Iowa State University

Center for Building Energy Research

Method to Evaluate and Develop Next Generation Vacuum Insulation Panels for Implementation in the Retrofit of Existing Building Envelopes

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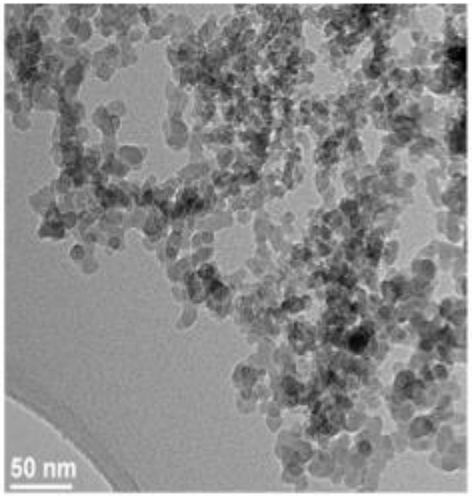
Overview

- New core materials for Vacuum Insulated Panels (VIPs):
- How would they impact whole building energy performance?
- Whole building energy impact on building retrofits
- Methodology:
  - Parametric modeling of DOE reference buildings with and without retrofit
  - Improvement in energy performance by climate zone
  - Improvement in energy performance by panel size and thickness
- Results:
  - Issues with impact on energy performance over time

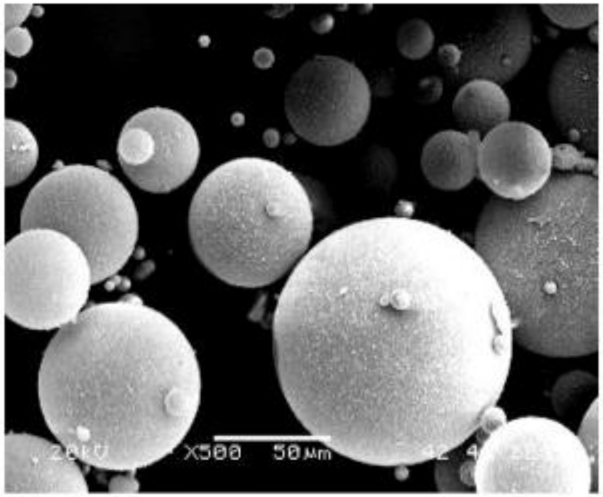
Vacuum Insulated Panels

http://www.builddifferent.co.uk/wp-content/uploads/2012/10/insulation1.jpg

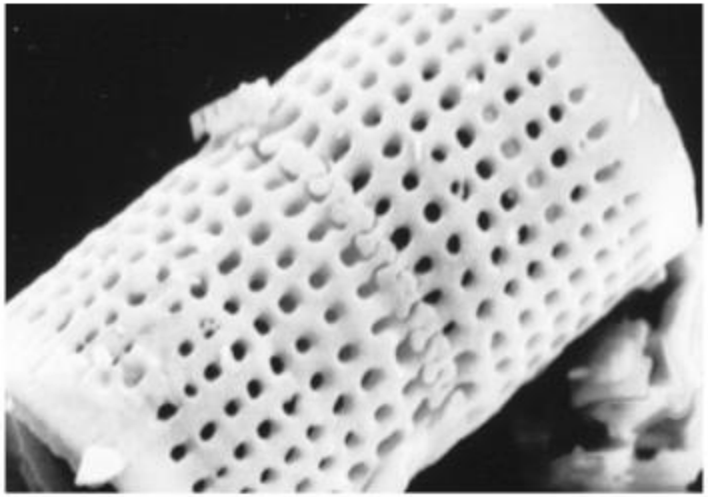
CORE MATERIAL FOR VIPs



Fumed Silica



Glass Bubbles



Diatom

Electron micrograph, thanks to Prof. Mufit Akinc, Material Science and Engineering

MATERIAL PROPERTIES

Material Type	Diatomaceous	Fumed Silica	Glass Bubbles	Glass Fiber
Thermal conductivity (W/m.K) @ 1 atm	0.0269	0.0175	0.0145	0.0106
Thermal conductivity (W/m.K) @ vacuum	0.0029	0.0042	0.0027	0.0041
Emissivity	0.930	0.930	0.930	0.930
Density (g/cm^3)	0.400	0.037	0.150	0.255
Specific heat (J/m^3K)	$0.5x10^6$	$0.1x10^6$	$0.06x10^6$	$0.1x10^6$
Moisture diffusivity (cm^2/s)	0.160	0.213	0.095	0.184

Material properties of the various core materials used (Chang, 2016)

DOE REFERENCE BUILDINGS

ASHRAE Climate Zone	Reference City	U-Value (BTU / ft^{2}hr°F)	R-Value (ft^{2}hr°F / BTU)
1A	Miami	0.550	1.818
2A	Houston	0.172	5.822
2B	Phoenix	0.240	4.169
3A	Atlanta	0.146	6.846
3B	Los Angeles	0.220	4.549
3C	San Francisco	0.130	7.699
4A	Baltimore	0.088	11.251
4B	Albuquerque	0.099	10.003
4C	Seattle	0.092	10.885
5A	Chicago	0.082	12.193
5B	Boulder	0.082	12.193
6A	Minneapolis	0.065	15.398
6B	Helena	0.072	13.892
7A	Duluth	0.058	17.270
8A	Fairbanks	0.045	22.195

pre-1980 residential exterior wall assemblies listed by ASHRAE climate zone (Standard 90.1-2007)

