The South African Institute of Refrigeration and Air Conditioning

FRIGAIR
EXHIBITION 2025

Energy efficiency in Insulated structures

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SAIRAC

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Energy efficiency in insulated structures

Topics

1. Definition
2. Terminology
3. Standard Density versus High Density
4. Cost Difference of Insulation Density
5. Insulation Material Types
6. Insulation affecting Energy Cost

SAIRAC

Energy efficiency in insulated structures

Topics

Energy Efficiency in Insulated Cold Stores
Thermal Envelope

Energy efficiency in insulated structures

Definition

insulation noun

in·su·la·tion

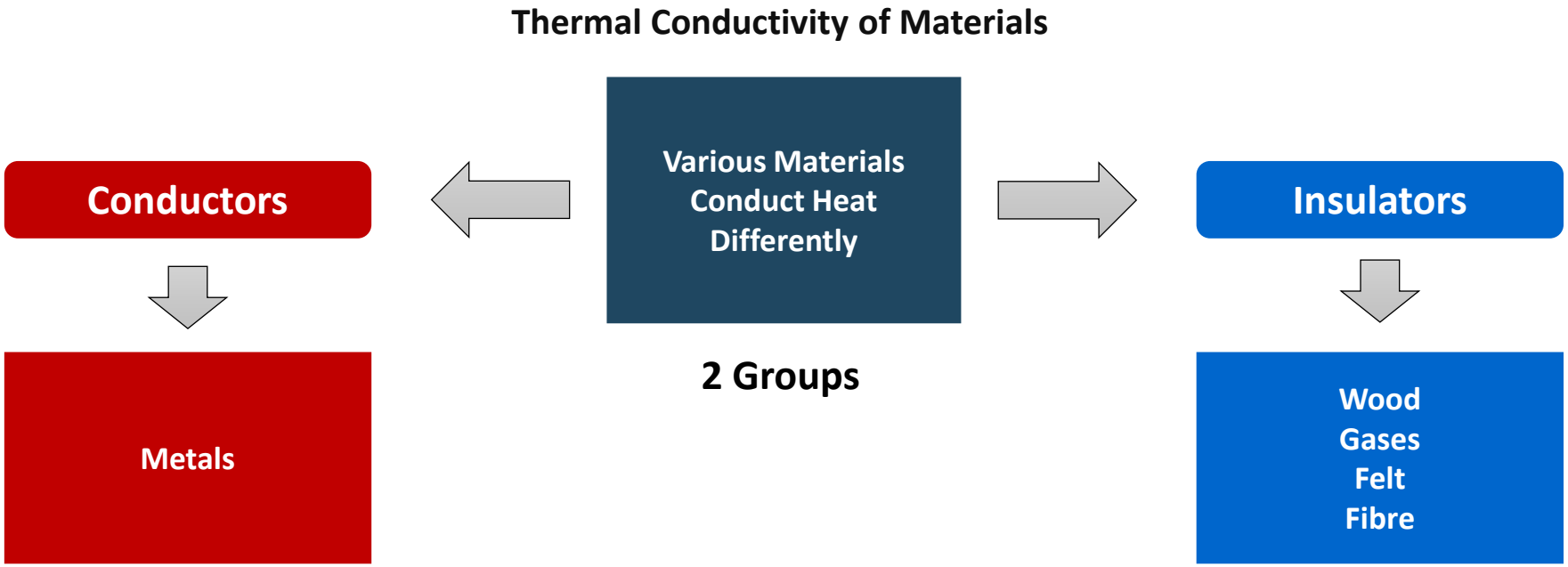
Definition of *insulation*

1 : material used in insulating
2 a : the state of being insulated
b : the action of insulating

Source: merriam-webster dictionary

Energy efficiency in insulated structures

Definition



Energy efficiency in insulated structures

Terminology

1. **Standard Density versus High Density**
2. **K-Value**
3. **C-Value**
4. **R-Value**
5. **U-Value**

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Standard Density versus High Density

How does one define **Standard Density** or **High Density**

This depends on one's interpretation, or what the insulation manufacturer classifies their density as.

Example: Expanded Polystyrene

15DV or 15 kg/m3 ⟹ Standard Density

20DV or 20 kg/m3 ⟹ High Density

30DV or 30 kg/m3 ⟹ Extra High Density

What does the letters DV mean

For Example: 15DV

15D ⟹ 15 kg/m3 Density

V ⟹ Virgin-Grade

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K-Value: Thermal Conductivity

What is the K-Value in insulation?

- The K factor of insulation represents the material's thermal conductivity or ability to conduct heat.
- Usually, insulation materials have a K Factor of less than one.
- The lower the K factor, the better the insulation.

K-value is simply shorthand for thermal conductivity. (not to be confused with Kelvin)

The ASTM Standard C168, defines the term as follows:

Thermal conductivity, n: the time rate of steady state heat flow through a unit area of a homogeneous material induced by a unit temperature gradient in a direction perpendicular to that unit area.

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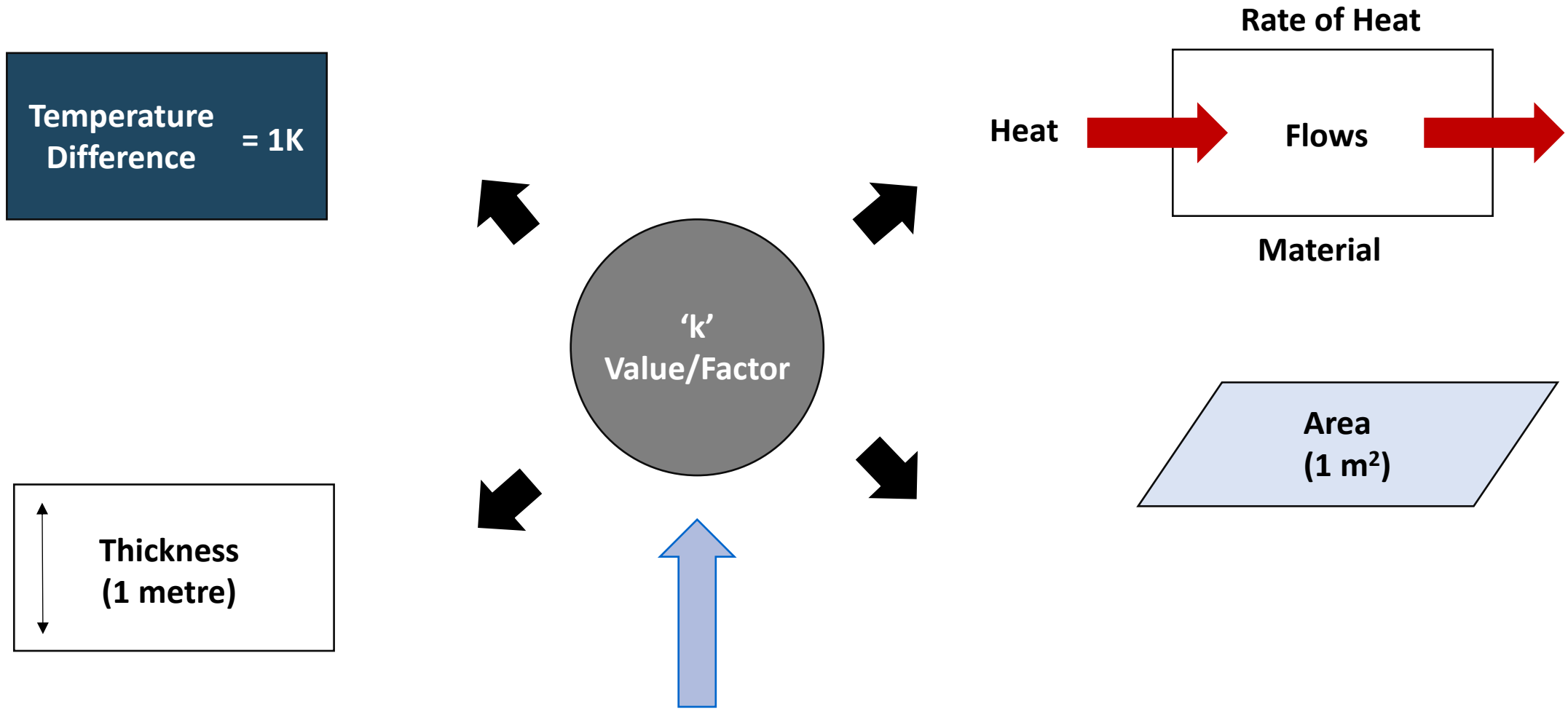
K-Value: Thermal Conductivity



Lower 'k' Value/Factor = Better Insulation

Energy efficiency in insulated structures

C-Value: Thermal Conductance

What is the **C-Value** of the insulation

The **C-Value** is simply shorthand for thermal conductance.

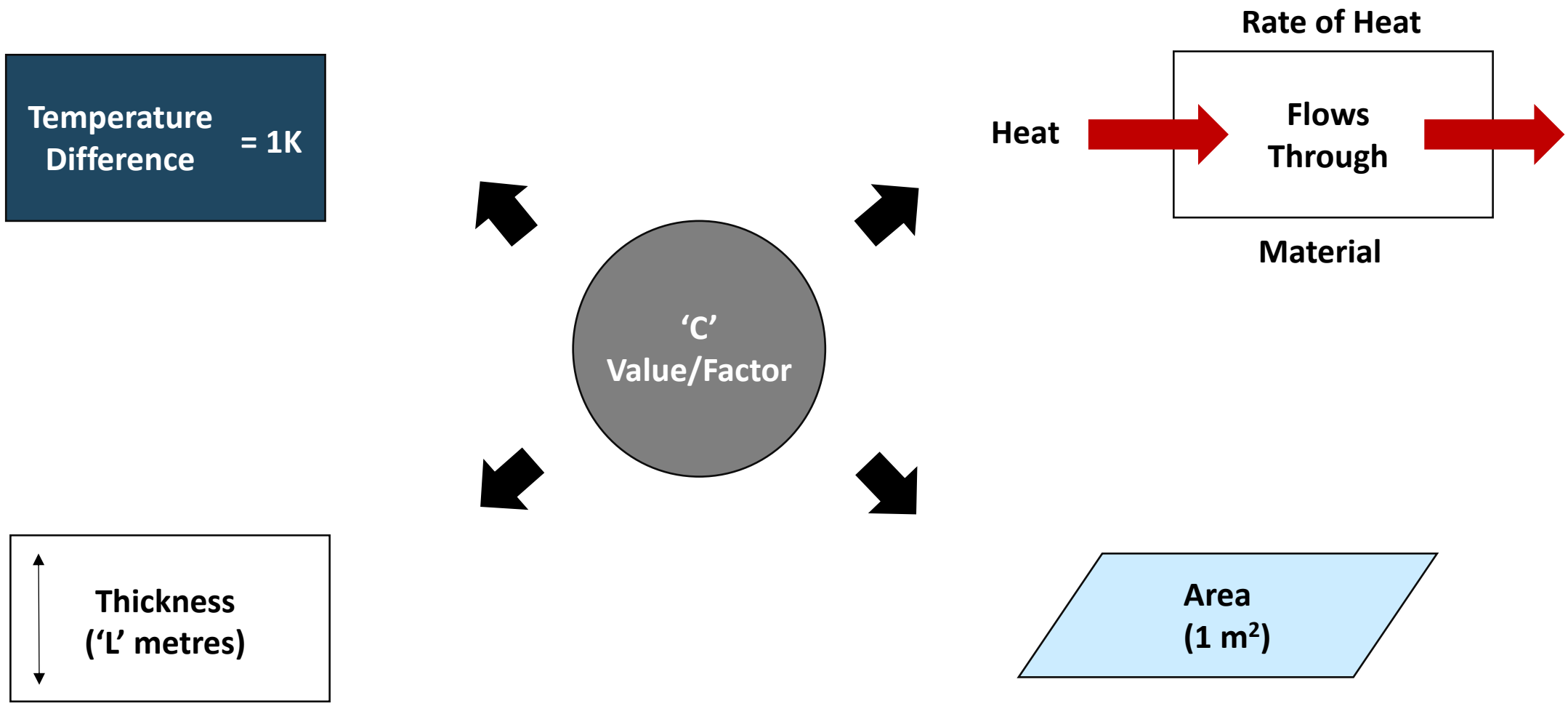
The **C-Value** depends on the thickness of the material; **K-Value** generally does not depend on thickness

The ASTM Standard C168, defines the term as follows:

Conductance, thermal, n: the time rate of steady state heat flow through a unit area of a material or construction induced by a unit temperature difference between the body surfaces.

