Accelerated Ageing and Global Warming Potential of VIP Thermal Insulation

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Accelerating ageing tests

The primary objective was to define the theoretical base supporting measurements of accelerated testing and the connection between ageing and the service life of vacuum insulation panels (VIP).

Thermal load

Laboratory measurements were carried out on VIPs exposed to stress under high temperature in a laboratory oven.

Due to the non-reversible deformation of VIPs, over-exposure to excessively high thermal loads must be avoided during the procedure of accelerated ageing.

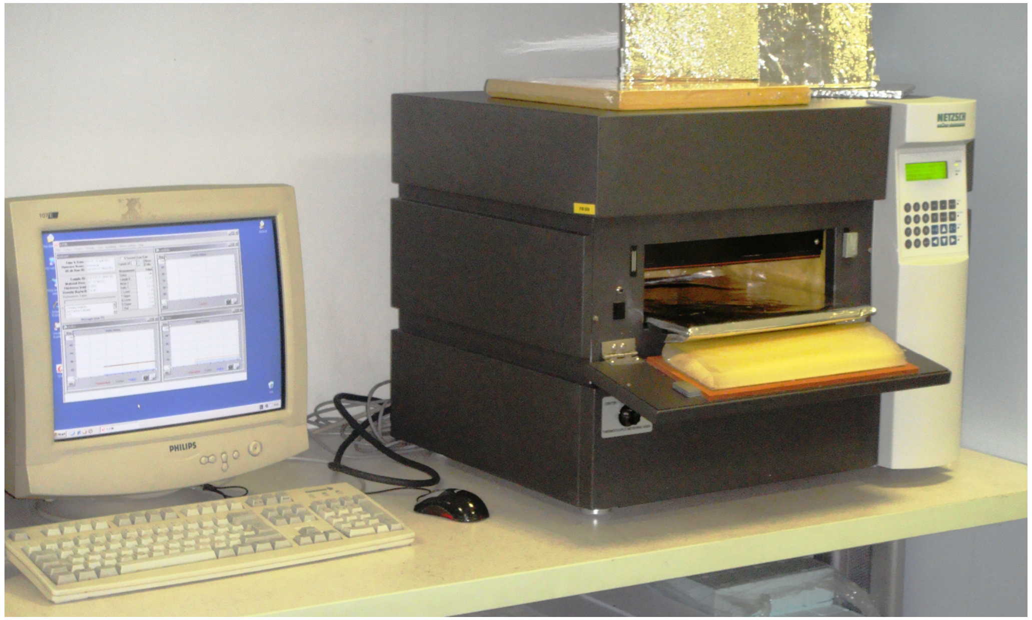
The following accelerated ageing temperatures were selected:

100°C, 90°C, 80°C, 70°C, and 60°C,

with time exposures from **half a day** up to **3 months** or, in some cases, even longer.

Thermal conductivity

lambda - λ **[mW/(m K)]**



The experimental methods were oriented to evaluating the rate of degradation of VIPs, i.e., to determine the <u>values of thermal conductivity</u> as a function of thermal loads.

It is believed that <u>temperature loads</u> have the primary impact on VIP failure and thus deserve detailed investigation.

Results and discussion of accelerating tests and determination of service life

It can be concluded that the thermal load to which the VIPs were exposed caused a degradation process that followed Arrhenius law.

The value of the activation energy is **Ea = 66,35 kJ/mol**

This value is used to evaluate the behaviour of the VIP products exposed to different temperatures, by interpolation within the test temperature interval at which accelerated ageing is performed or, more commonly, by extrapolation outside the test temperature interval.

Conclusions of accelerating tests and determination of service life

On the basis of assumptions in this study, the service life is the time until the thermal conductivity value is double the initial value of the VIP (i.e., increase of thermal conductivity by 100 %).

•**double** thermal conductivity after a period of **26.2** years

•thermal conductivity reached value **12** mW/(m K) after **48.1** years.