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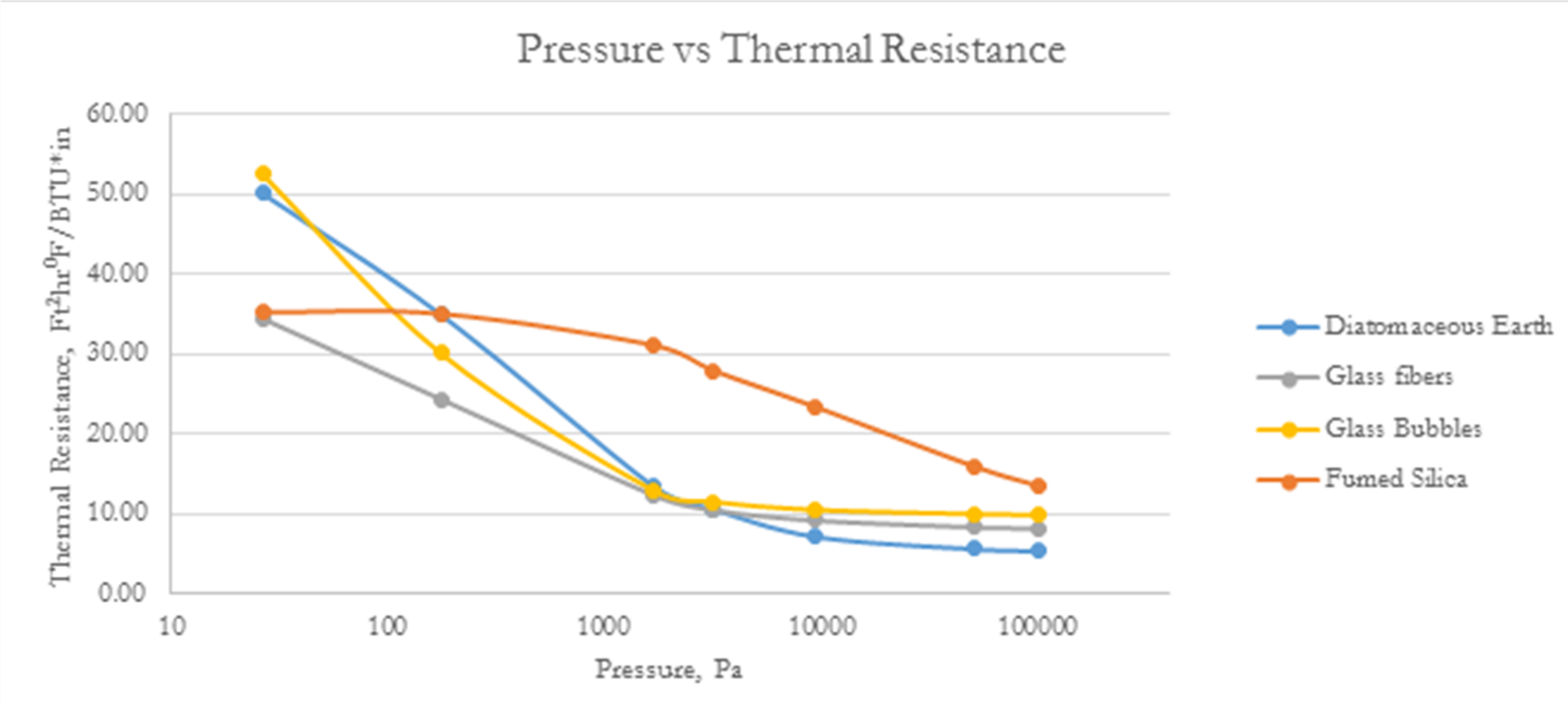
PRESSURE VERSUS TIME



Thermal resistance of various core material types as tested across pressures ranging from 26 Pa to one- atmosphere

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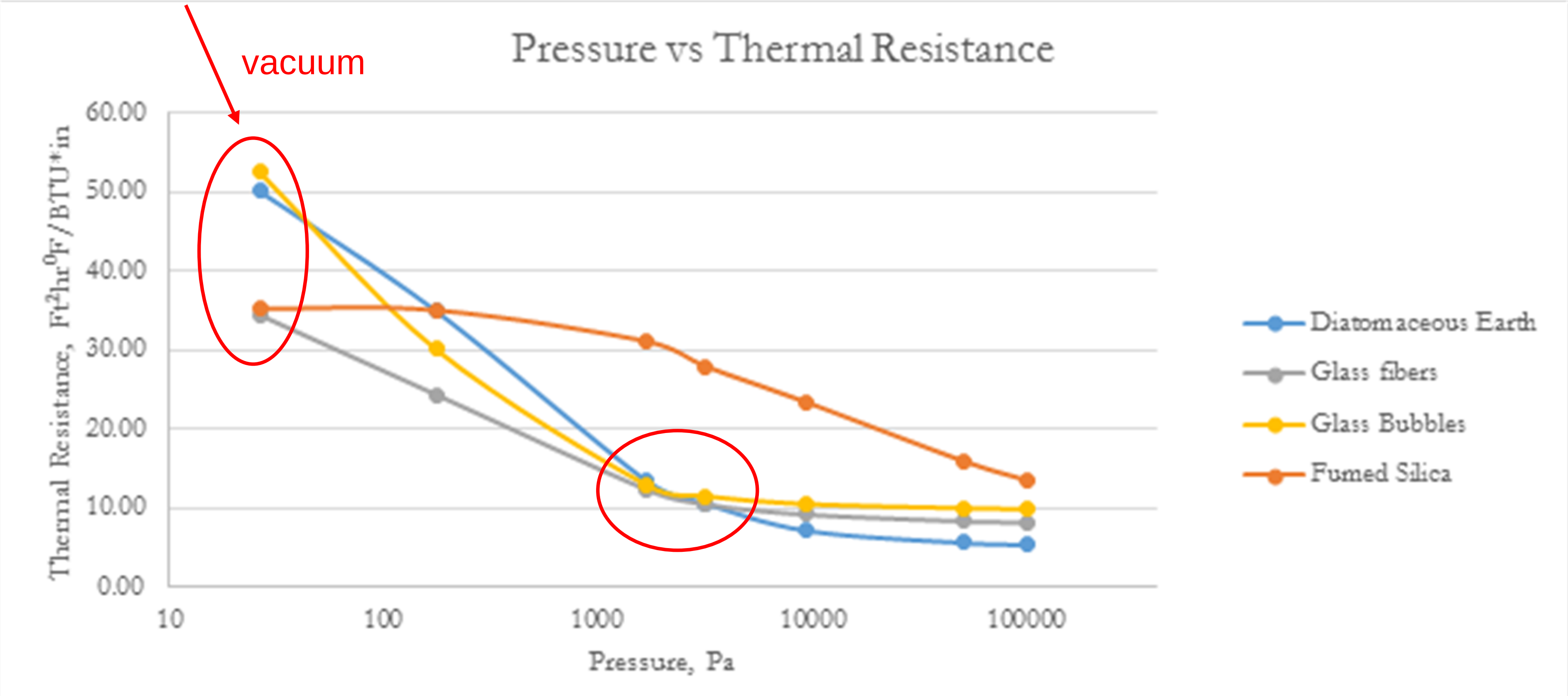