Energy efficiency in insulated structures

C-Value: Thermal Conductance



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R-Value: Thermal Resistance

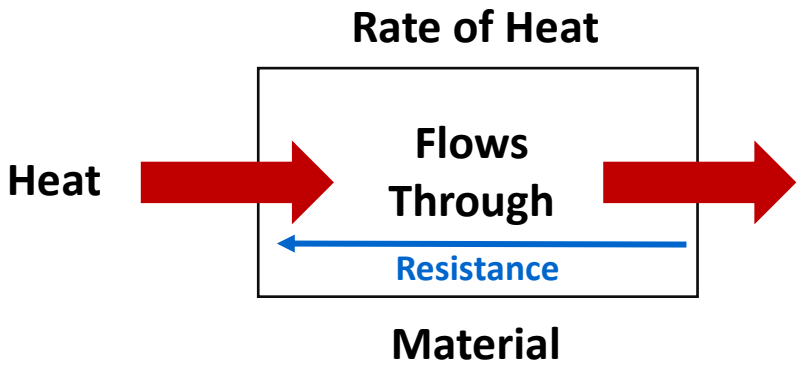
What is the **R-Value** of the insulation

Typically, this term is used to describe the labeled performance rating of insulation

Its official designation is thermal resistance.

The ASTM Standard C168, defines the term as follows

Resistance, thermal, n: the quantity determined by the temperature difference, at steady state, between two defined surfaces of a material or construction that induces a unit heat flow through a unit area.



High ‘R’ Value/Factor = Better Insulation

Energy efficiency in insulated structures

U-Value: Overall Coefficient of Heat Transfer

What is the **U-Value** of the insulation

The is **U-Value**, known officially as thermal transmittance.

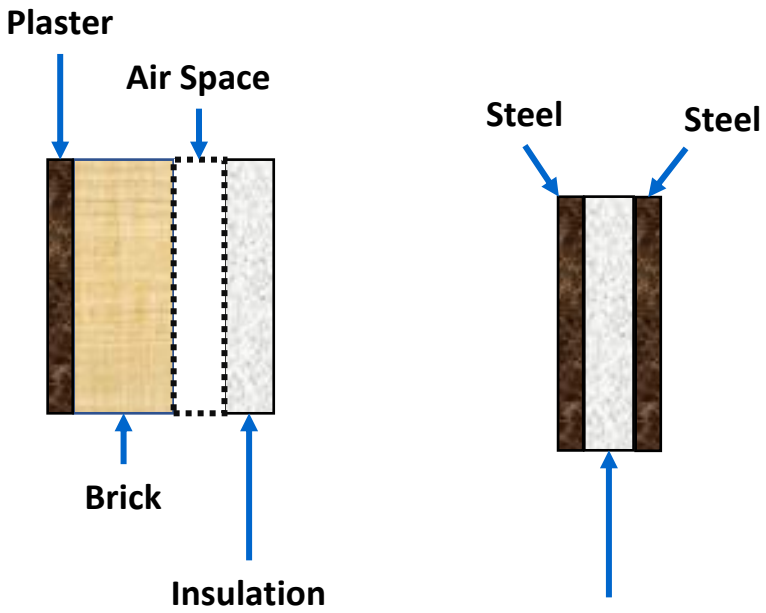
This is more of an engineering term used to designate the thermal performance of a system of materials as opposed to a homogeneous material.

The ASTM Standard C168, defines the term as follows

Transmittance, thermal, n: the heat transmission in unit time through unit area of a material construction and the boundary air films, induced by unit temperature difference between the environments on each side.

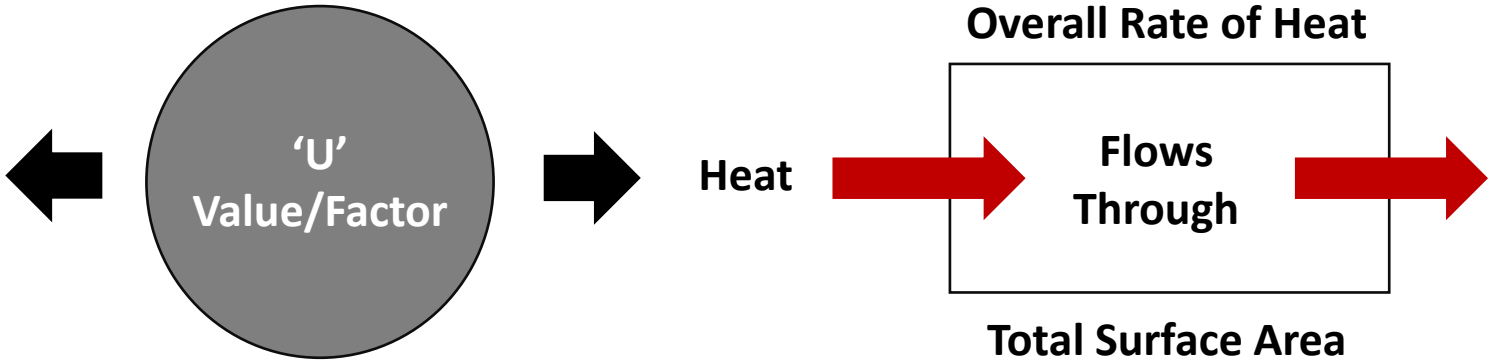
Energy efficiency in insulated structures

U-Value: Overall Coefficient of Heat Transfer



Compound Structure

Compound Structure



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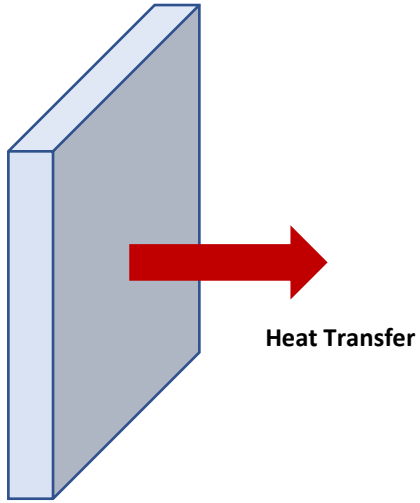
Ambient or Surrounding Air Temperature



Room Temperature

Ceilings | **Walls** | **Floor**

Principle of Heat Transfer

Energy efficiency in insulated structures

Insulation Material Types

1. **Expanded Polystyrene (EPS)**
2. **Extruded Polystyrene (XPS)**
3. **Rigid and Foam Injection Polyurethane (PUR) / Polyisocyanurate (PIR)**
4. **Mineral Wool**
5. **Hybrid Insulation**

Energy efficiency in insulated structures

Insulation Materials: Expanded Polystyrene (EPS)

Definition of Expanded Polystyrene (EPS)

Expanded Polystyrene (EPS) is a lightweight cellular plastic material consisting of small hollow spherical balls. It is this closed cellular construction that gives EPS its remarkable characteristics.

EPS is produced in a wide range of densities providing a varying range of physical properties.

These are matched to the various applications where the material is used to optimise its performance and strength.

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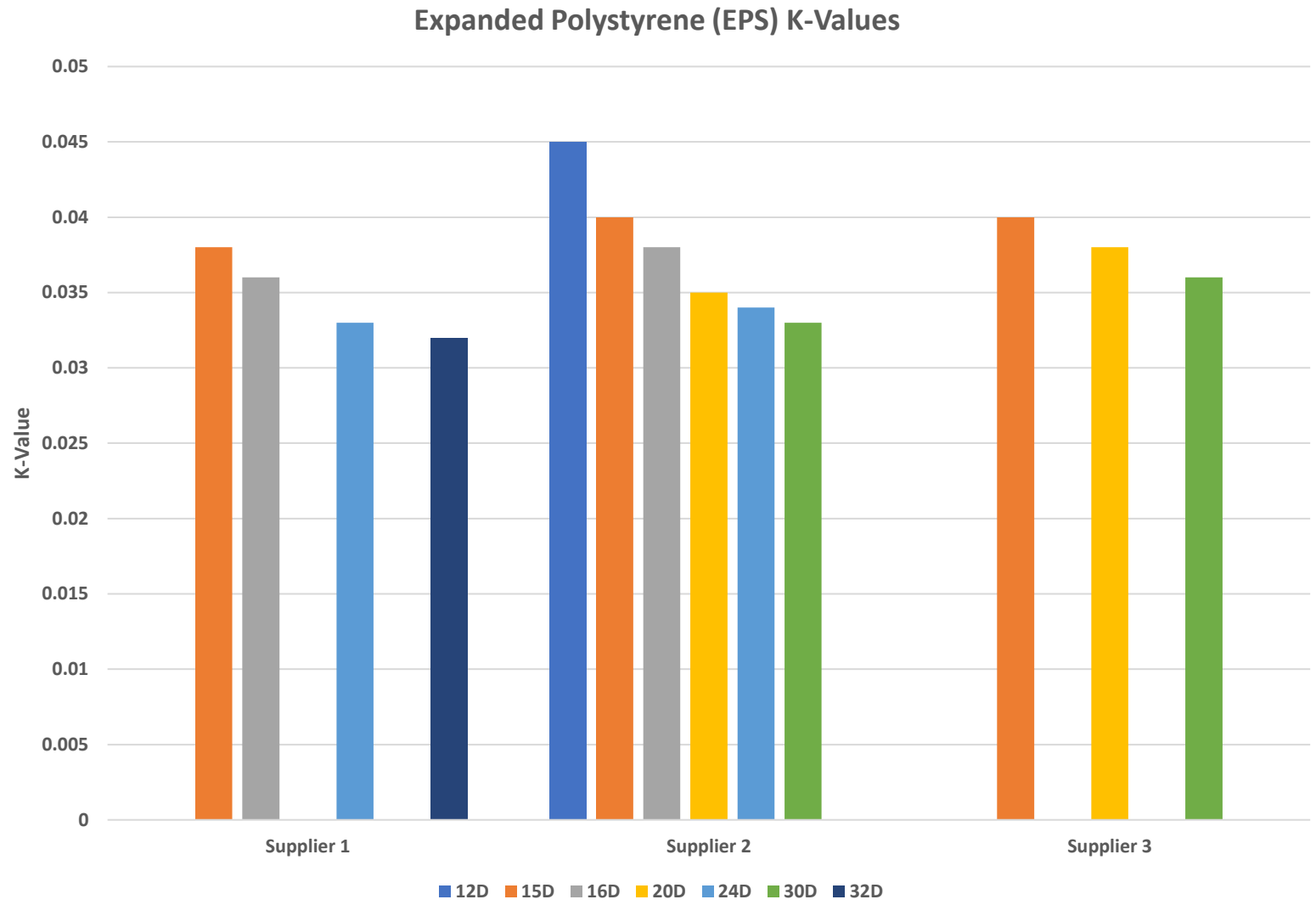
Insulation Material: Expanded Polystyrene (EPS) Densities and K-Values