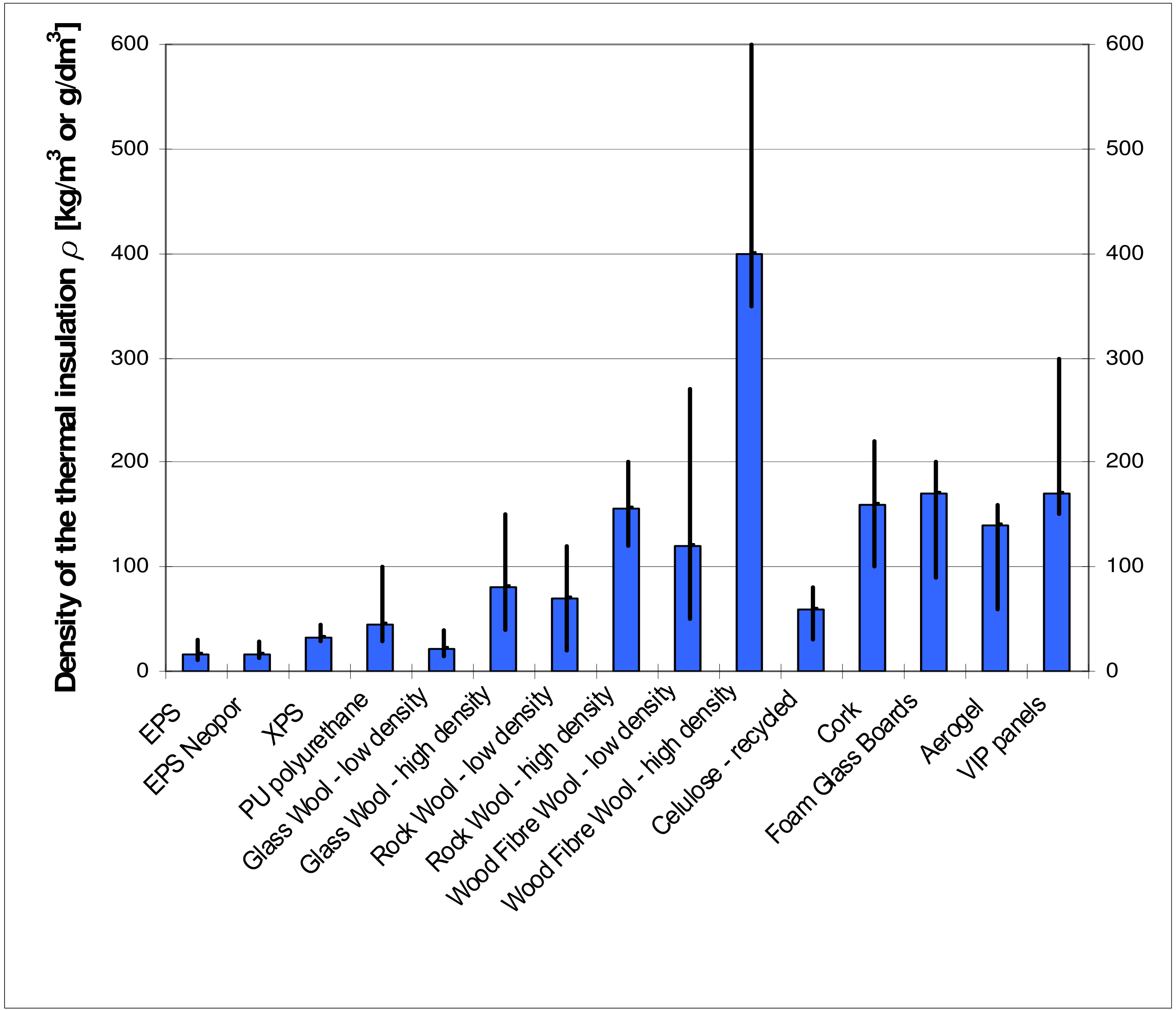
Based on these experiments it can be concluded that VIPs are a durable and high quality product, mainly in terms of maintaining an exceptional thermal insulation.

Carbon footprint - Global warming potential GWP

We have analysed carbon footprint of 15 different thermal insulation materials.