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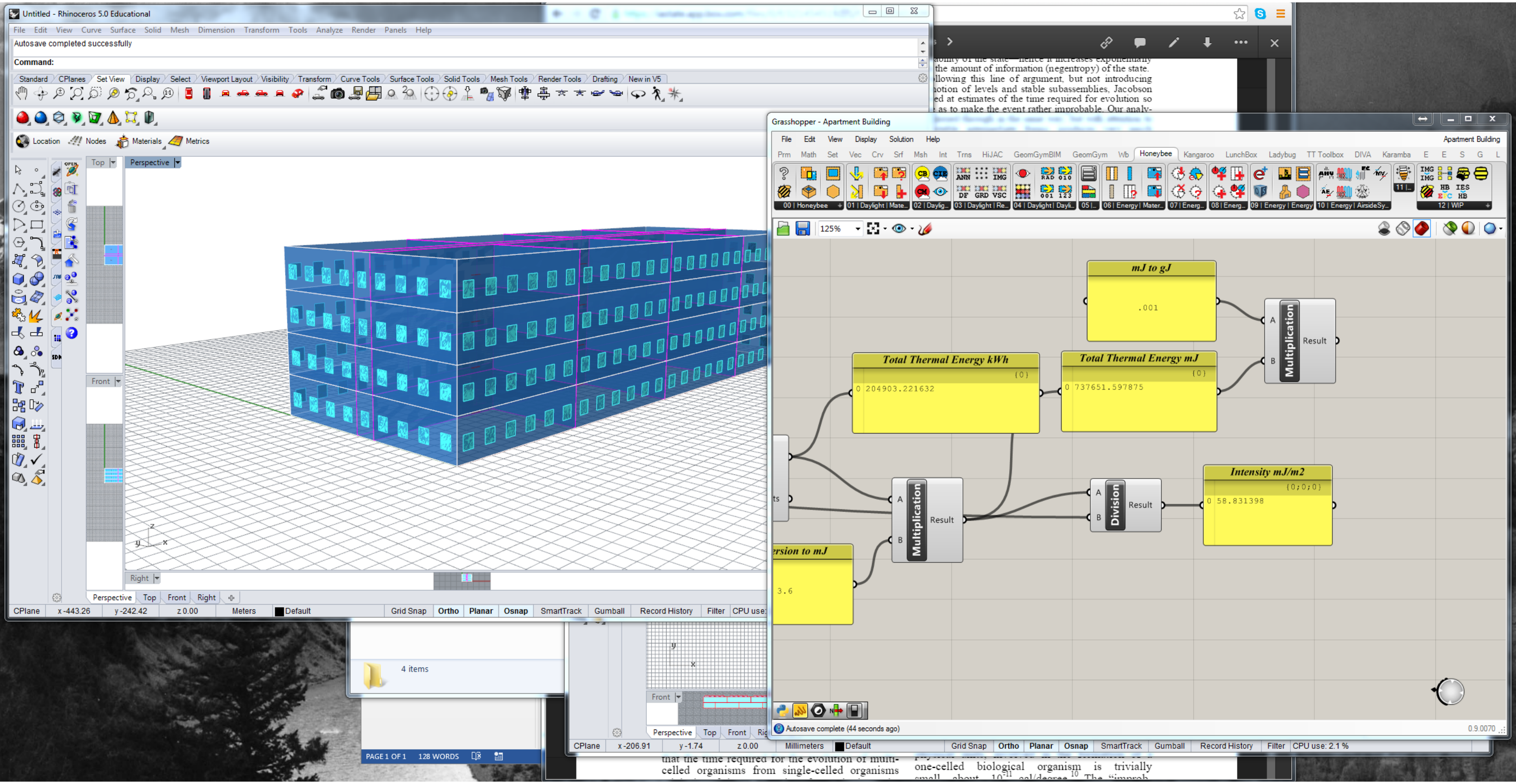
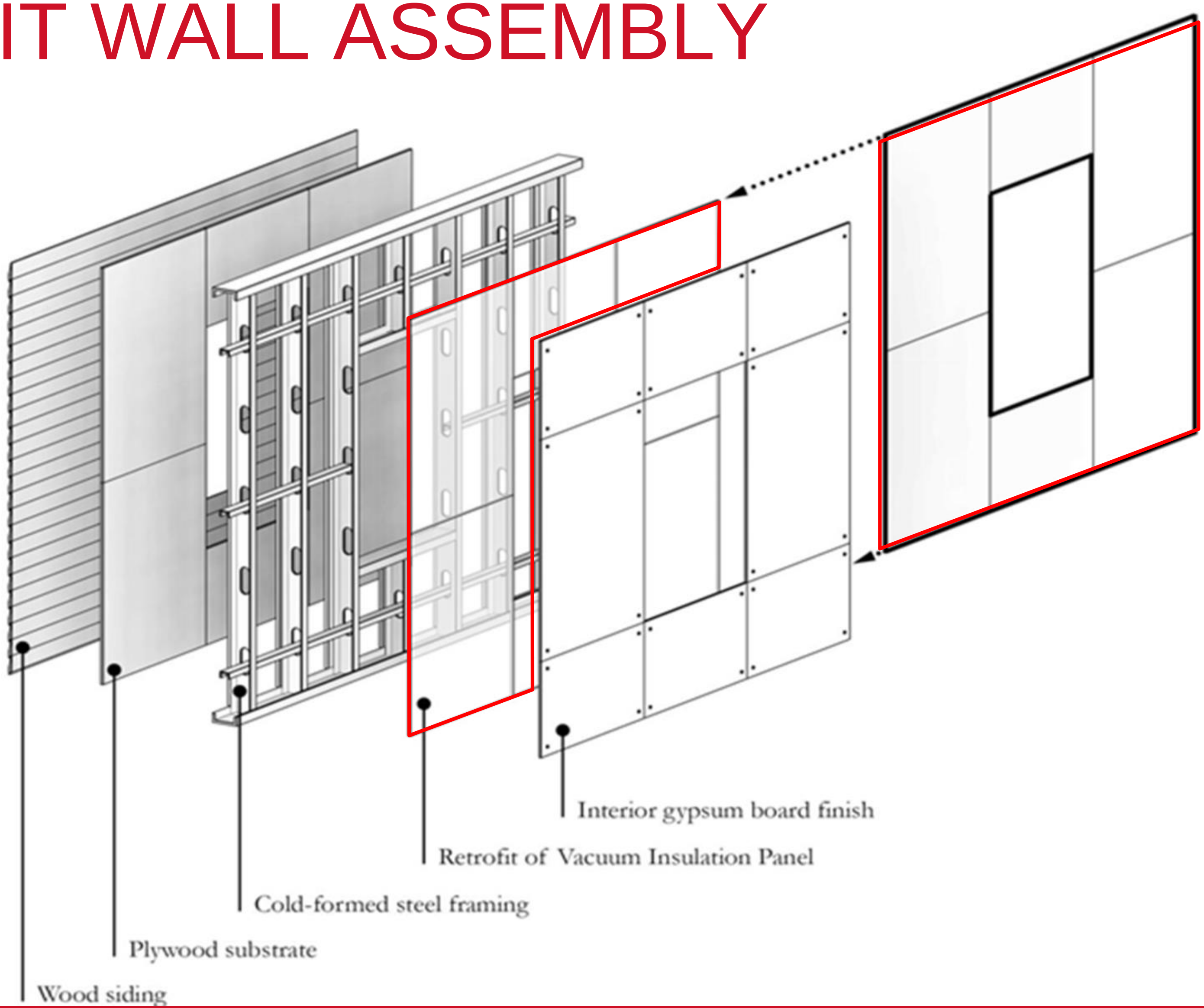
Parametric Model