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Insulation Materials: Rigid and Foam Injected Polyurethane (PUR) / Rigid Polyisocyanurate (PIR)

Definition of Rigid and Foam Injected Polyurethane (PUR) / Rigid Polyisocyanurate (PIR)

Polyurethane is substantially made of two raw materials:

- isocyanate and
- polyol,

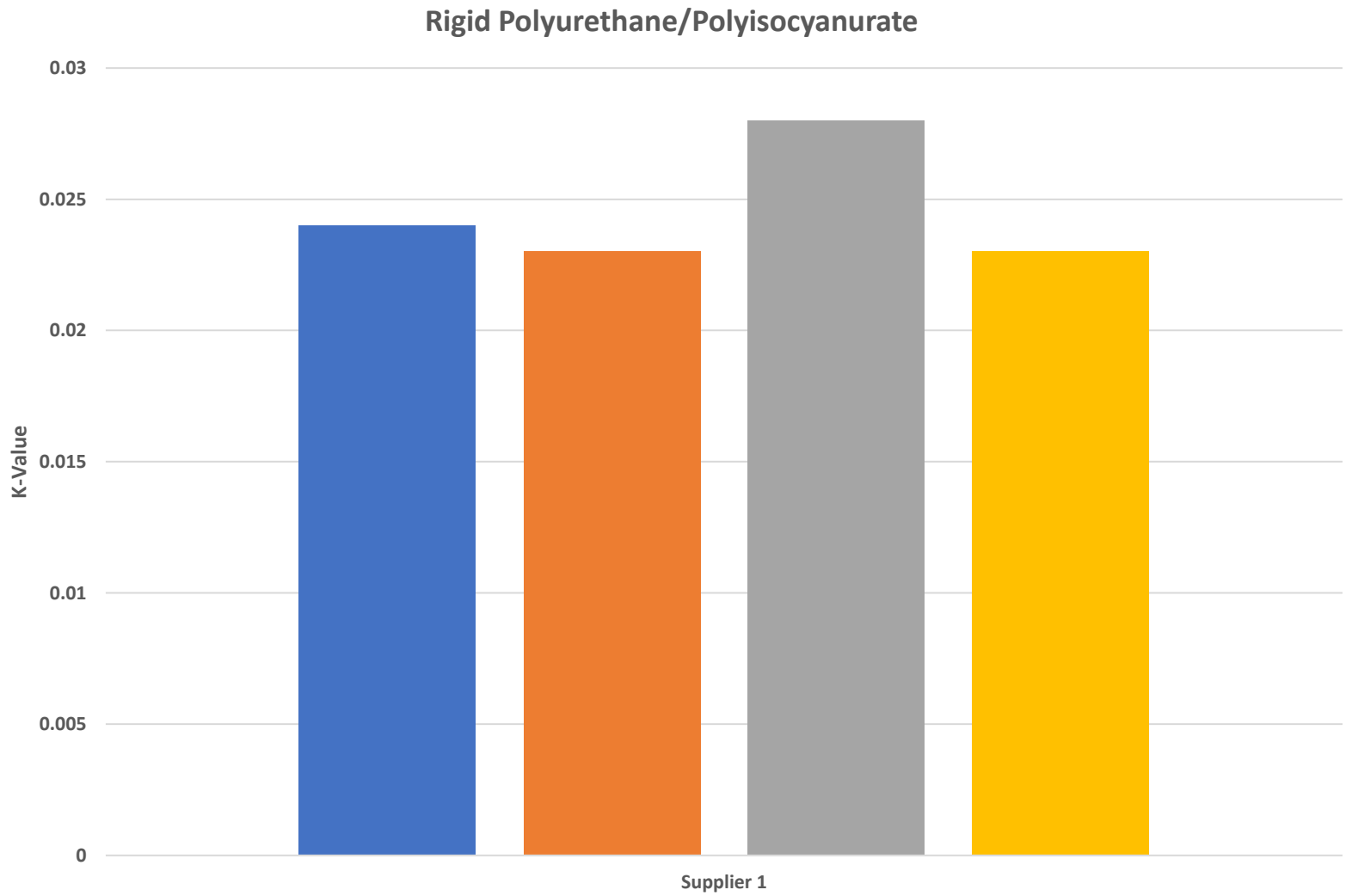
This is derived from crude oil. After mixing those two process-ready liquid components of the system with various auxiliary materials, (namely catalysts, foaming agents, and stabilizers), a chemical reaction starts.

Polyurethanes are in the class of compounds called 'reaction polymers' and are produced by mixing two or more isocyanates' groups in the presence of a catalyst.

The properties of polyurethane can be influenced by the types of isocyanates and the polyols used to make them. These can range from tough or rigid versions, through to long, flexible segments; with different characteristics being controlled by the polyol using cross-links - the term given to a bond that links one polymer chain to another - with long chains and intermediate cross-linking making a polymer useful for foam

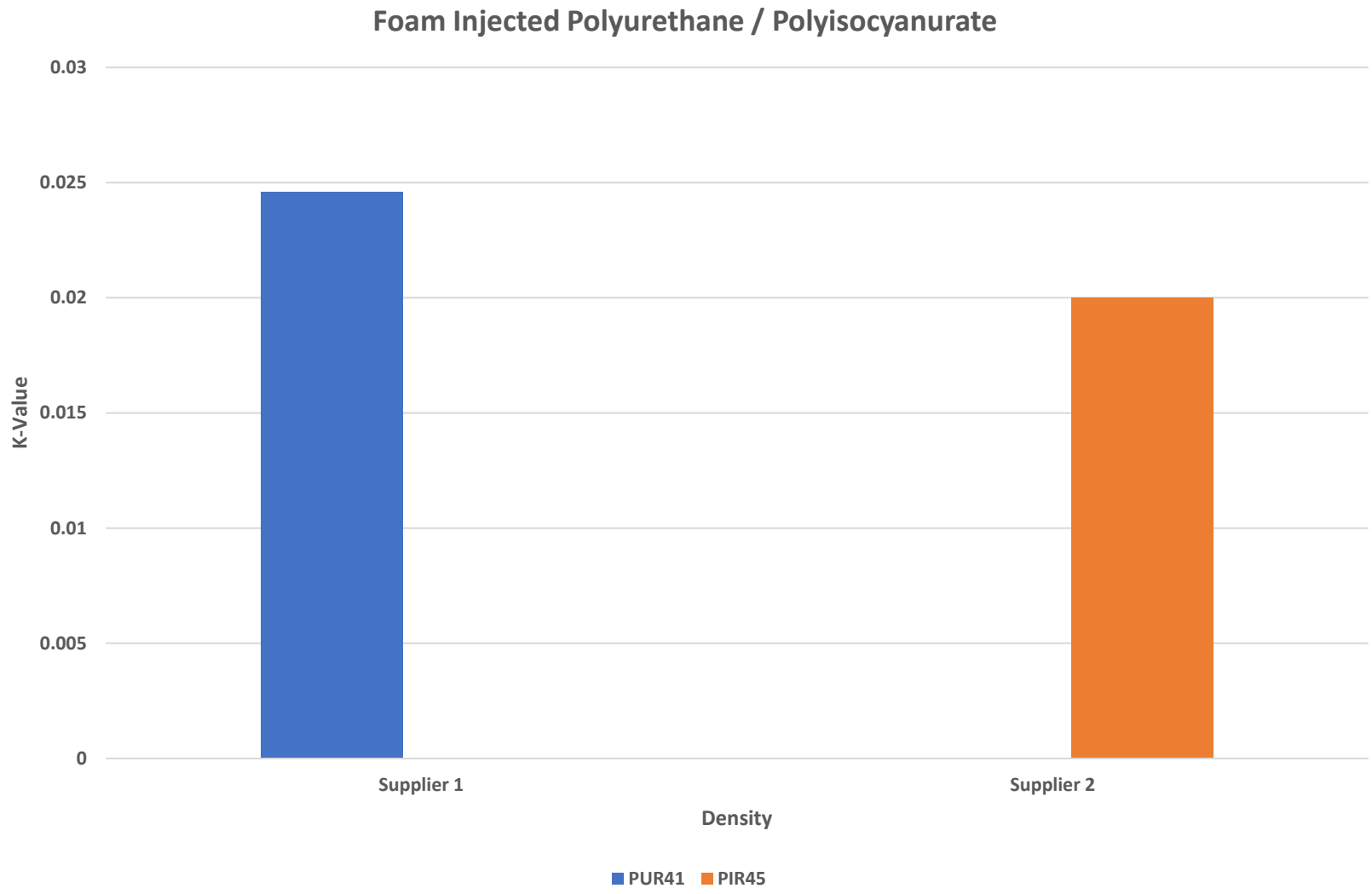
Energy efficiency in insulated structures

Insulation Material: Rigid Polyurethane (PUR) / Rigid Polyisocyanurate (PIR) Densities and K-Values



Energy efficiency in insulated structures

Insulation Material: Foam injected Polyurethane (PUR) / Foam injected Polyisocyanurate (PIR) Densities and K-Values



Technical Talk - ENERGY EFFICIENCY IN INSULATED COLD STORE STRUCTURES

Definition of Mineral Wool

Mineral wool is any fibrous material formed by spinning or drawing molten mineral or rock materials such as slag and ceramics.

Applications of mineral wool include thermal insulation, filtration, soundproofing, and hydroponic growth medium.