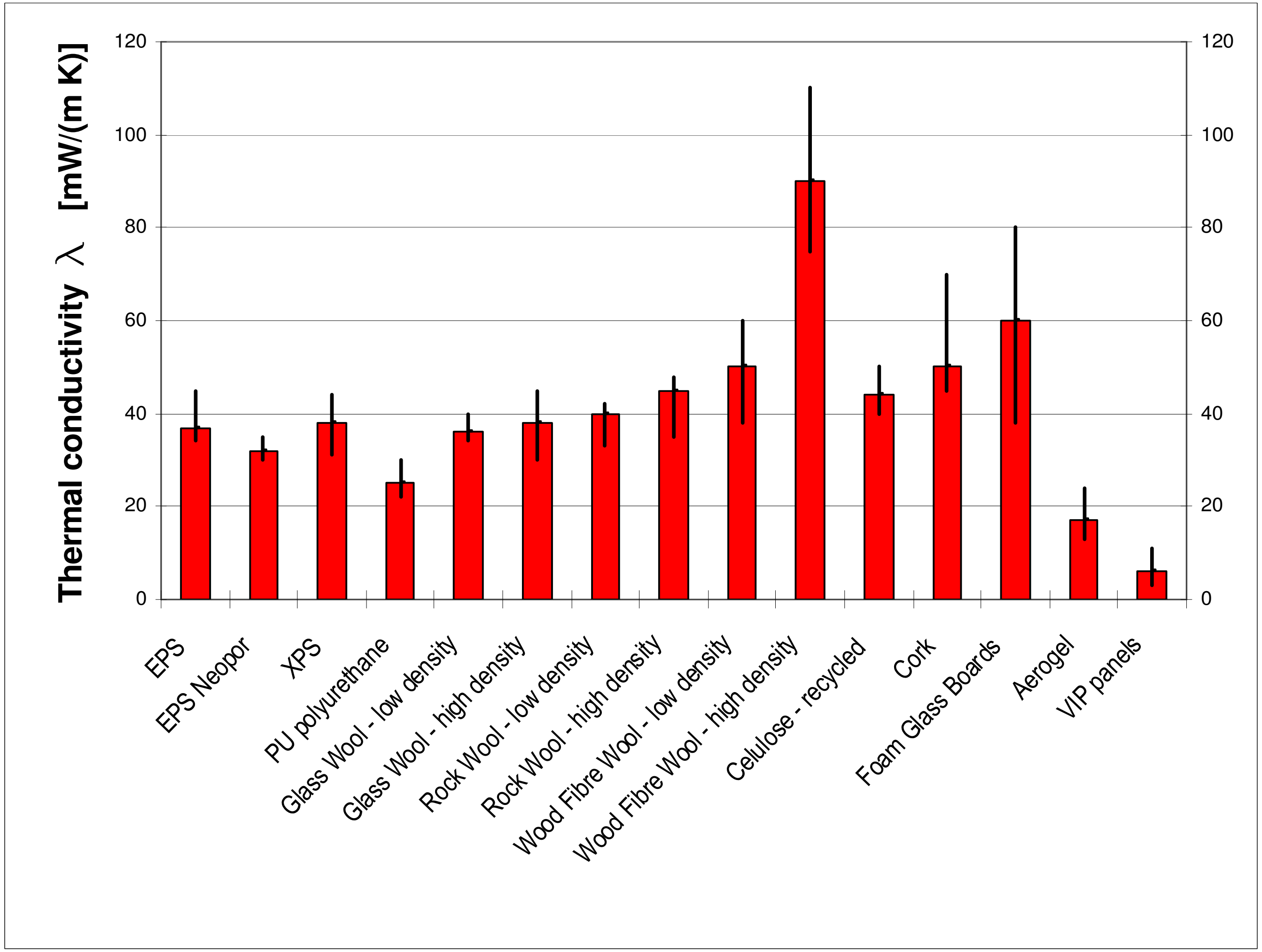
The evaluation and consideration of environmental impact **per unit weight** (expressed in kg CO_2-eq. per kilogram) of thermal insulation materials is **inappropriate** and can lead to misleading decisions.

