Thermal conductivity measured at center of panel - that is only half the truth !

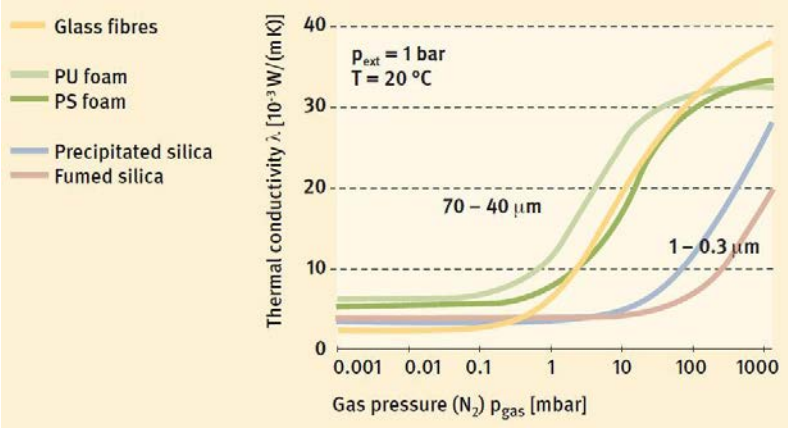
Hans-Frieder Eberhardt

Research & Development Director
Porextherm Dämmstoffe GmbH

Presentation Content

- Introduction
- Effective thermal conductivity λ_{eff}
- Comparison of λ_{eff} for vacuum insulation panels (VIP) with fumed silica and fiber core material
- Consequence for insulation performance considering λ_{eff}
- Attempt to cut the Gordion knot of „cost-performance-ratio“
- Current standardisation of VIP for building and construction applications
- Sustainability – environmental product declaration (EPD)

Thermal conductivity vs. pressure of different VIP core materials

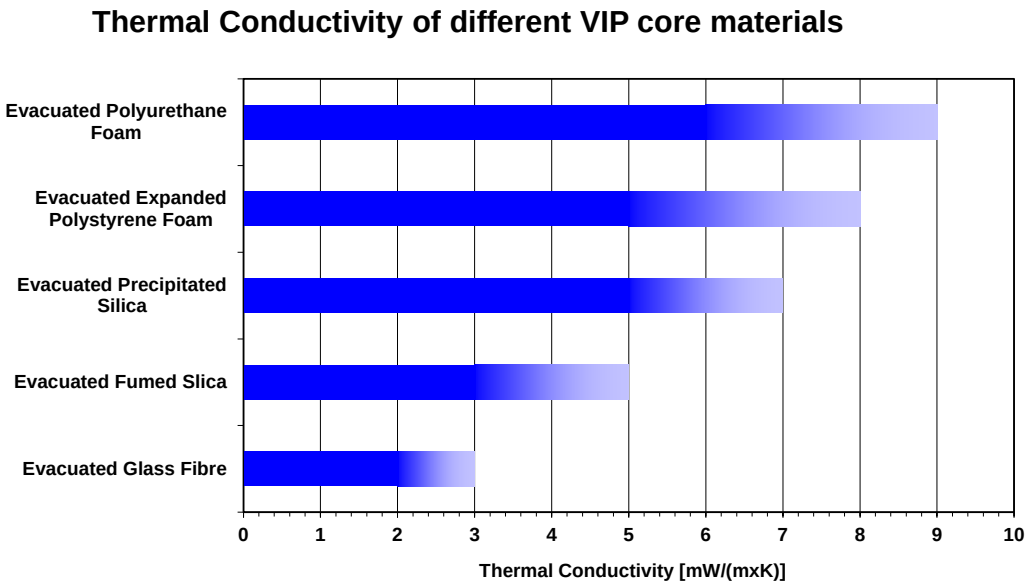


BINE Themeninfo I/2011 „Insulation through vacuums“
Source: ZAE Bayern

Thermal Conductivity at Center-Of-Panel:

λ_{COP}

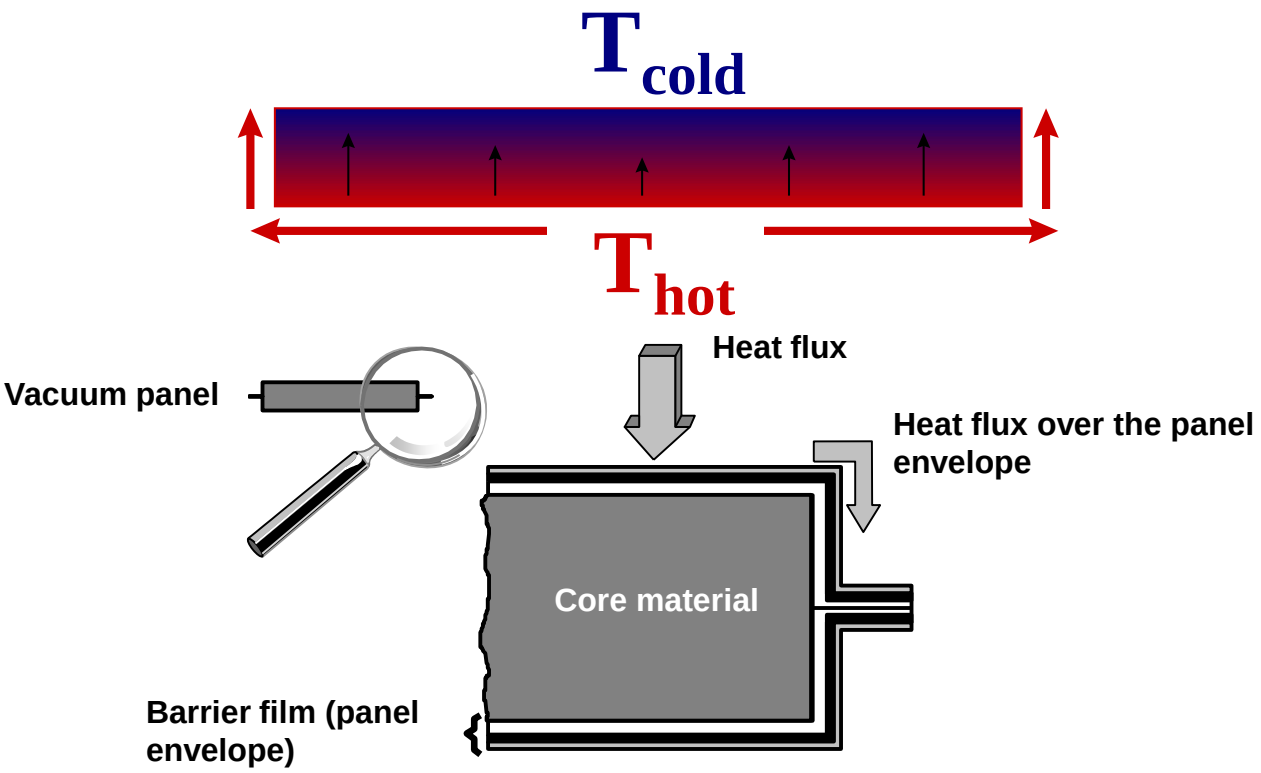
Thermal conductivity at initial state



Don‘t believe everything you think.

You have to consider an additional summand for receiving effective thermal conductivity λ_{eff} of vacuum insulation panel:

„ Thermal edge effect“



The effective thermal conductivity λ_{eff} is calculated with the following equation *:

Share of „Thermal Edge Effect“

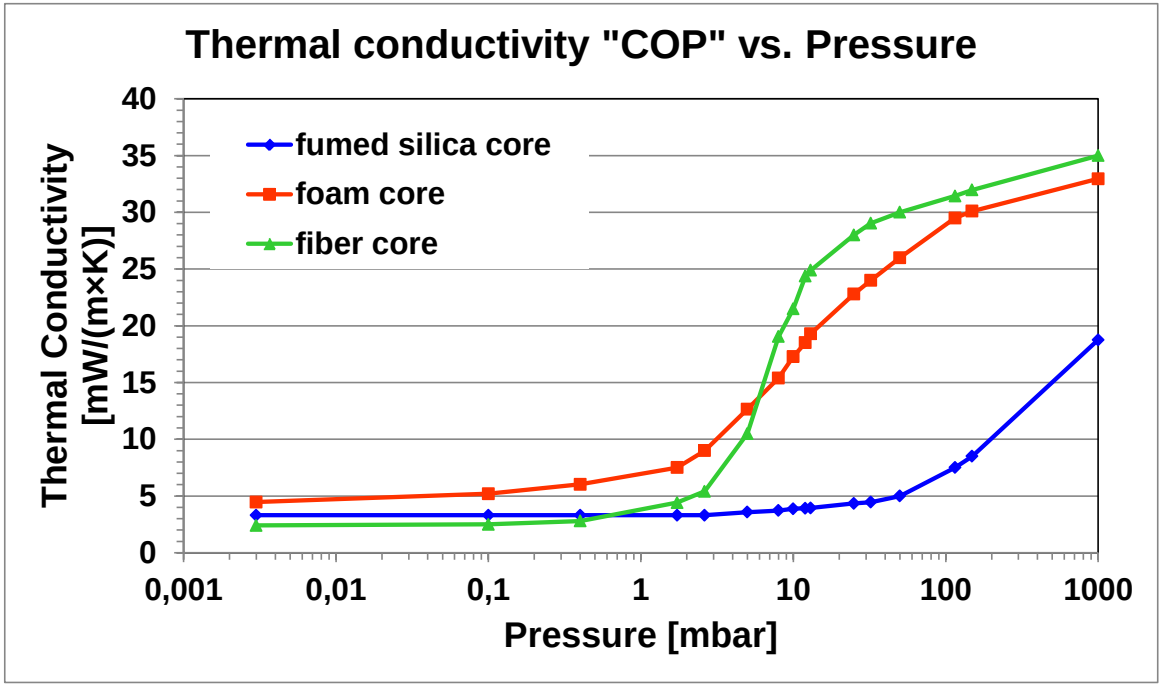
$$\lambda_{eff} = \lambda_{COP} + \Psi \times Thickness_{VIP} \times \frac{Perimeter_{VIP}}{Area_{VIP}}$$

with

λ_{eff}	…	effective thermal conductivity of VIP
λ_{COP}	…	thermal conductivity in „Centre of Panel“
Ψ	…	linear heat transmittance

* K. Ghazi Wakili et.al., Building Reserach & Information (July – August 2004) 32(4), 293 - 299

Comparison of λ_{eff} for different VIP core materials



To be able to guarantee an increase of inner pressure of a VIP which does not effect in a dramatic increase of thermal conductivity λ_{COP} you have to choose the right barrier material for each used insert material:

Fumed silica core ⇒ metallized laminated film

Fiber and foam core ⇒ aluminium film

Comparison of λ_{eff} for different VIP core materials

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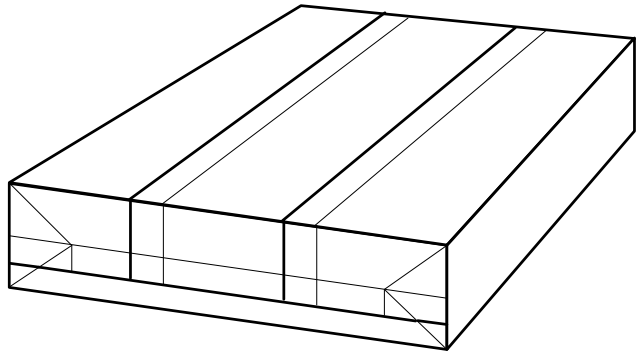
Considered VIP:

- Double seams on surface
- No film flap on long side
- Film flap joined to short side
- Corners bent to short side