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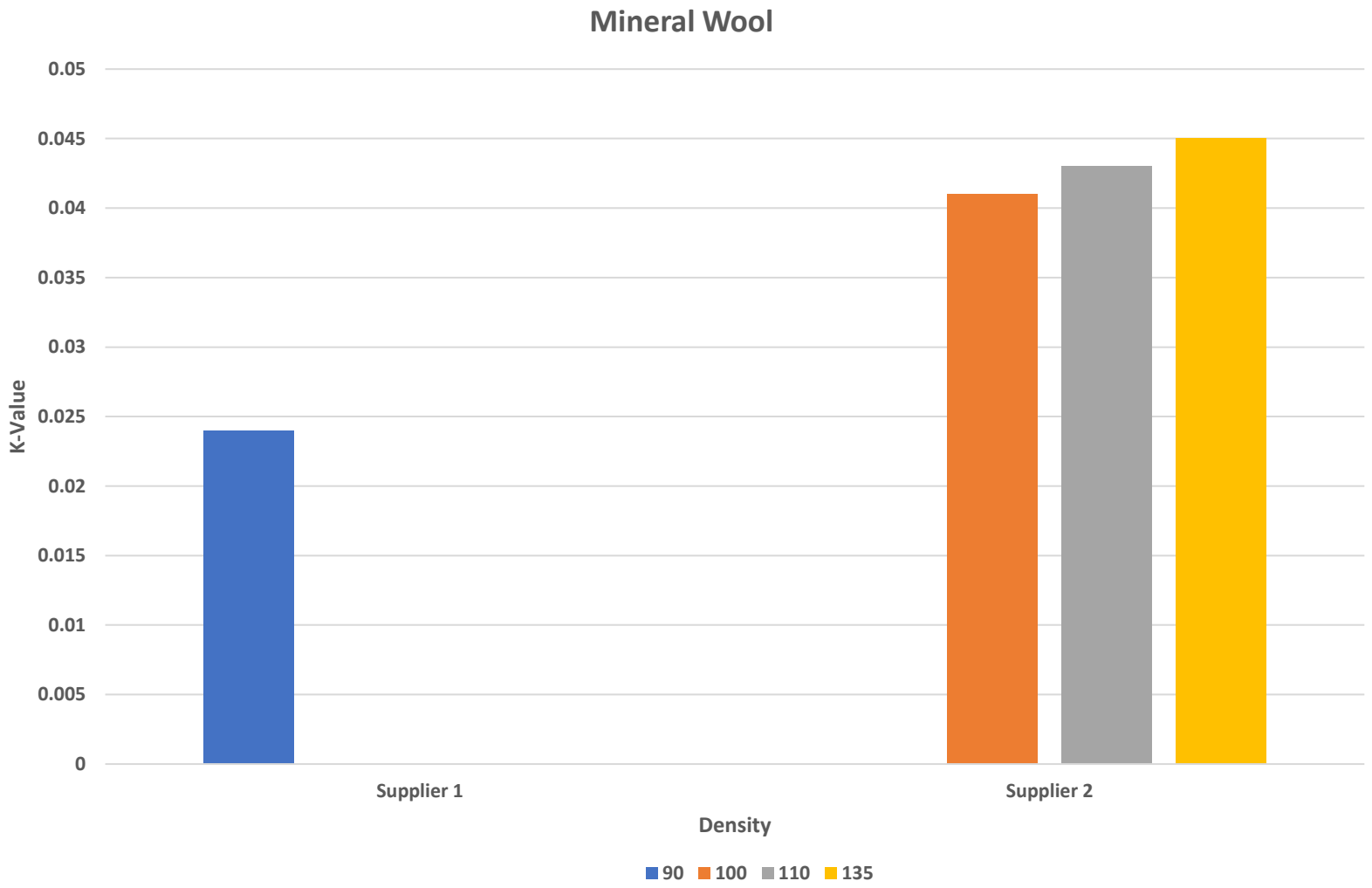
Insulation Material: Mineral Wool Densities and K-Values



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Insulation Material: Hybrid Insulation

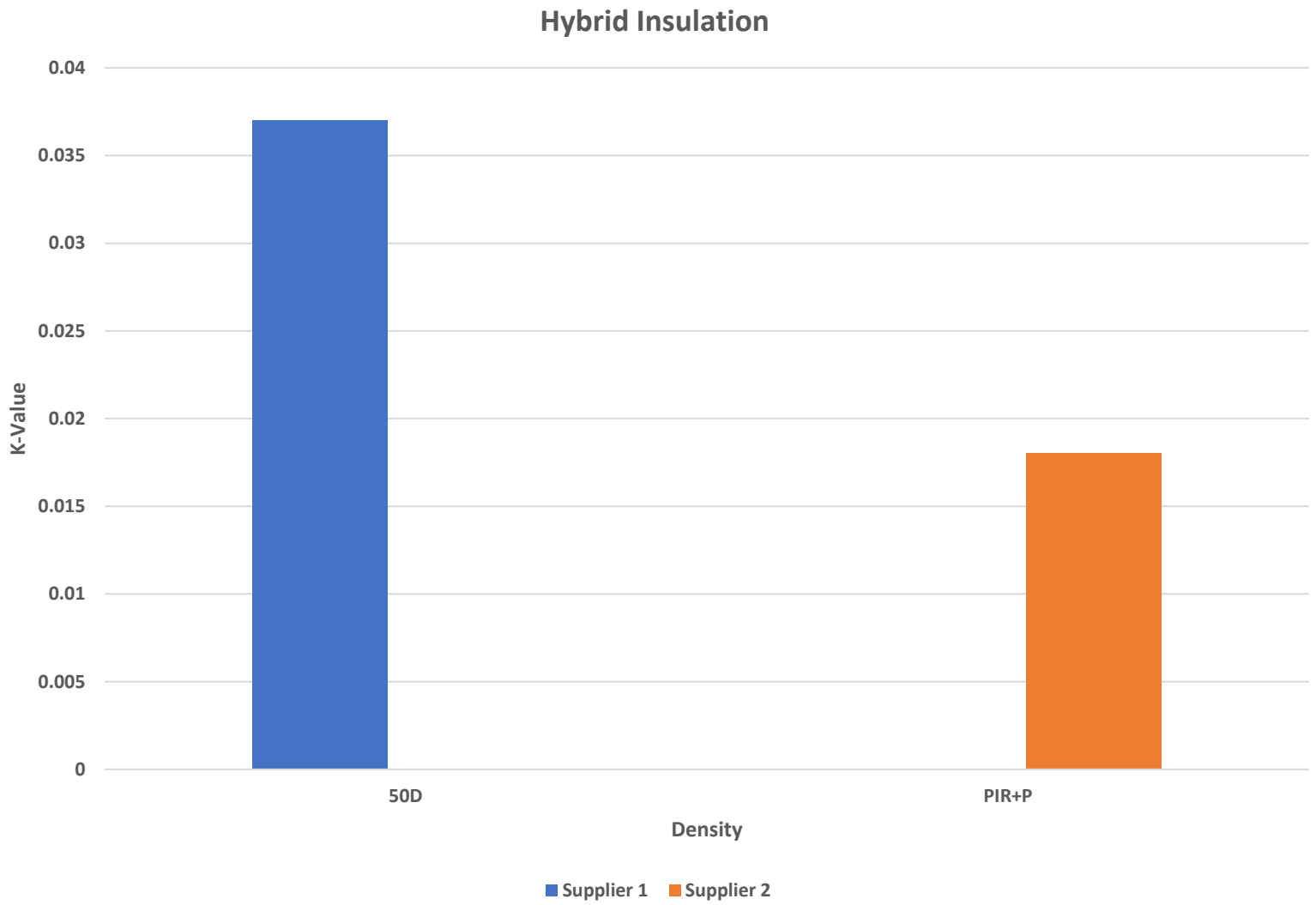
Definition of Hybrid Insulation

Hybrid insulation systems –These combine two types of insulation to maximize the value of each material.

It is a cost-effective way to achieve lower insulation **K-Value** and a higher **R-value**