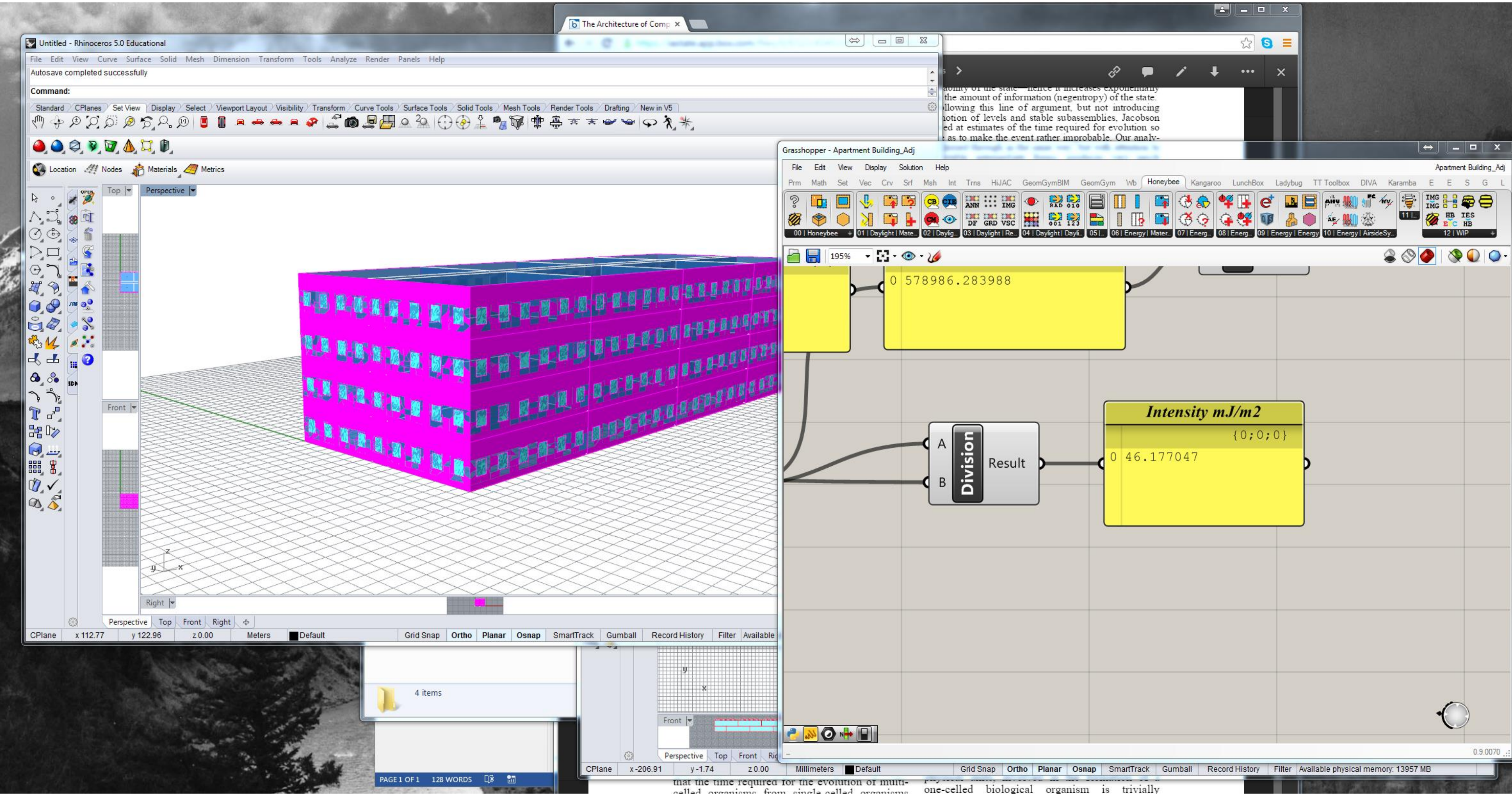


RETROFIT WALL ASSEMBLY

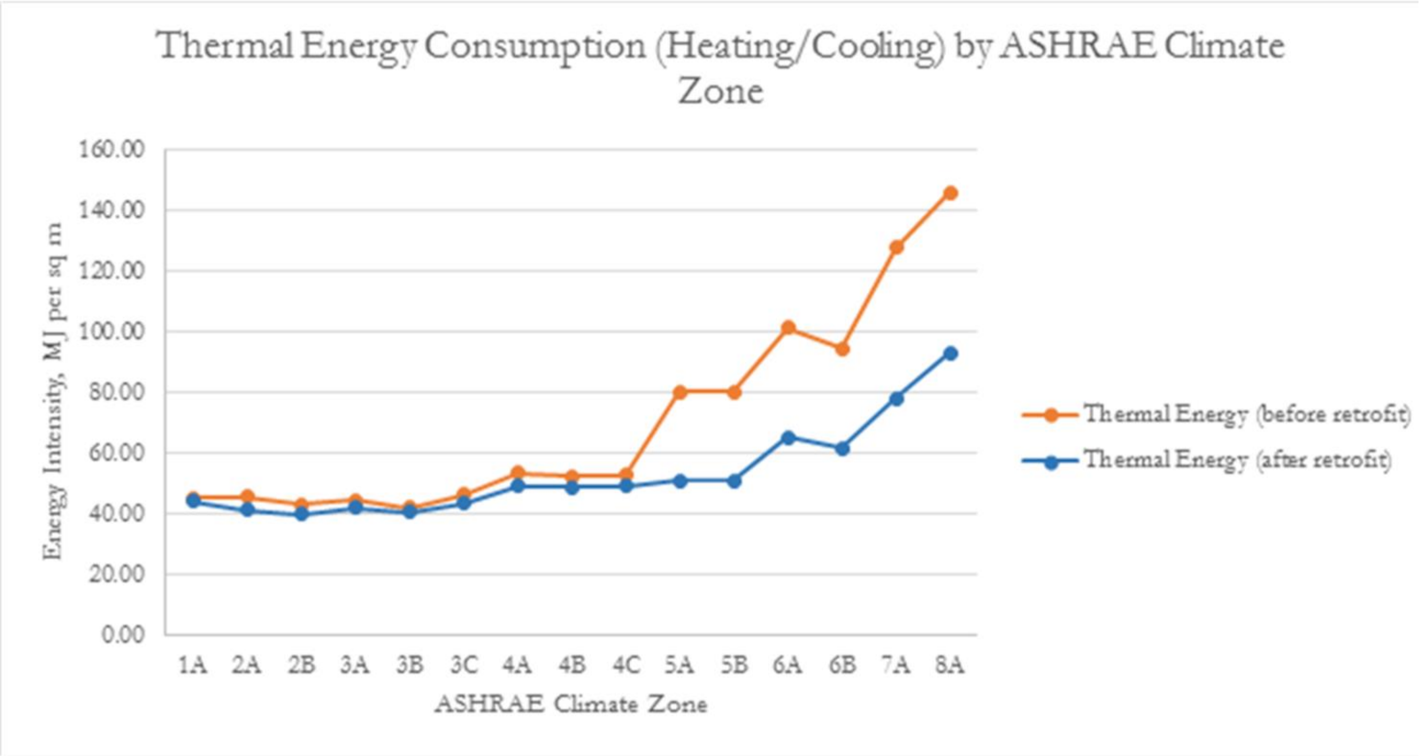
VIP assembly showing elements of the construction, standard across all climate zones with varying levels of insulation in the steel stud cavity



