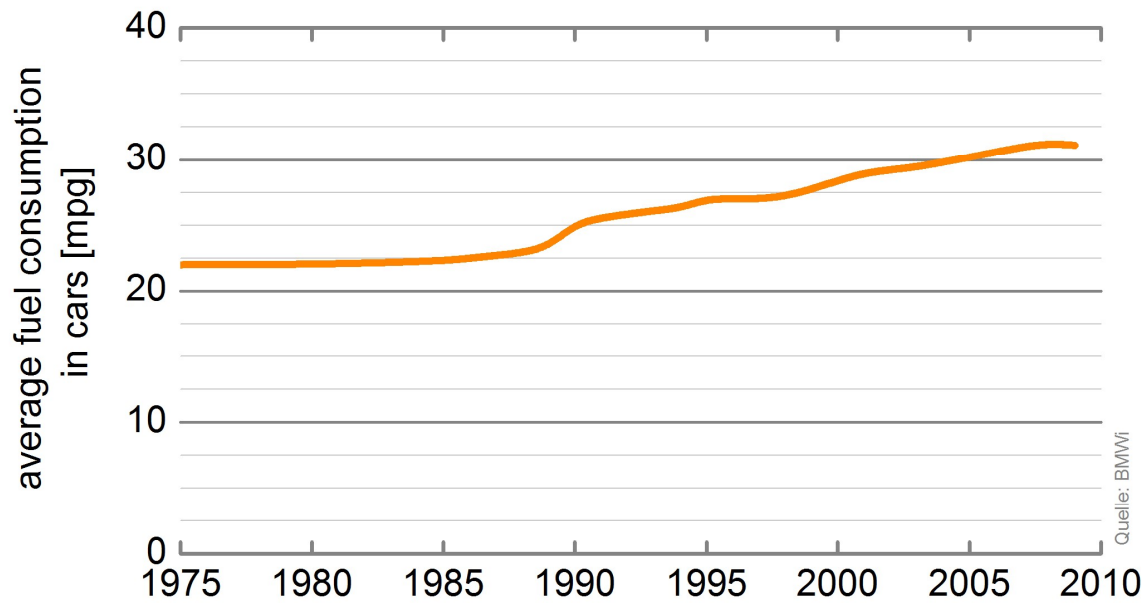
# Efficiency of cars



EBIHERKTODAY

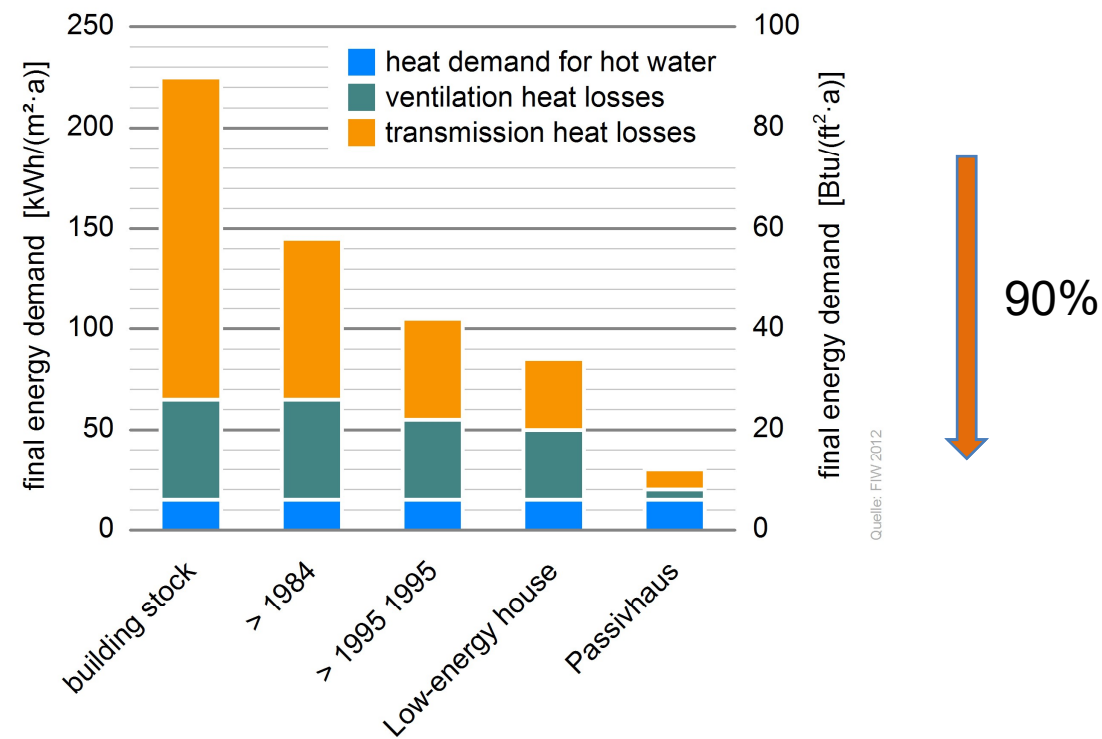


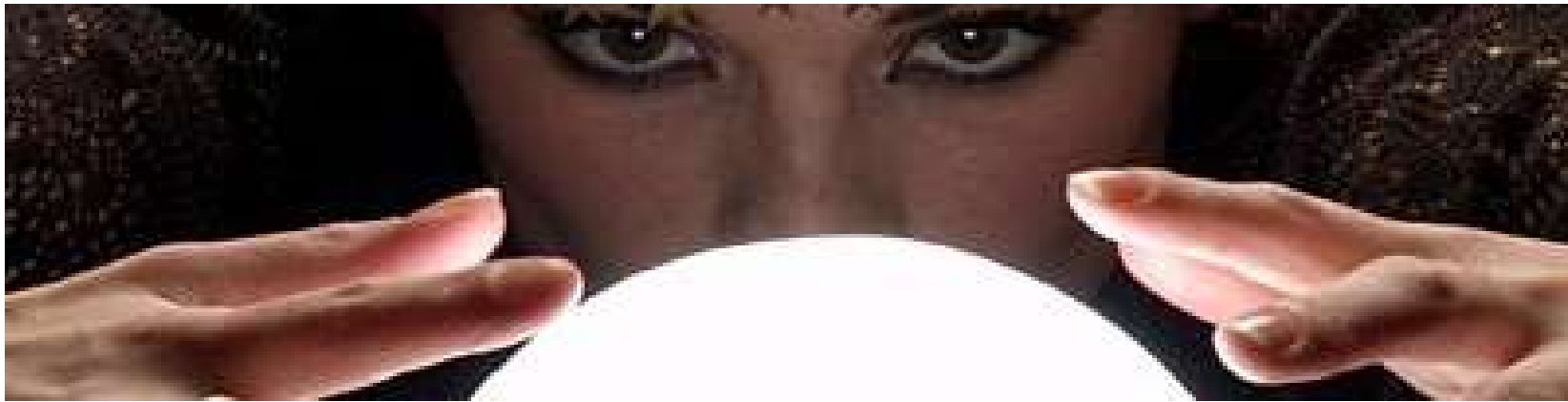
# Efficiency of cars



↑  
22%

# Efficiency of buildings





# Future

sueddeutsche.de

# Requirements



*proftec.com*

## Requirements



*rentalcarsingapore.com*

# Requirements



*<http://www.nationalgeographic.de>*