Energy efficiency in insulated structures

Insulation Material: Hybrid Insulation Densities and K-Values



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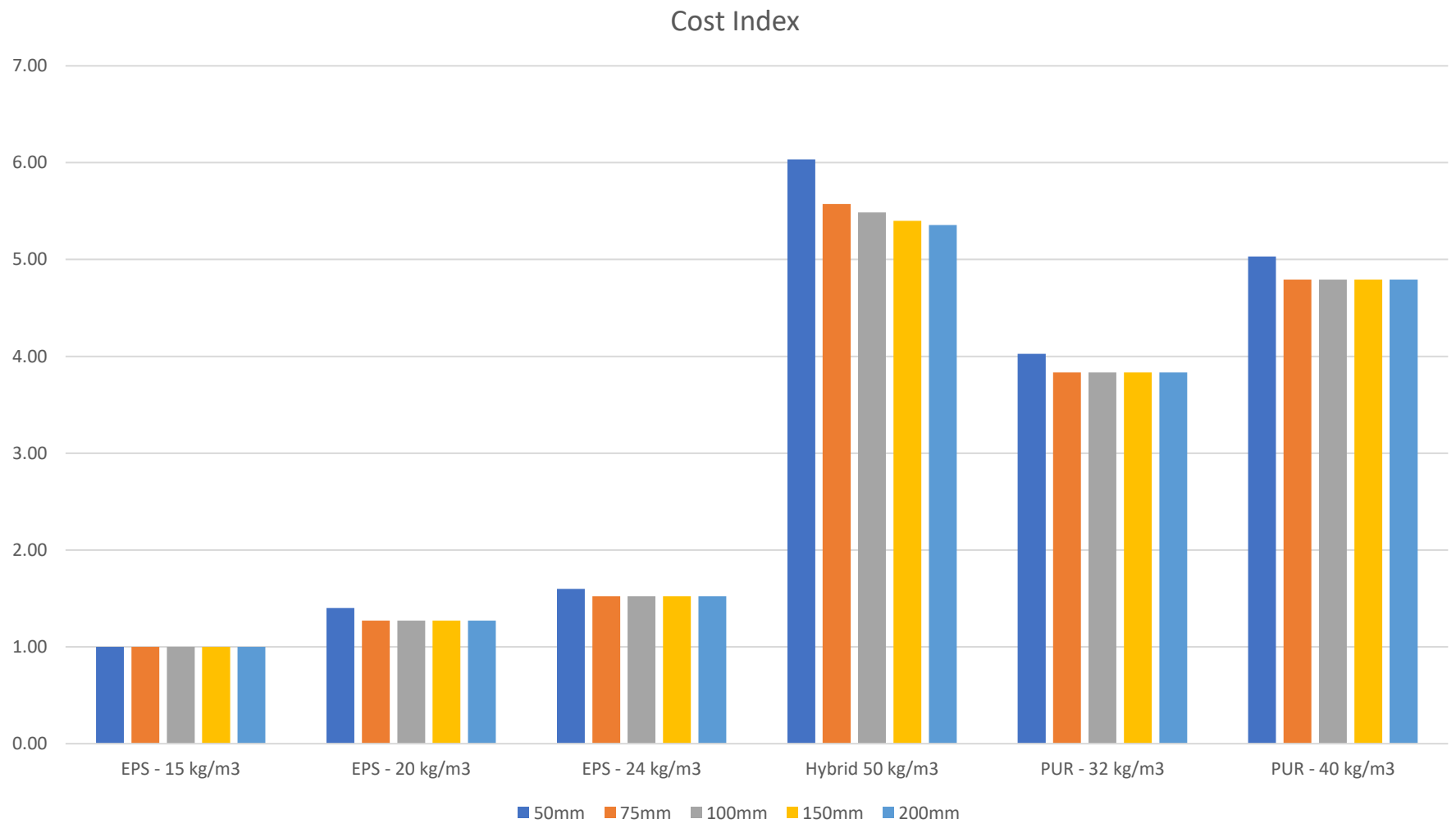
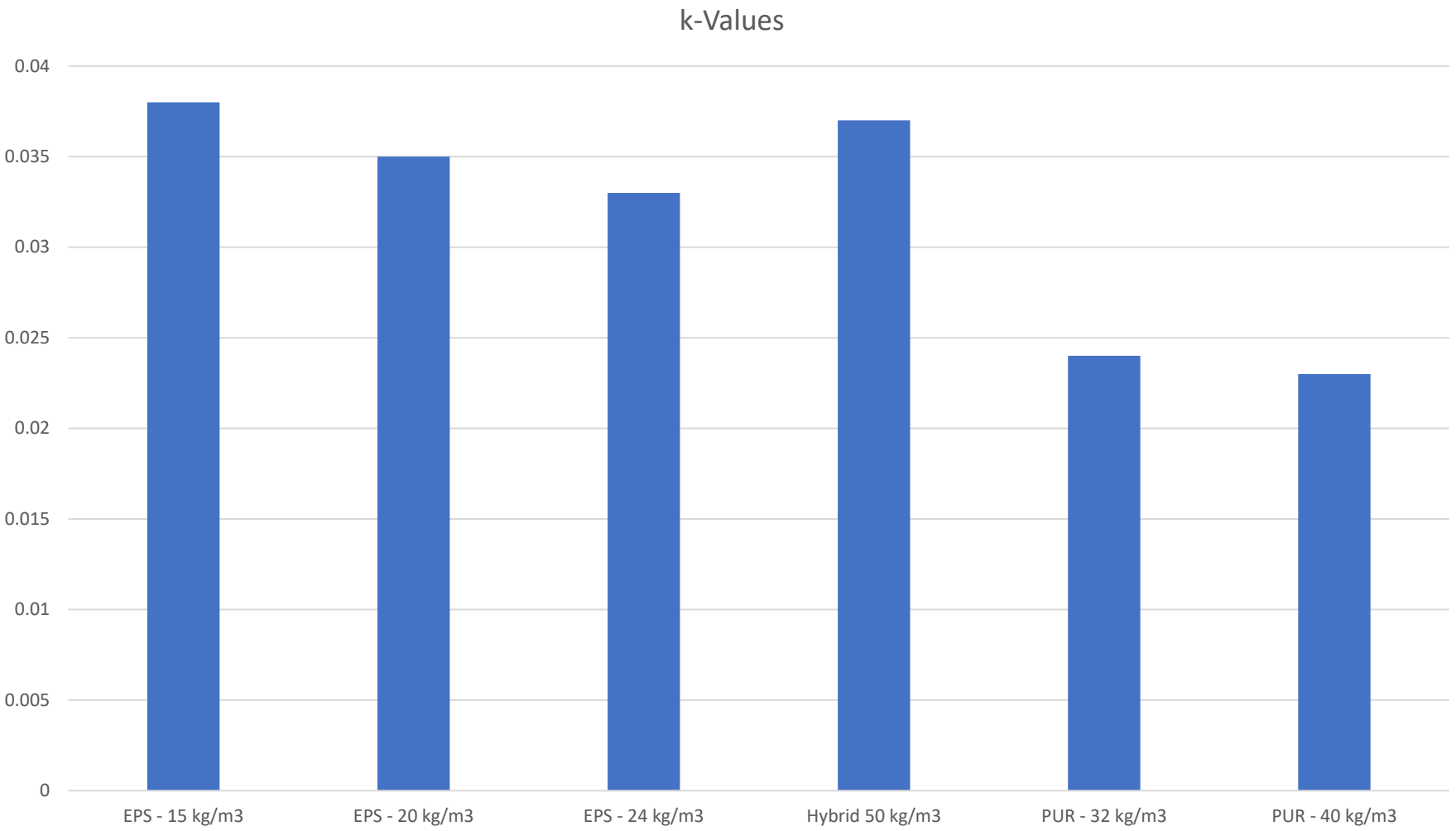
Cost Index of Insulation Density



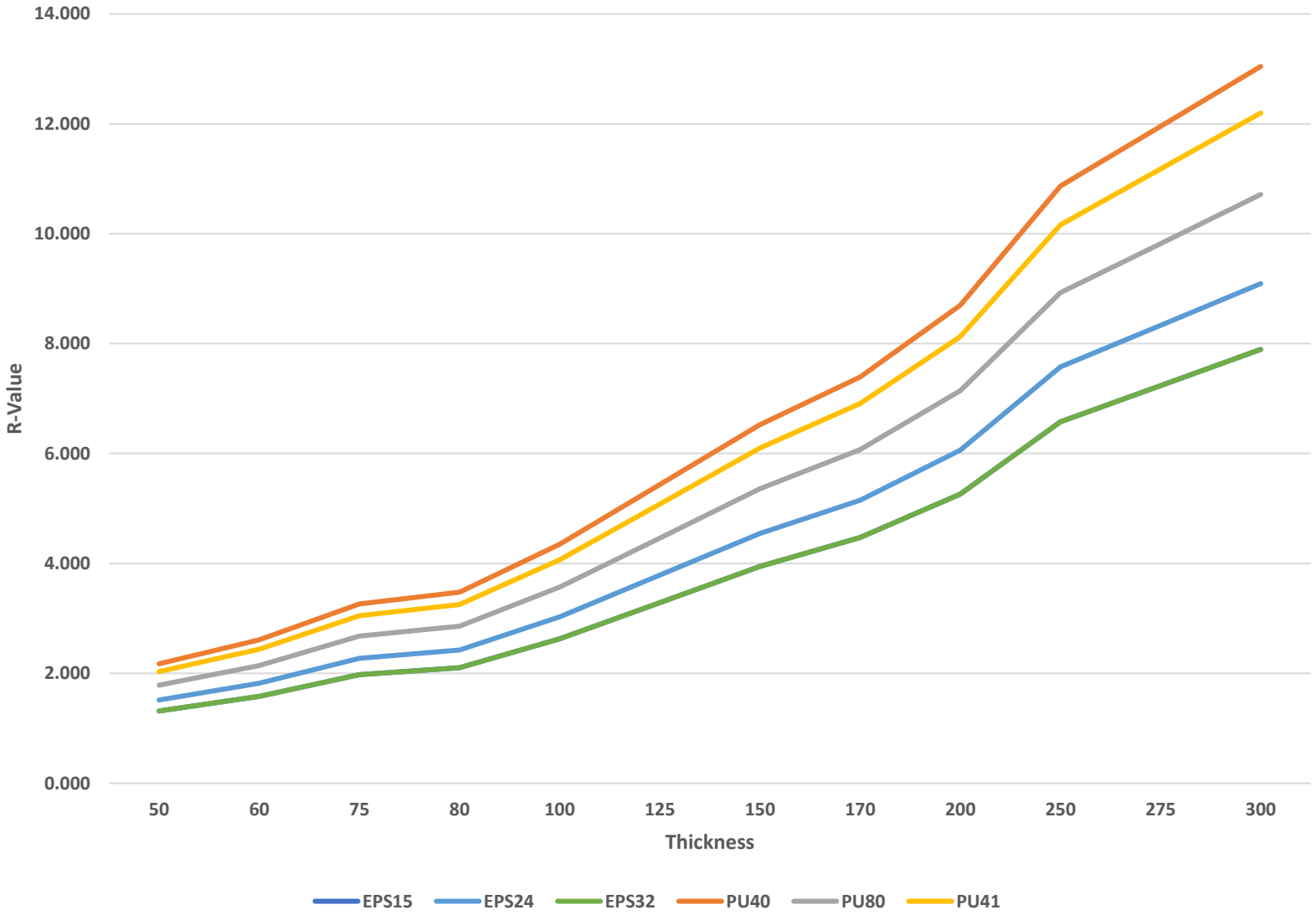
Energy efficiency in insulated structures

Insulation Materials: Comparison of K-Values



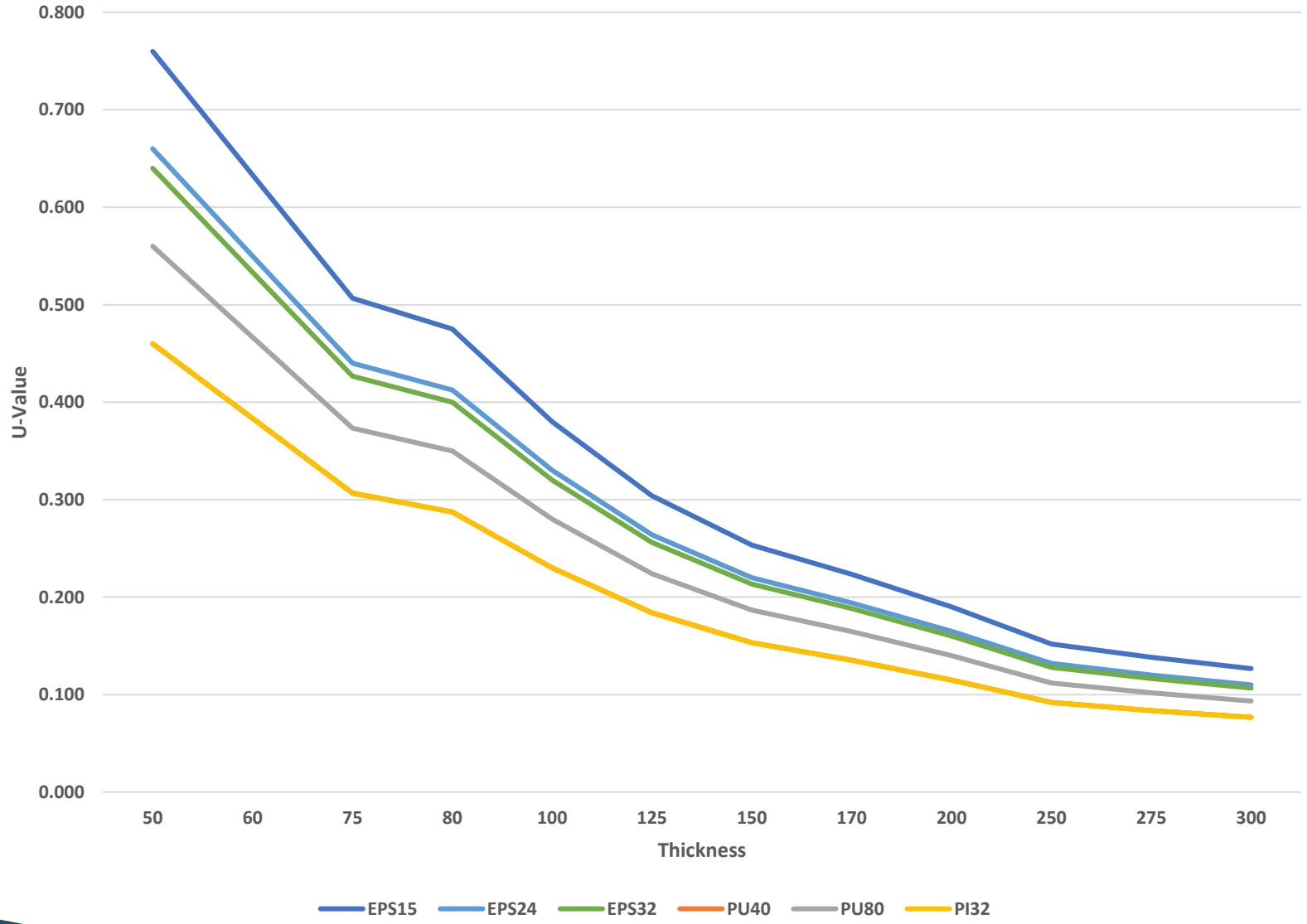
Energy efficiency in insulated structures