Revised Results

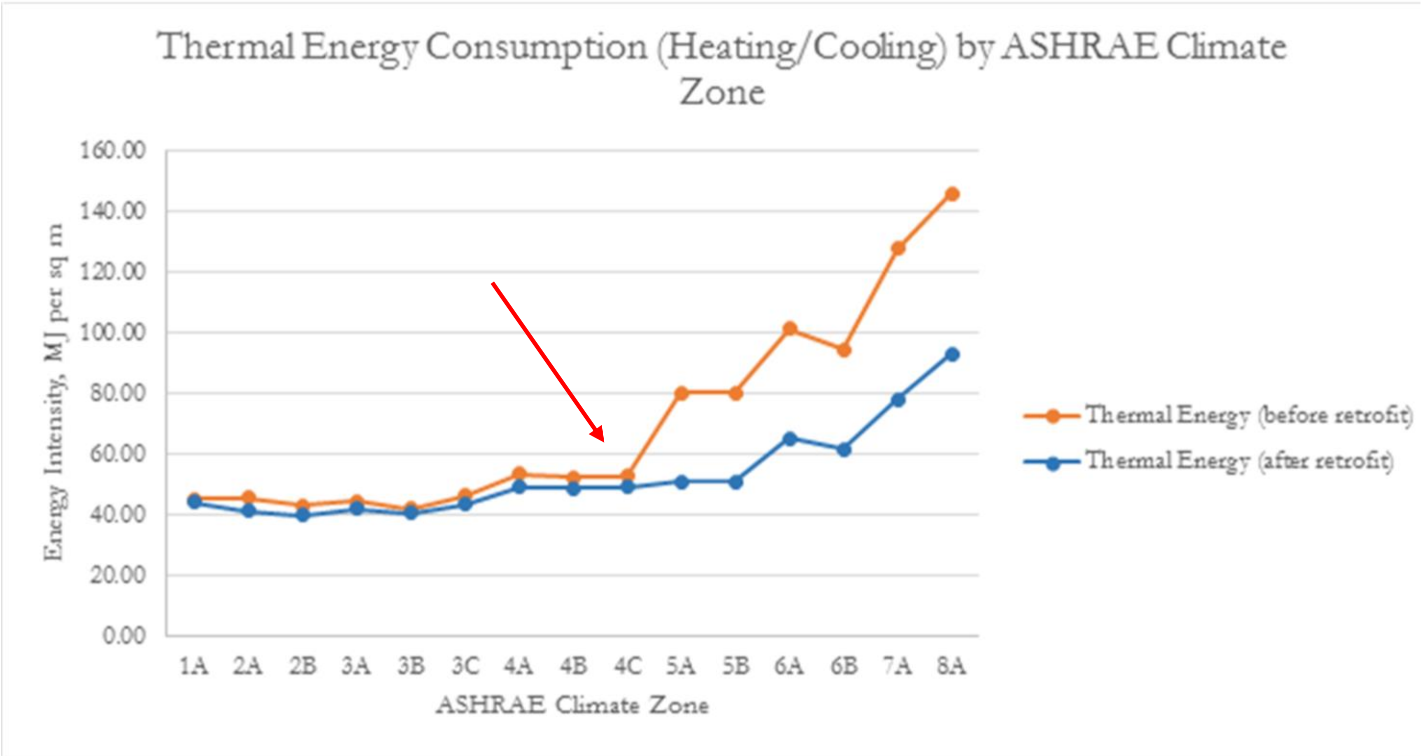


RETROFIT ENERGY PERFORMANCE



Results of EnergyPlus simulation showing thermal energy consumption by ASHRAE climate zone

RETROFIT ENERGY PERFORMANCE



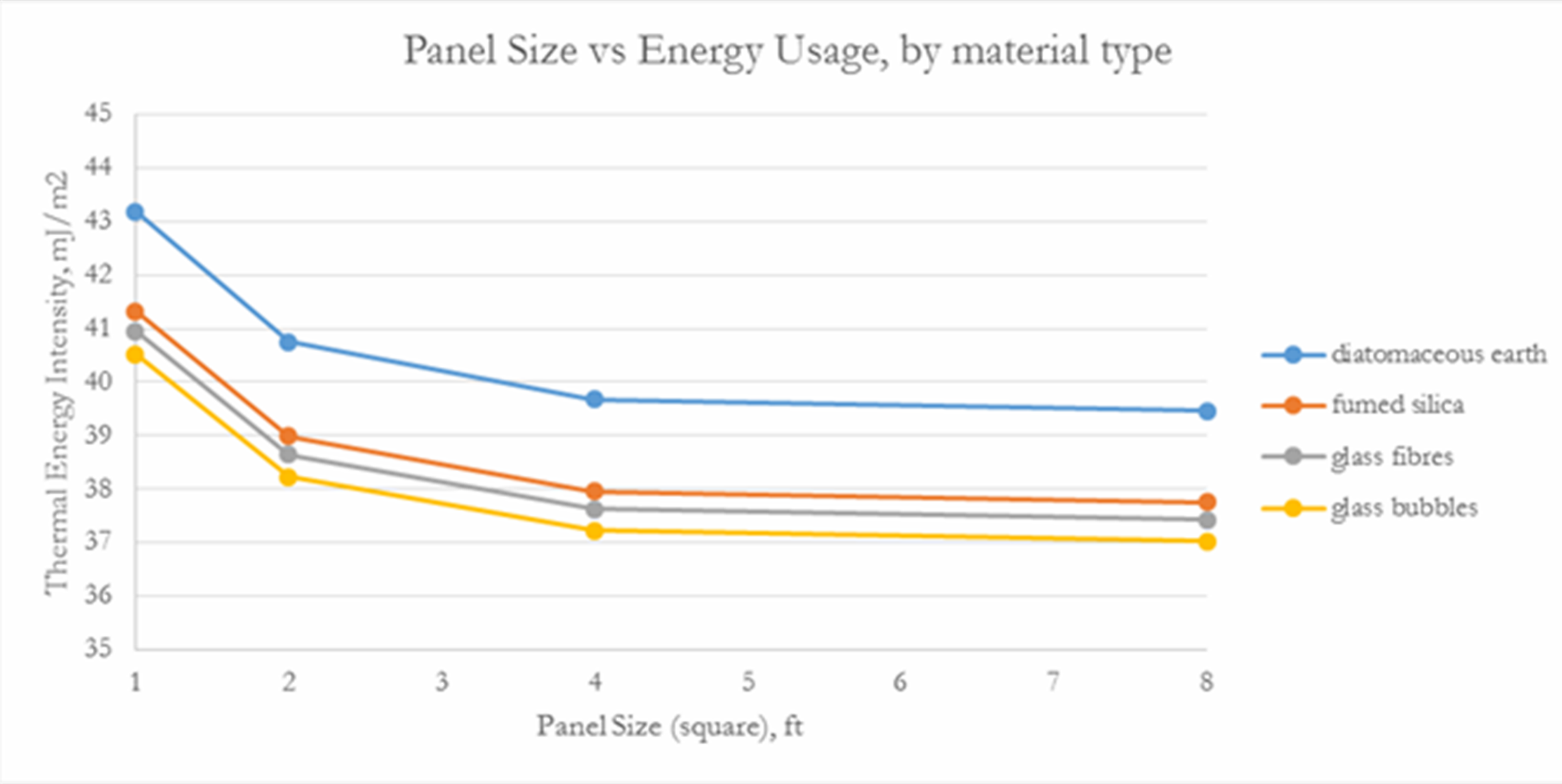
Results of EnergyPlus simulation showing thermal energy consumption by ASHRAE climate zone