Density of different thermal insulation materials ρ [kg/m^3 or g/dm^3]



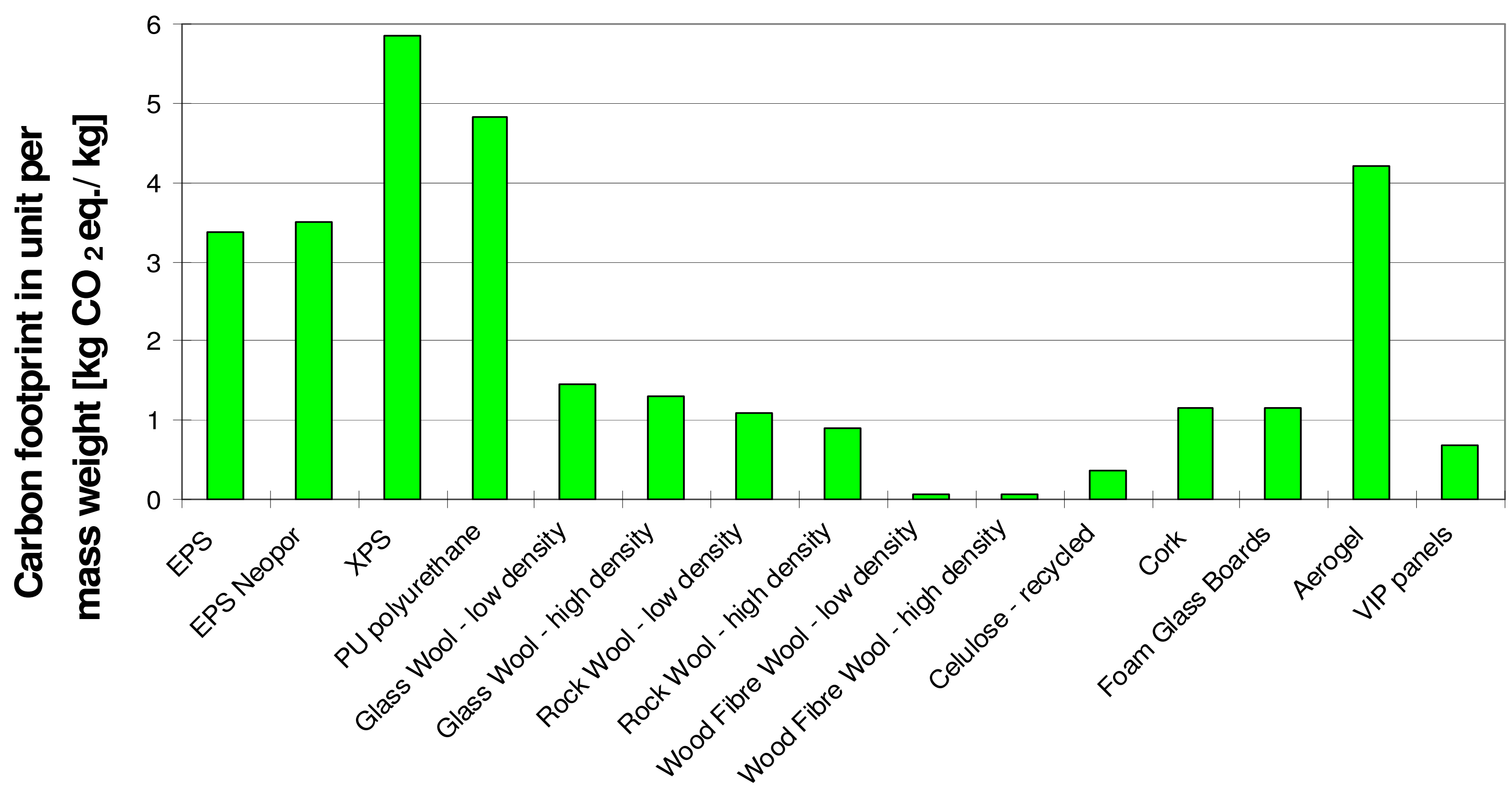
- **density** (ρ) varies from **16** kg/m^3 to **400** kg/m^3 - ratio of more than **1 : 25**