Insulation Materials: Comparison of R-Values



Energy efficiency in insulated structures

Insulation Materials: Comparison of U-Values



Energy efficiency in insulated structures

Insulation Materials: Table of U and R Values

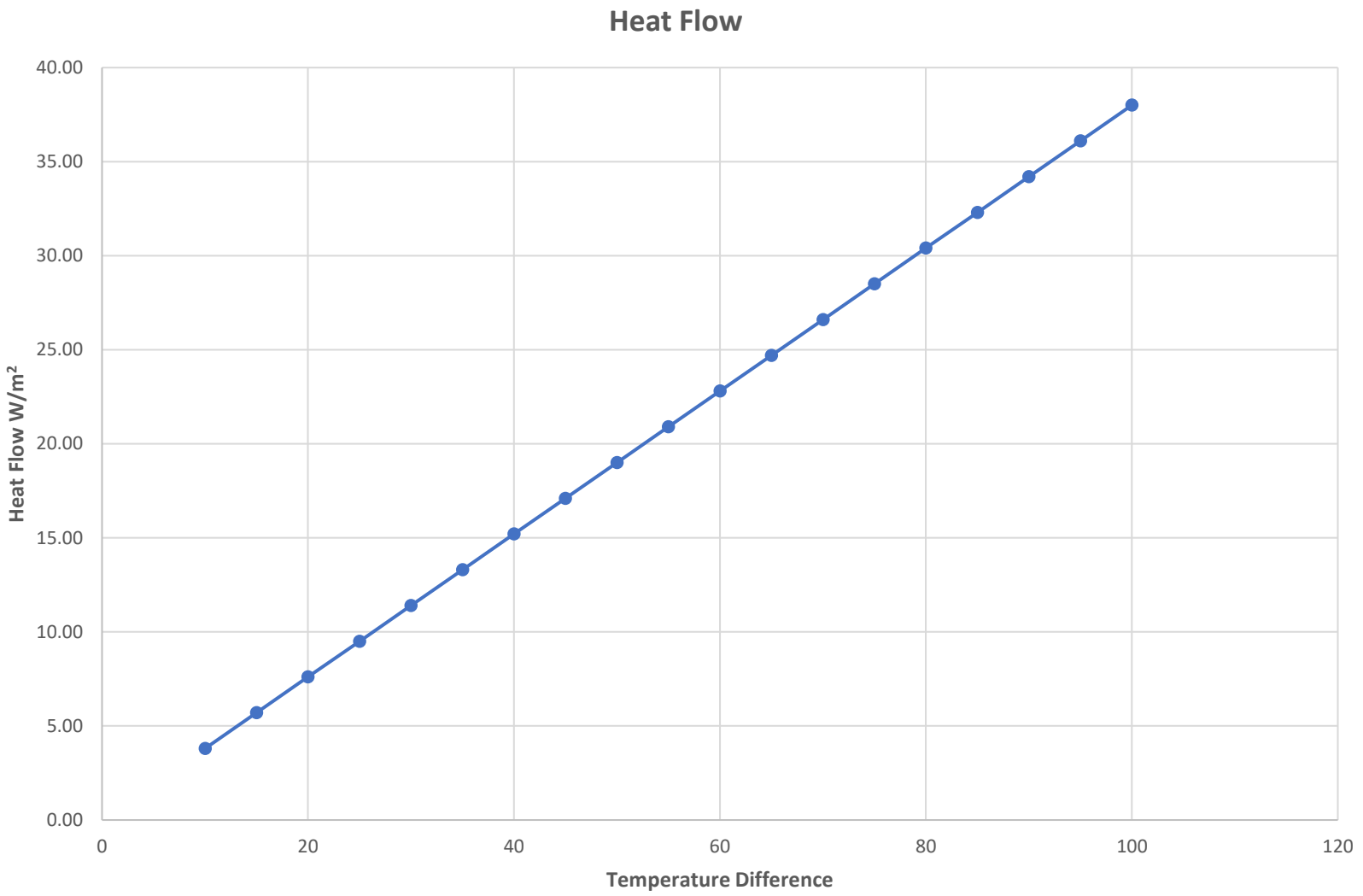
Revision 15

INSULATION k, U and R-VALUES

	Supplier 1								Supplier 2												Supplier 3					
	Expanded Polystyrene (EPS)								Expanded Polystyrene (EPS)												Expanded Polystyrene (EPS)					
Grade	15D		16D		24D		32D		12SD		15 SD		16DV		20DV HD		24DV		30DV EHD		15D		20D		30D	
Density (kg/m3)	15		16		24		32		12		15		16		20		24		30		15		20		30	
k-Values (W/mk)	0.038		0.036		0.033		0.032		0.045		0.040		0.038		0.035		0.034		0.033		0.040		0.038		0.036	
	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value	U-Value	R-Value
Thickness (mm)	Watts/°C	$K.m^2/W$	Watts/°C	$K.m^2/W$	Watts/°C	$K.m^2/W$	Watts/°C	$K.m^2/W$	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W	Watts/°C	K.m2/W
10	3.800	0.263	3.600	0.278	3.300	0.303	3.200	0.313	4.500	0.222	4.000	0.250	3.800	0.263	3.500	0.286	3.400	0.294	3.300	0.303	4.000	0.250	3.800	0.263	3.600	0.278
15	2.533	0.395	2.400	0.417	2.200	0.455	2.133	0.469	3.000	0.333	2.667	0.375	2.533	0.395	2.333	0.429	2.267	0.441	2.200	0.455	2.667	0.375	2.533	0.395	2.400	0.417
20	1.900	0.526	1.800	0.556	1.650	0.606	1.600	0.625	2.250	0.444	2.000	0.500	1.900	0.526	1.750	0.571	1.700	0.588	1.650	0.606	2.000	0.500	1.900	0.526	1.800	0.556
25	1.520	0.658	1.440	0.694	1.320	0.758	1.280	0.781	1.800	0.556	1.600	0.625	1.520	0.658	1.400	0.714	1.360	0.735	1.320	0.758	1.600	0.625	1.520	0.658	1.440	0.694
30	1.267	0.789	1.200	0.833	1.100	0.909	1.067	0.938	1.500	0.667	1.333	0.750	1.267	0.789	1.167	0.857	1.133	0.882	1.100	0.909	1.333	0.750	1.267	0.789	1.200	0.833
35	1.086	0.921	1.029	0.972	0.943	1.061	0.914	1.094	1.286	0.778	1.143	0.875	1.086	0.921	1.000	1.000	0.971	1.029	0.943	1.061	1.143	0.875	1.086	0.921	1.029	0.972
40	0.950	1.053	0.900	1.111	0.825	1.212	0.800	1.250	1.125	0.889	1.000	1.000	0.950	1.053	0.875	1.143	0.850	1.176	0.825	1.212	1.000	1.000	0.950	1.053	0.900	1.111
45	0.844	1.184	0.800	1.250	0.733	1.364	0.711	1.406	1.000	1.000	0.889	1.125	0.844	1.184	0.778	1.286	0.756	1.324	0.733	1.364	0.889	1.125	0.844	1.184	0.800	1.250
50	0.760	1.316	0.720	1.389	0.660	1.515	0.640	1.563	0.900	1.111	0.800	1.250	0.760	1.316	0.700	1.429	0.680	1.471	0.660	1.515	0.800	1.250	0.760	1.316	0.720	1.389
55	0.691	1.447	0.655	1.528	0.600	1.667	0.582	1.719	0.818	1.222	0.727	1.375	0.691	1.447	0.636	1.571	0.618	1.618	0.600	1.667	0.727	1.375	0.691	1.447	0.655	1.528
60	0.633	1.579	0.600	1.667	0.550	1.818	0.533	1.875	0.750	1.333	0.667	1.500	0.633	1.579	0.583	1.714	0.567	1.765	0.550	1.818	0.667	1.500	0.633	1.579	0.600	1.667
65	0.585	1.711	0.554	1.806	0.508	1.970	0.492	2.031	0.692	1.444	0.615	1.625	0.585	1.711	0.538	1.857	0.523	1.912	0.508	1.970	0.615	1.625	0.585	1.711	0.554	1.806
70	0.543	1.842	0.514	1.944	0.471	2.121	0.457	2.188	0.643	1.556	0.571	1.750	0.543	1.842	0.500	2.000	0.486	2.059	0.471	2.121	0.571	1.750	0.543	1.842	0.514	1.944
75	0.507	1.974	0.480	2.083	0.440	2.273	0.427	2.344	0.600	1.667	0.533	1.875	0.507	1.974	0.467	2.143	0.453	2.206	0.440	2.273	0.533	1.875	0.507	1.974	0.480	2.083
80	0.475	2.105	0.450	2.222	0.413	2.424	0.400	2.500	0.563	1.778	0.500	2.000	0.475	2.105	0.438	2.286	0.425	2.353	0.413	2.424	0.500	2.000	0.475	2.105	0.450	2.222
85	0.447	2.237	0.424	2.361	0.388	2.576	0.376	2.656	0.529	1.889	0.471	2.125	0.447	2.237	0.412	2.429	0.400	2.500	0.388	2.576	0.471	2.125	0.447	2.237	0.424	2.361
90	0.422	2.368	0.400	2.500	0.367	2.727	0.356	2.813	0.500	2.000	0.444	2.250	0.422	2.368	0.389	2.571	0.378	2.647	0.367	2.727	0.444	2.250	0.422	2.368	0.400	2.500
95	0.400	2.500	0.379	2.639	0.347	2.879	0.337	2.969	0.474	2.111	0.421	2.375	0.400	2.500	0.368	2.714	0.358	2.794	0.347	2.879	0.421	2.375	0.400	2.500	0.379	2.639
100	0.380	2.632	0.360	2.778	0.330	3.030	0.320	3.125	0.450	2.222	0.400	2.500	0.380	2.632	0.350	2.857	0.340	2.941	0.330	3.030	0.400	2.500	0.380	2.632	0.360	2.778