THERMAL ENERGY CONSUMPTION

Climate Zone	Thermal Energy (mJ/m2) (before retrofit)	Thermal Energy (mJ/m2) (after retrofit)	Net Reduction
1A	45.4	44.2	2.6%
2A	45.7	41.4	9.4%
2B	43.2	40.2	6.9%
3A	44.6	42.3	5.2%
3B	42.4	40.7	4.0%
3C	46.6	43.6	6.4%
4A	53.7	49.3	8.2%
4B	52.4	49.1	6.3%
4C	53.1	49.2	7.3%
5A	80.4	51.2	36.3%
5B	80.4	51.2	36.3%
6A	101.4	65.3	35.6%
6B	94.6	61.9	34.6%
7A	127.8	78.4	38.7%
8A	145.9	93.1	36.2%

Results of EnergyPlus simulation showing thermal energy consumption by ASHRAE climate zone comparison between pre-1980 and retrofit case

PANEL SIZE VS ENERGY USAGE



Change in performance across core materials and panel size

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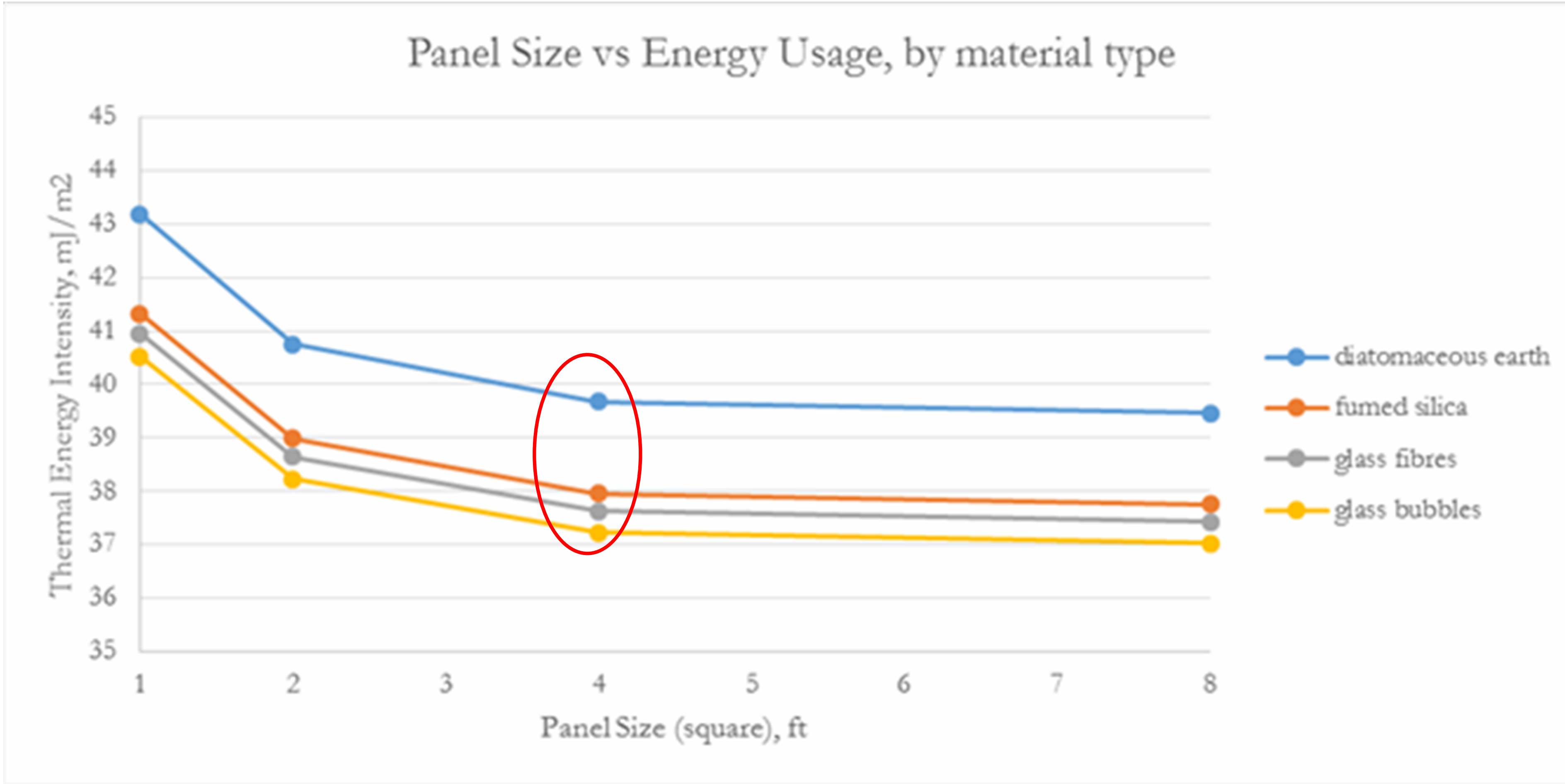
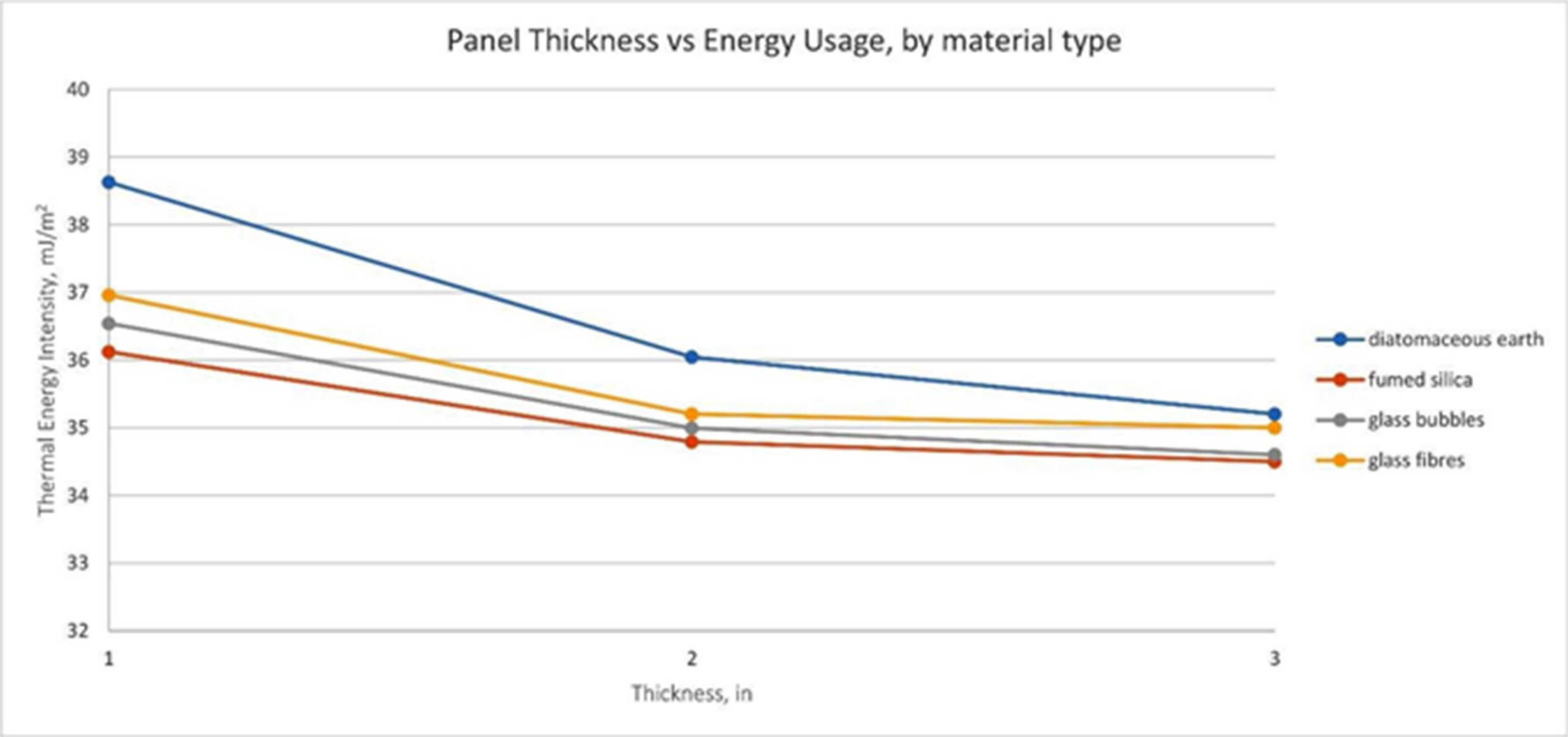