Thermal conductivity (λ) of thermal insulation materials

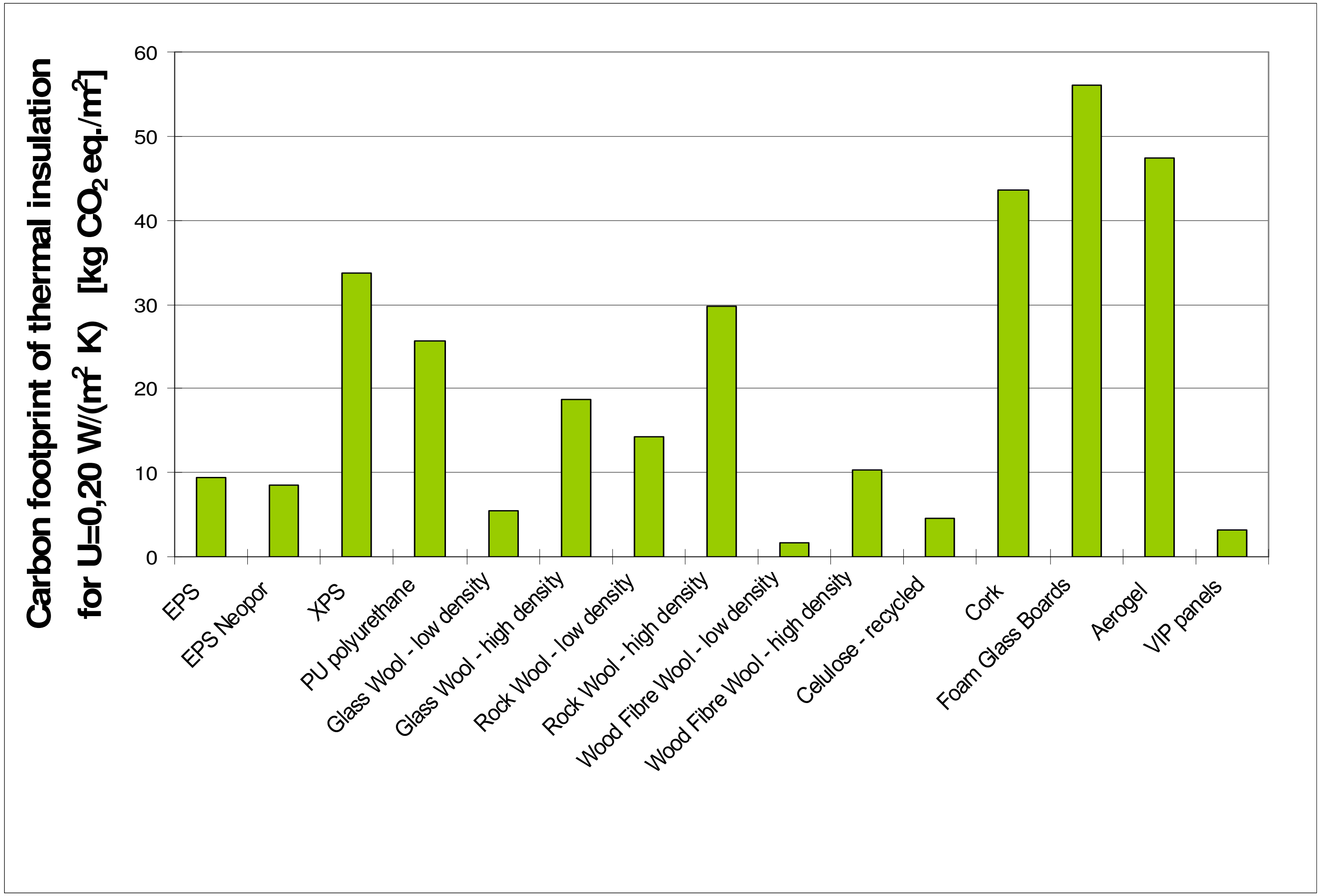


- **thermal conductivity** (λ) from **7** mW/(m K) to **90** mW/(m K)), - ratio of more than **1 : 12**.