Energy efficiency in insulated structures

Insulation Materials: Heat Flow



Energy efficiency in insulated structures

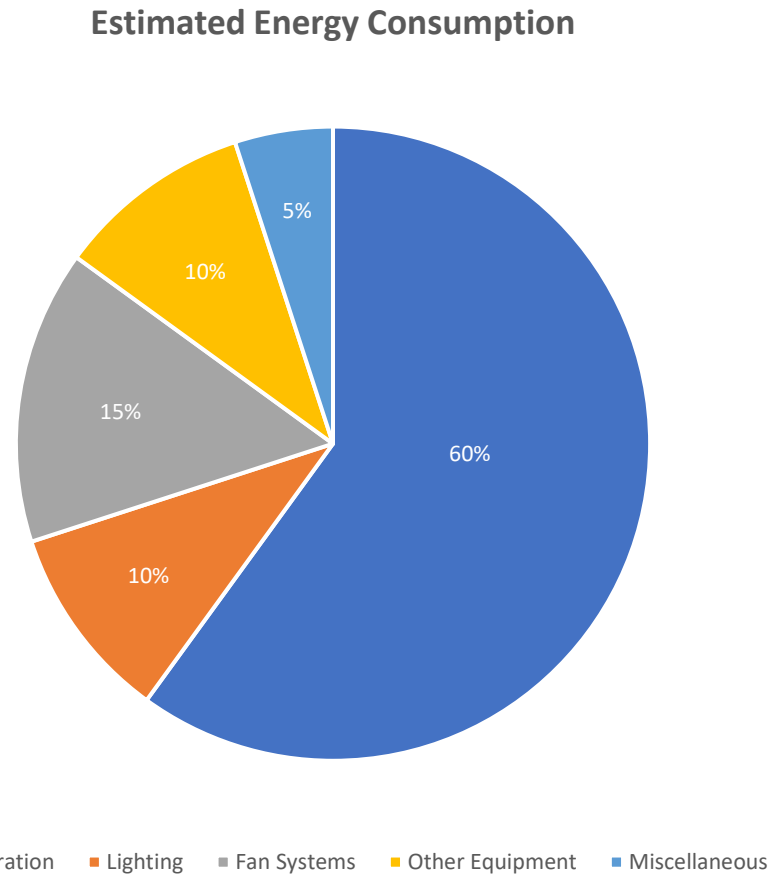
Calculated Heat Flow

Product	Expanded Polystyrene (EPS)									
Grade	15D									
Density	15	kg/m3								
K-Value	0.038	W/mK								
Panel Thickness (mm)	50	60	75	80	100	125	150	175	200	220
U-Value (Watts/°C)	0.76	0.63	0.51	0.48	0.38	0.30	0.25	0.22	0.19	0.17
Temperature Difference										
10	7.60	6.33	5.07	4.75	3.80	3.04	2.53	2.17	1.90	1.73
15	11.40	9.50	7.60	7.13	5.70	4.56	3.80	3.26	2.85	2.59
20	15.20	12.67	10.13	9.50	7.60	6.08	5.07	4.34	3.80	3.45
25	19.00	15.83	12.67	11.88	9.50	7.60	6.33	5.43	4.75	4.32
30	22.80	19.00	15.20	14.25	11.40	9.12	7.60	6.51	5.70	5.18
35	26.60	22.17	17.73	16.63	13.30	10.64	8.87	7.60	6.65	6.05
40	30.40	25.33	20.27	19.00	15.20	12.16	10.13	8.69	7.60	6.91
45	34.20	28.50	22.80	21.38	17.10	13.68	11.40	9.77	8.55	7.77
50	38.00	31.67	25.33	23.75	19.00	15.20	12.67	10.86	9.50	8.64
55	41.80	34.83	27.87	26.13	20.90	16.72	13.93	11.94	10.45	9.50
60	45.60	38.00	30.40	28.50	22.80	18.24	15.20	13.03	11.40	10.36
65	49.40	41.17	32.93	30.88	24.70	19.76	16.47	14.11	12.35	11.23
70	53.20	44.33	35.47	33.25	26.60	21.28	17.73	15.20	13.30	12.09
75	57.00	47.50	38.00	35.63	28.50	22.80	19.00	16.29	14.25	12.95
80	60.80	50.67	40.53	38.00	30.40	24.32	20.27	17.37	15.20	13.82
85	64.60	53.83	43.07	40.38	32.30	25.84	21.53	18.46	16.15	14.68
90	68.40	57.00	45.60	42.75	34.20	27.36	22.80	19.54	17.10	15.55
95	72.20	60.17	48.13	45.13	36.10	28.88	24.07	20.63	18.05	16.41
100	76.00	63.33	50.67	47.50	38.00	30.40	25.33	21.71	19.00	17.27