VIP Dimensions [mm]	VIP Core Material	Barrier film	λ_{COP} [mW/(m×K)]	λ_{eff} [mW/(m×K)]	Increase [%]
1700 × 560 × 20	Fumed Silica	metallized 240 nm	3.7	4.0	8
	Fiber	aluminium 4 µm	2.5	4.3	72
		aluminium 9 µm	2.5	5.8	132
	Foam	aluminium 4 µm	4.5	6.3	40
		aluminium 9 µm	4.5	7.8	73
820 × 420 × 20	Fumed Silica	metallized 240 nm	3.7	4.1	11
	Fiber	aluminium 4 µm	2.5	5.3	112
		aluminium 9 µm	2.5	7.5	200
	Foam	aluminium 4 µm	4.5	7.3	62
		aluminium 9 µm	4.5	9.5	111
390 × 150 × 20	Fumed Silica	metallized 240 nm	3.7	4.8	30
	Fiber	aluminium 4 µm	2.5	9.6	284
		aluminium 9 µm	2.5	15.2	508
	Foam	aluminium 4 µm	4.5	11.6	158
		aluminium 9 µm	4.5	17.2	282

Ψ-values calculated by FIW Munich, May 2013

U- and R-value for refrigerator wall containing VIP with fumed silica and fiber core:

Steel, t = 0.5 mm,
λ = 45 W/(m×K)

Plastic inner liner,
t = 1 mm,
λ = 0.12 W/(m×K)

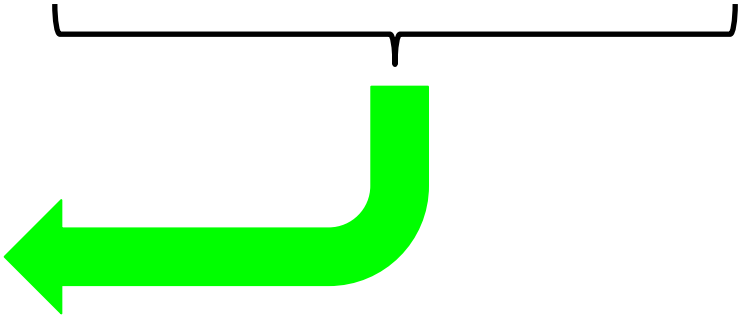
VIP, t = 20 mm,
λ_{eff} = XX W/(m×K)

Polyurethane foam , t = 40 mm,
λ = 0.019 W/(m×K)

VIP Dimensions [mm]	VIP Core Material	Barrier film	λ_{eff} [mW/(m×K)]	U-Value [W/(m²×K)]	R-Value [(m²×K)/W]
1700 × 560 × 20	Fumed Silica	metallized 240 nm	4.0	0.14	7.7
	Fiber	aluminium 4 µm	4.3	0.15	6.8
820 × 420 × 20	Fumed Silica	metallized 240 nm	4.1	0.14	7.5
	Fiber	aluminium 4 µm	5.3	0.17	5.9
390 × 150 × 20	Fumed Silica	metallized 240 nm	4.8	0.16	6.7
	Fiber	aluminium 4 µm	9.6	0.24	4.2

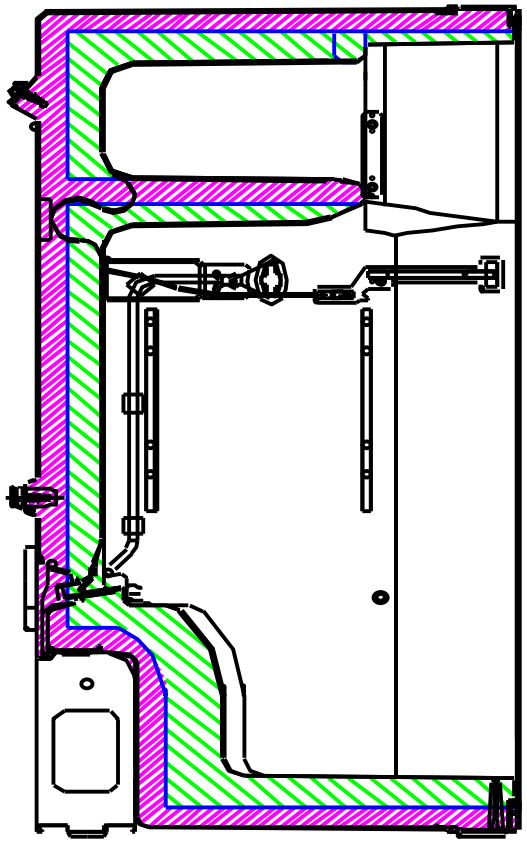
Increase of wall thickness for receiving same U-value for VIPs with same dimensions but different core materials:

VIP Dimensions [mm]	VIP Core Material	Barrier film	U-Value [W/(m²×K)]	Wall Thickness [mm]	Increase [%]
1700 × 560 × 20	Fumed Silica	metallized 240 nm	0.14	60	-
	Fiber	aluminium 4 µm		66	10
820 × 420 × 20	Fumed Silica	metallized 240 nm	0.14	60	-
	Fiber	aluminium 4 µm		82	37
390 × 150 × 20	Fumed Silica	metallized 240 nm	0.16	60	-
	Fiber	aluminium 4 µm		100	67



Loss of appliance inner volume !

The first two VIPs are e.g. used in refrigerator side walls. The increase of wall thickness accompanies with loss of appliance inner volume:



VIP Dimensions [mm]	VIP Core Material	Wall Thickness [mm]	loss of inner volume [liter]
1700 × 560 × 20	Fumed Silica	60	-
	Fiber	66	12
820 × 420 × 20	Fumed Silica	60	-
	Fiber	82	15

Two other possible angle of view:

U-value of refrigerator wall with fiber core VIPs is sufficient for required reduction of energy consumption …

- **… wall thickness with fumed silica VIP can be reduced ⇒ gain of inner volume !**

or

- **… wall thickness is kept with 60 mm, but the thickness of the fumed silica VIP is reduced ⇒ reduction of VIP costs !**

Attempt to cut the Gordion knot of „cost-performance-ratio“

Daily area of conflict:

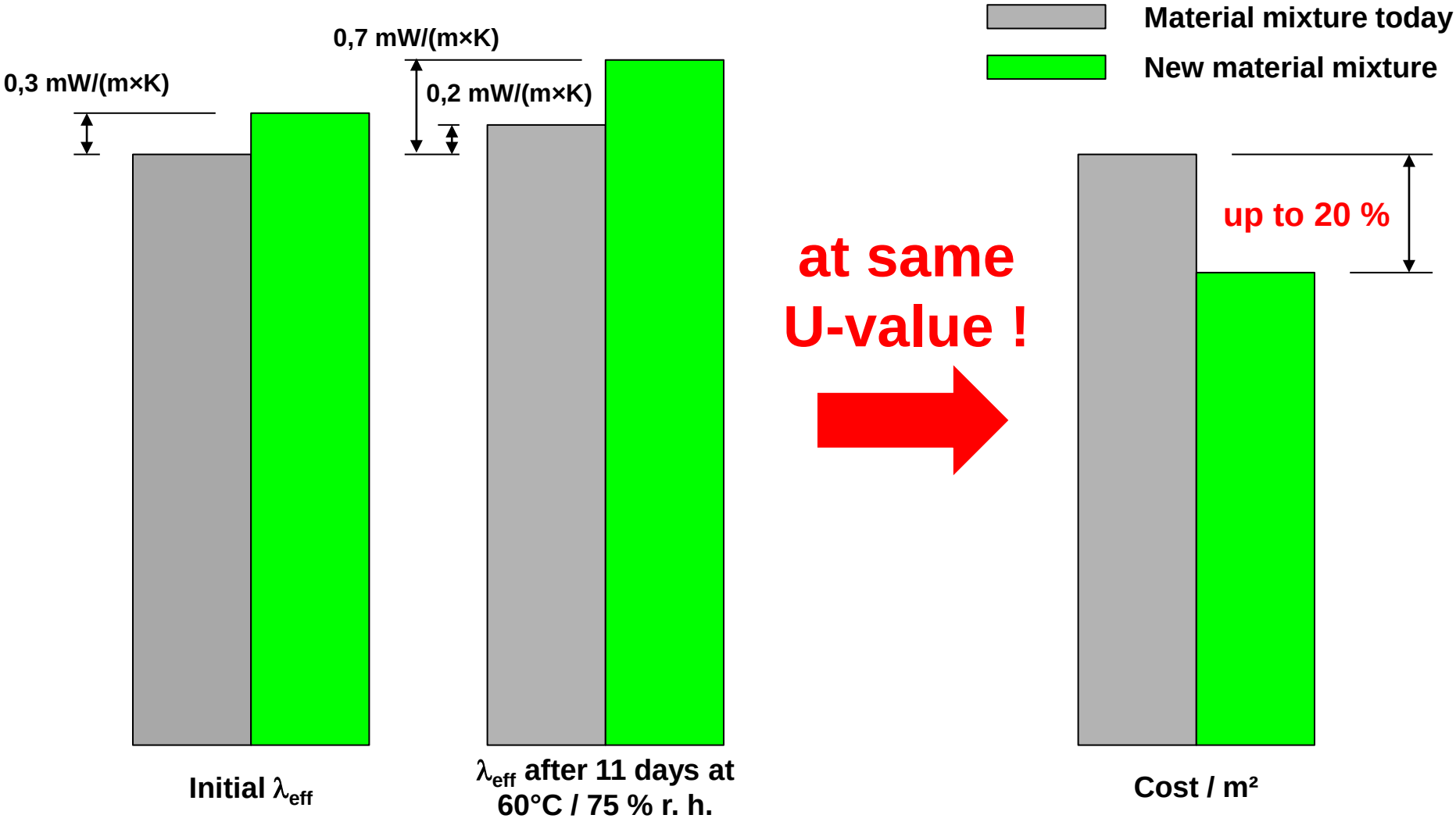
Lower Cost ⟺ **Better Performance (lower λ_{eff})**