Change in performance across core materials and panel size

PANEL THICKNESS VS ENERGY USE



Effects of panel thickness on whole building thermal energy consumption when compared with the baseline condition

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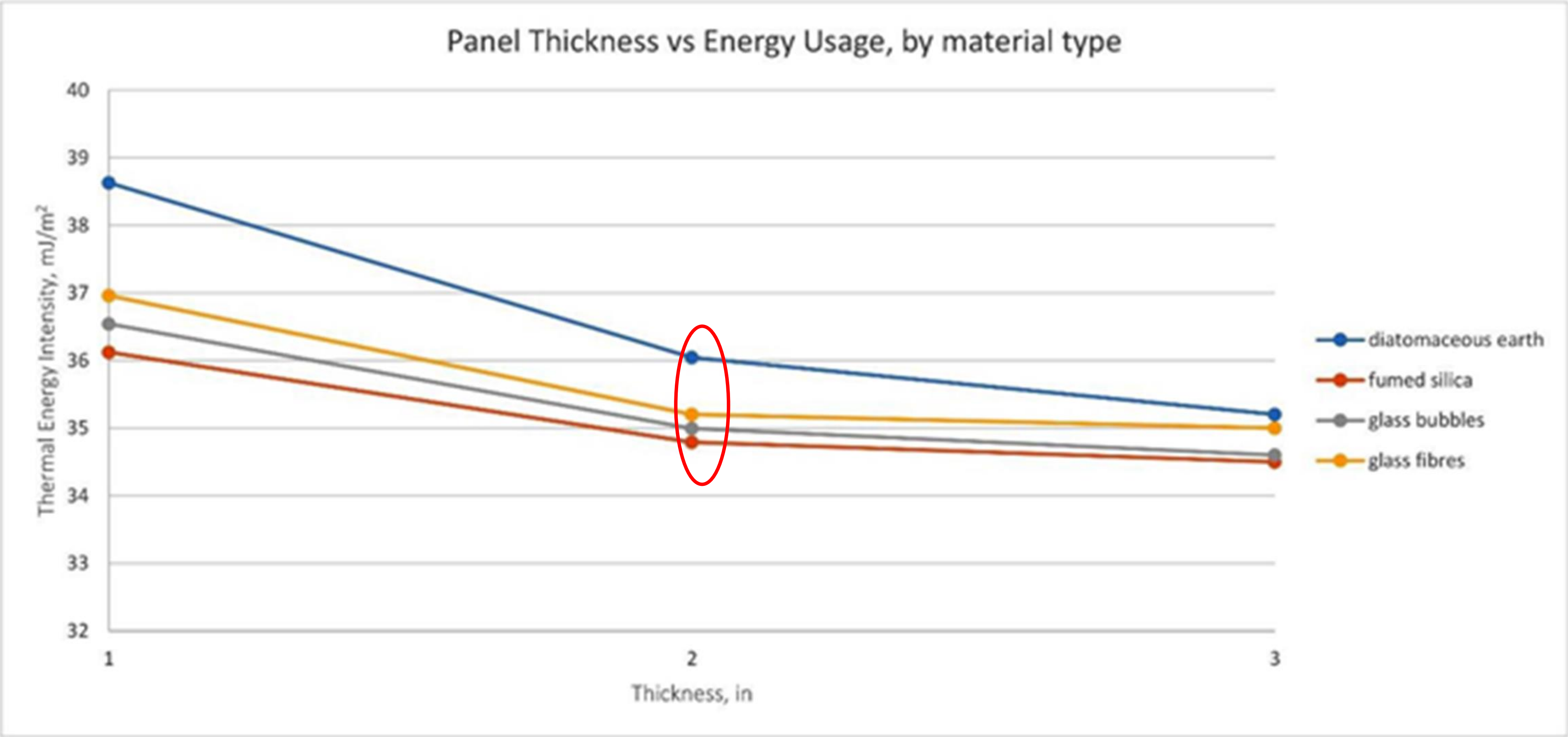