Carbon footprint of different thermal insulation materials expressed <u>per kilogram</u> weight of the selected material



Carbon footprint of thermal insulation materials needed to achieve a value of thermal insulation of the building envelope U = 0.20 W / (m² K); presented per unit area of building envelope [m²]



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Environmental neutrality, i.e., the time in which, because of the implementation of thermal insulation materials in the external building envelope, the carbon footprint equals the carbon footprint of heat losses in the heating season between a current averagely insulated external building envelope and a newly insulated building envelope with U = 0.20 W/(m^2 K)

Thermal insulation material	GWP of thermal insulation for U=0,20 W/(m^2 K)	GWP of heat losses through averige external envelope	GWP of heat losses through insulated external envelope U=0,20 W/(m^2 K)	Difference of GWP between averige and insulated insulated external envelope U=0,20 W/(m^2 K)	1 year	2 years	3 years	4 years	5 years	10 years		
	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2	kg CO_2–eq./ m^2		
	GWP of thermal insualation	GWP ot existing building enve	GWP of new building envelope	difference	GWP of insulation for U-value 0,20 W/(m^2 K) and difference of heat losses throug averige existing external envelope and heat losses through insulated (U=0,20 W/(m^2 K)) external envelope							
	kg CO2 eq.	kg CO2 eq.	kg CO2 eq.	kg CO2 eq.	1	2	3	4	5	6	7	8
EPS	9,473	11,532	4,435	7,096	2,377	**-4,719**	**-11,815**	**-18,912**	**-26,008**	**-33,104**	**-40,201**	**-47,297**
EPS Neopor	8,484	11,532	4,435	7,096	1,388	**-5,708**	**-12,805**	**-19,901**	**-26,997**	**-34,094**	**-41,190**	**-48,286**
XPS	33,737	11,532	4,435	7,096	26,640	19,544	12,448	5,351	**-1,745**	**-8,841**	**-15,938**	**-23,034**
PU polyurethane	25,726	11,532	4,435	7,096	18,630	11,533	4,437	**-2,659**	**-9,756**	**-16,852**	**-23,948**	**-31,045**
Glass Wool - low densi	5,475	11,532	4,435	7,096	**-1,622**	**-8,718**	**-15,814**	**-22,911**	**-30,007**	**-37,103**	**-44,200**	**-51,296**
Glass Wool - high dens	18,711	11,532	4,435	7,096	11,614	4,518	**-2,578**	**-9,675**	**-16,771**	**-23,867**	**-30,964**	**-38,060**
Rock Wool - low densit	14,317	11,532	4,435	7,096	7,221	0,124	**-6,972**	**-14,068**	**-21,165**	**-28,261**	**-35,357**	**-42,454**
Rock Wool - high densi	29,721	11,532	4,435	7,096	22,624	15,528	8,432	1,335	**-5,761**	**-12,857**	**-19,954**	**-27,050**
Wood Wool - low densi	1,733	11,532	4,435	7,096	**-5,364**	**-12,460**	**-19,556**	**-26,652**	**-33,749**	**-40,845**	**-47,941**	**-55,038**
Wood Wool - high dens	10,397	11,532	4,435	7,096	3,301	**-3,796**	**-10,892**	**-17,988**	**-25,085**	**-32,181**	**-39,277**	**-46,374**
Celulose - recycled	4,562	11,532	4,435	7,096	**-2,534**	**-9,631**	**-16,727**	**-23,823**	**-30,919**	**-38,016**	**-45,112**	**-52,208**
Cork	43,557	11,532	4,435	7,096	36,461	29,364	22,268	15,172	8,075	0,979	**-6,117**	**-13,214**
Foam Glass	56,018	11,532	4,435	7,096	48,922	41,826	34,729	27,633	20,537	13,440	6,344	**-0,752**
Aerogel	47,326	11,532	4,435	7,096	40,229	33,133	26,037	18,940	11,844	4,748	**-2,349**	**-9,445**
VIP panels	3,255	11,532	4,435	7,096	**-3,841**	**-10,938**	**-18,034**	**-25,130**	**-32,227**	**-39,323**	**-46,419**	**-53,516**

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Environmental neutrality

- smallest impact: low density Wood wool - environmental neutrality after **0,57** years
- VIPs - environmental neutrality after **0,65** heating season
- EPS - environmental neutrality after **1,33** heating season
- highest impact: foam glass - environmental neutrality after **7,89** heating seasons
- **1/2** of insulations reached environmental neutrality before **2nd** heating season
- **2/3** of insulations reached environmental neutrality before **4th** heating season

Conclusions and outlook

The analysis and comparison of the carbon footprint of various thermal insulations of an external building envelope showed that VIPs have a surprisingly small environmental impact, primarily because of their extremely low thermal conductivity (λ).

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many thanks for your attention !