Approach to solving the problem:

Maintain the magnitude of λ_{eff} …

… with simultaneous reduction of cost !

Attempt to cut the Gordion knot of „cost-performance-ratio“



CEN / TC 88 / WG 11 and ISO / TC 163 / SC 3 / WG 10 are working on an international standard for vacuum insulation panels in the building and construction industry.

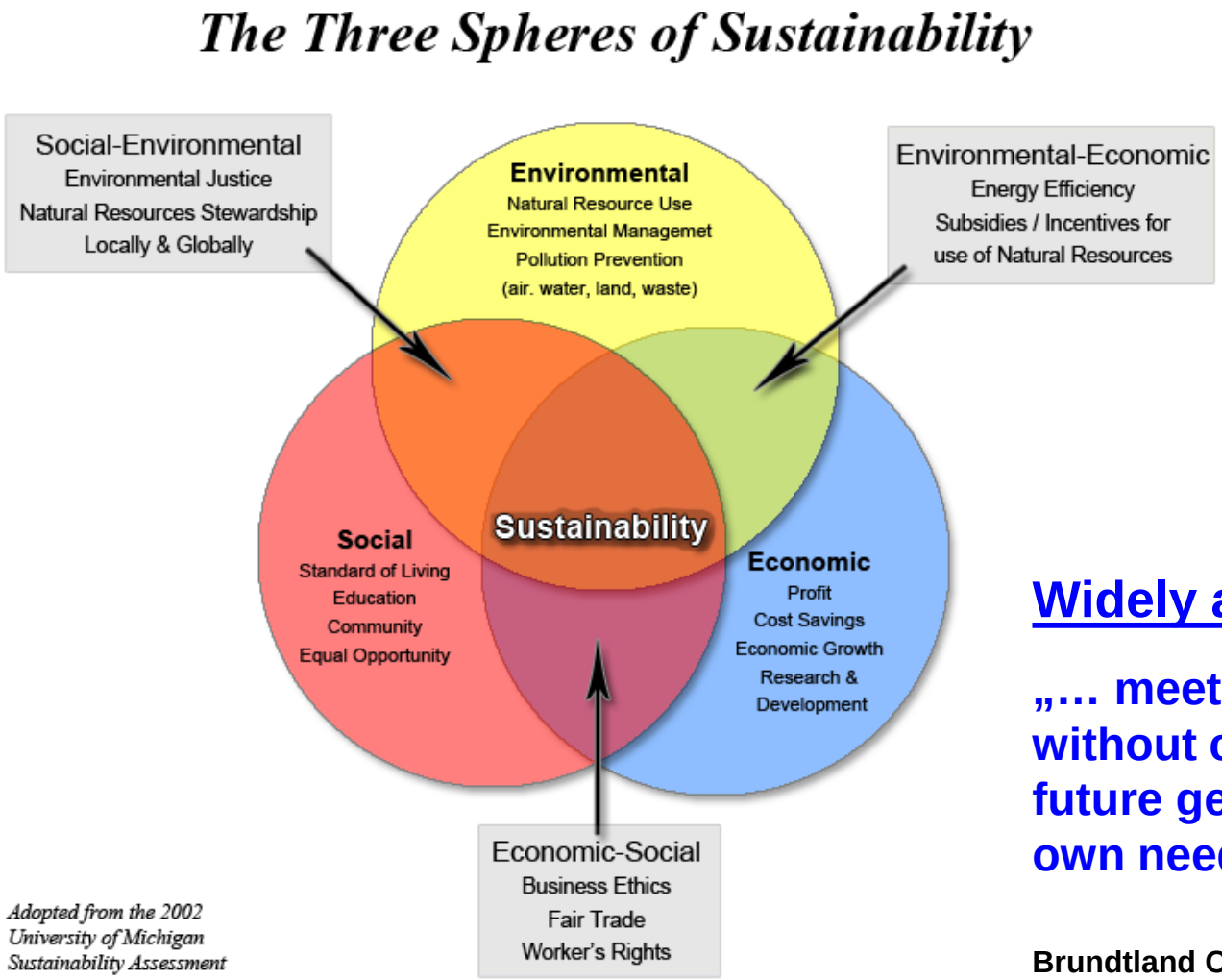
Thermal insulation products for buildings — Factory made Vacuum Insulation Panels (VIP) — Specification