Energy efficiency in insulated structures

Hourly Temperature

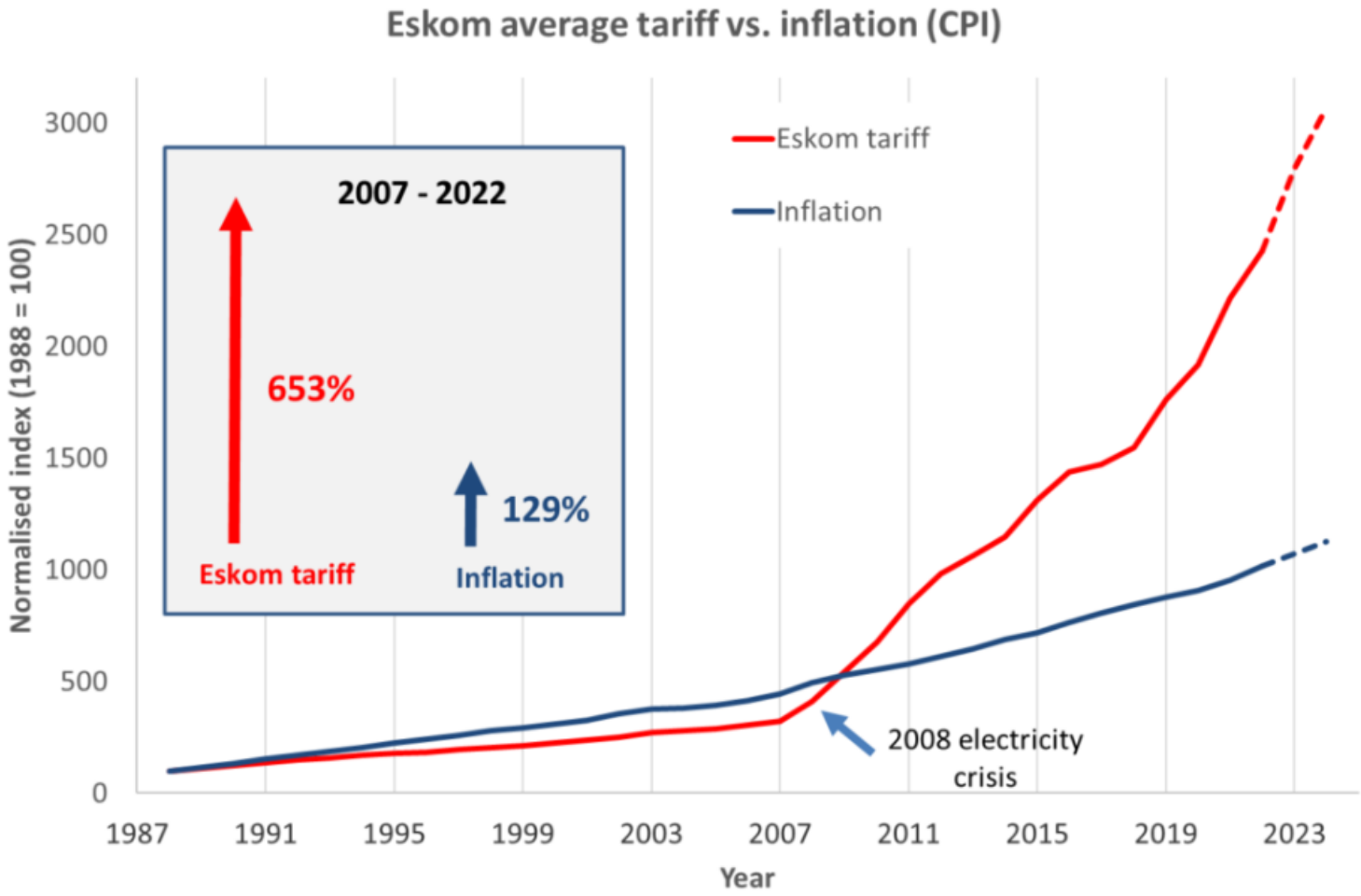
Energy Consumption



Energy efficiency in insulated structures

Hourly Temperature

Electricity Costs



Energy efficiency in insulated structures

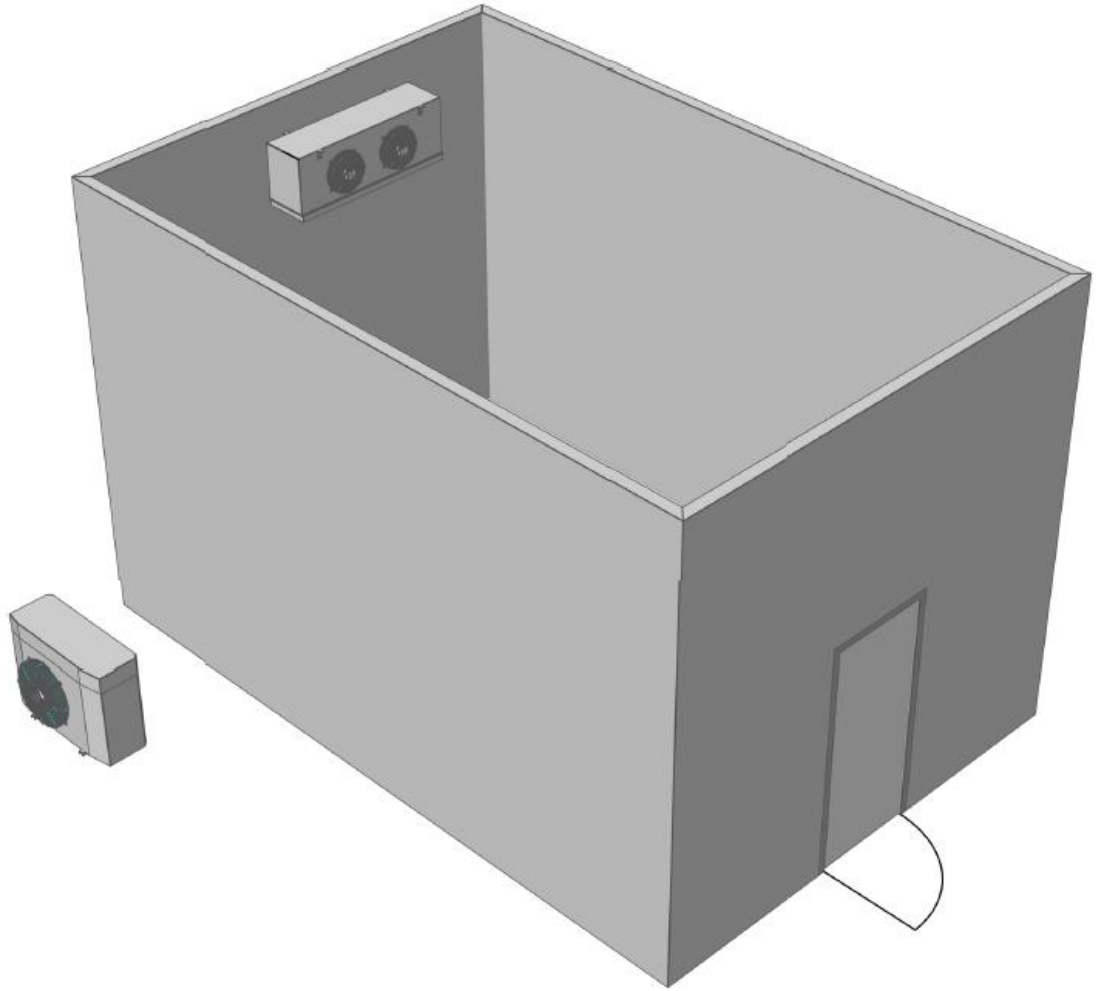
Example

Site: Johannesburg

Extreme Annual Temperature

Max DB: 31°C

Room Temperature: +2°C



Energy efficiency in insulated structures

Hourly Temperature

Site: Johannesburg

Extreme Annual Temperature

Max DB: 31°C

2021 ASHRAE Handbook - Foundamentals (SI)

JOHANNESBURG INTL, SOUTH AFRICA (WMO: 683680)

Lat:**26.143S** Long:**28.235E** Elev:**1695** StdP: **82.55** Time zone:**2.00 (E02)** Period:**94-19** WBAN:**99999**

Annual Heating, Humidification, and Ventilation Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		WSF
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
7	0.4	2.2	-14.0	1.4	14.2	-12.0	1.6	13.4	10.4	9.6	9.4	10.2	4.3	210	0.455

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
1	9.7	29.1	14.8	28.1	14.9	27.0	15.1	19.4	23.9	18.7	23.3	18.1	22.9	4.9	350

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
18.0	16.0	21.2	17.2	15.1	20.3	16.8	14.8	20.0	63.4	24.2	61.0	23.4	59.0	22.9	23.8

Extreme Annual Design Conditions

Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
9.4	8.4	7.5	DB	-2.5	31.1	2.1	1.2	-4.0	32.0	-5.3	32.7	-6.4	33.4	-8.0	34.3
			WB	-4.4	20.4	1.7	1.2	-5.7	21.2	-6.7	21.9	-7.7	22.6	-8.9	23.4

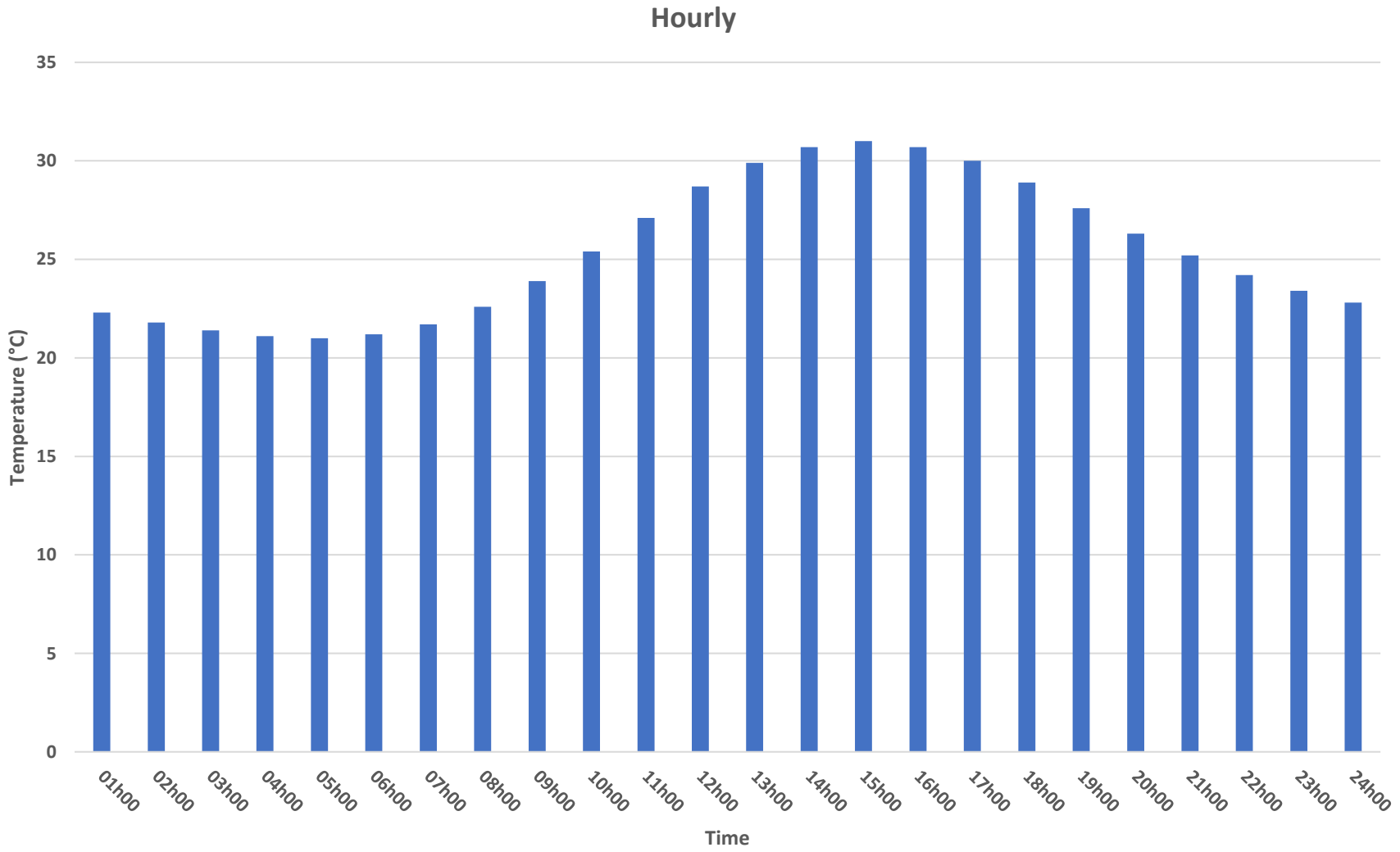
Energy efficiency in insulated structures

Hourly Temperature

Site: Johannesburg

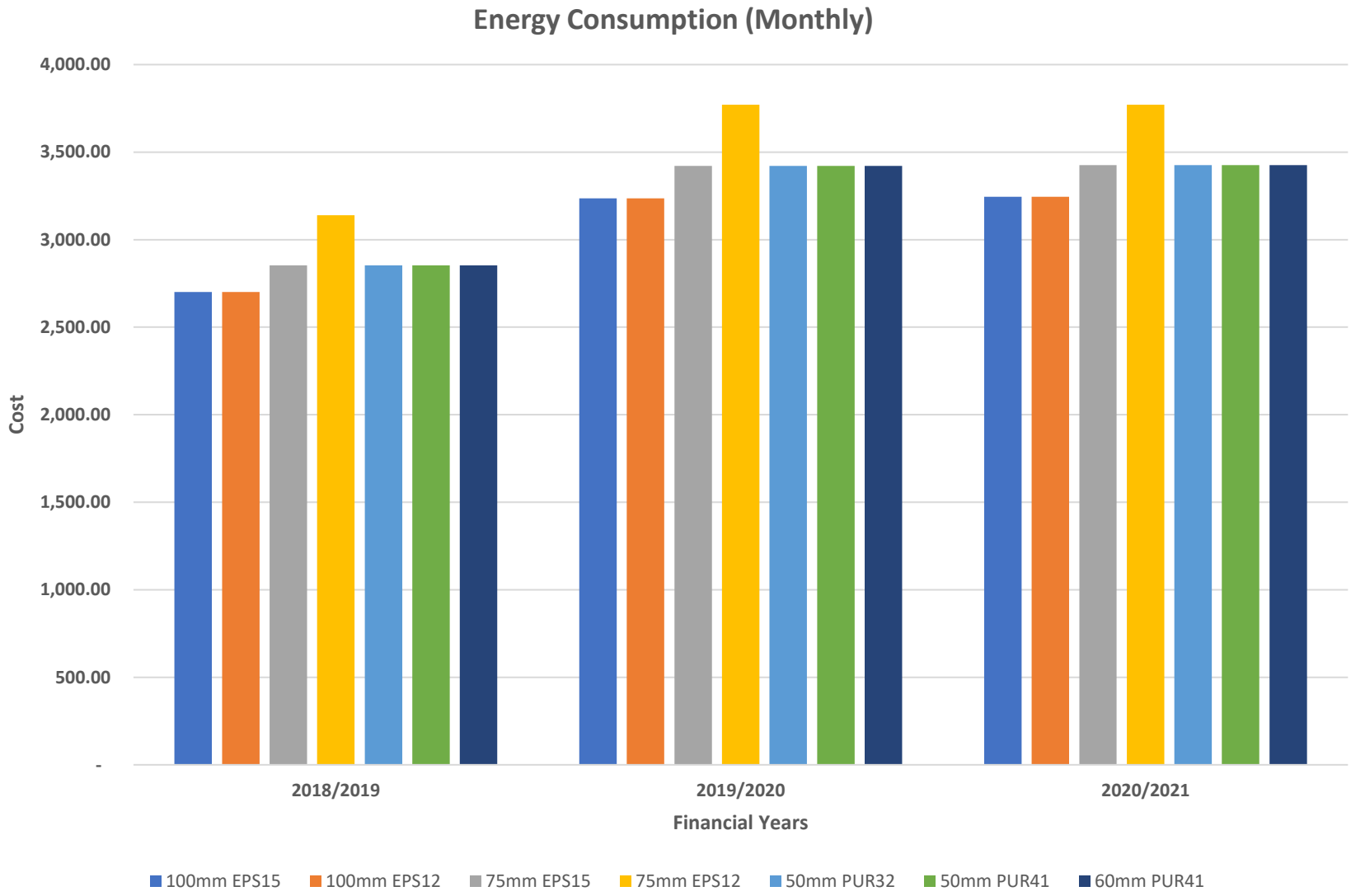
Extreme Annual Temperature

Max DB: 31°C



Energy efficiency in insulated structures

Energy Consumption



Energy efficiency in insulated structures

Conclusion

Factor to take into account

1. **Room Temperature**
2. **Ambient Temperature**
3. **Insulation Type**
4. **Thickness of Insulation**

Q&A

Thank You