Produits isolants thermiques pour le bâtiment — Produits manufacturés en laine vacuum isolation panel (VIP) — Spécification

Annex C
(normative)

Determination of the aged values of thermal resistance and thermal conductivity including thermal bridging

Sustainability – environmental product declaration (EPD)



Widely accepted definition:

„… meet the needs of the present without comprising the ability of future generations to meet their own needs“.

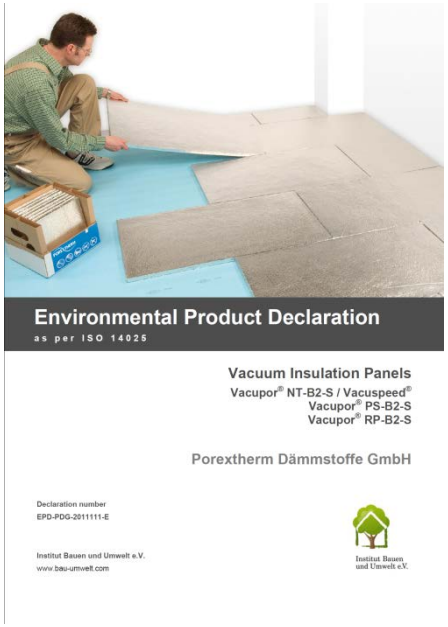
Brundtland Commission, 1987

Environmental Product Declaration according to ISO 14025

Vacuum Insulation Panels
Porextherm Dämmstoffe GmbH
Declaration number: EPD-PDG-2011111-E

Results of Life Cycle Assessment

Evaluation factor and unit per m² VIP



	Total
Primary energy deployment from resources (lower heating value) [MJ]	257.2
Primary energy deployment from regenerative resources (lower heating value) [MJ]	43.0
Global Warming Potential (GWP 100 years) [kg CO_2- equiv.]	15.4
Ozone Depletion Potential (ODP, catalytical) [kg R11 equiv.]	2.3E-06
Acidification Potential (AP) [kg SO_2 equiv.]	3.8E-02
Eutrification Potential (EP) [kg phosphate equiv.]	3.4E-03
Photochemical Ozone Creation Potential (POCP) [kg ethene equiv.]	3.0E-03

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Thank you for your attention !