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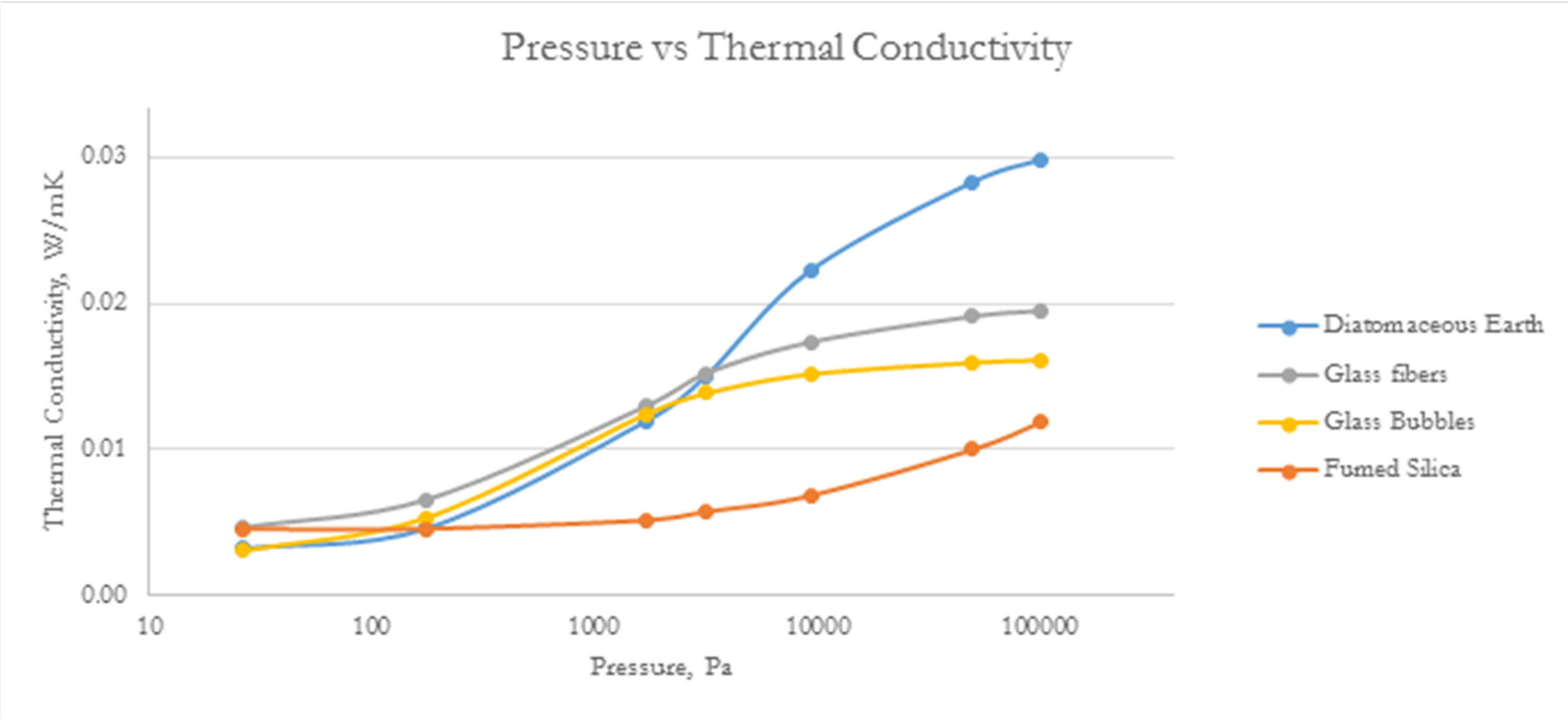
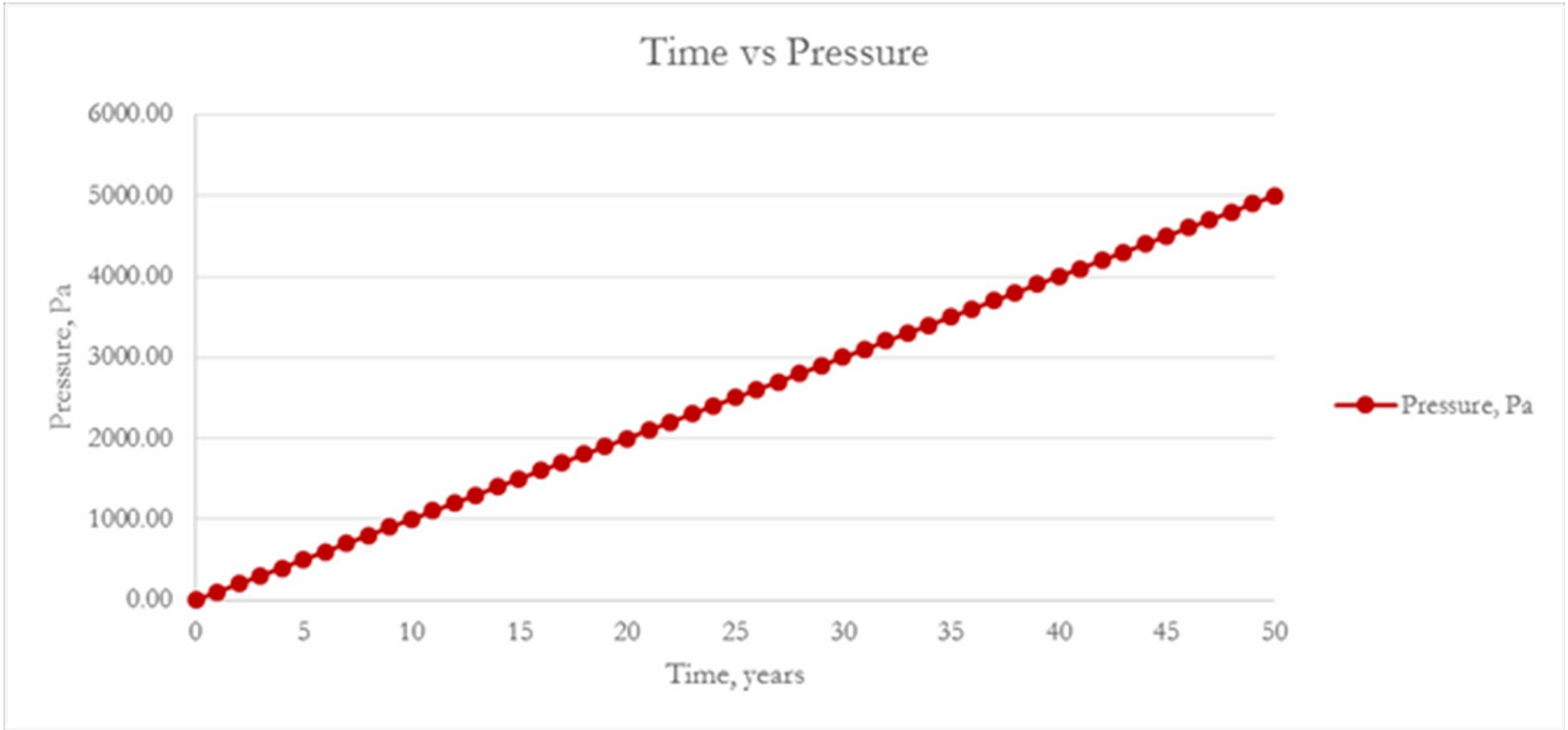
PRESSURE VS THERMAL



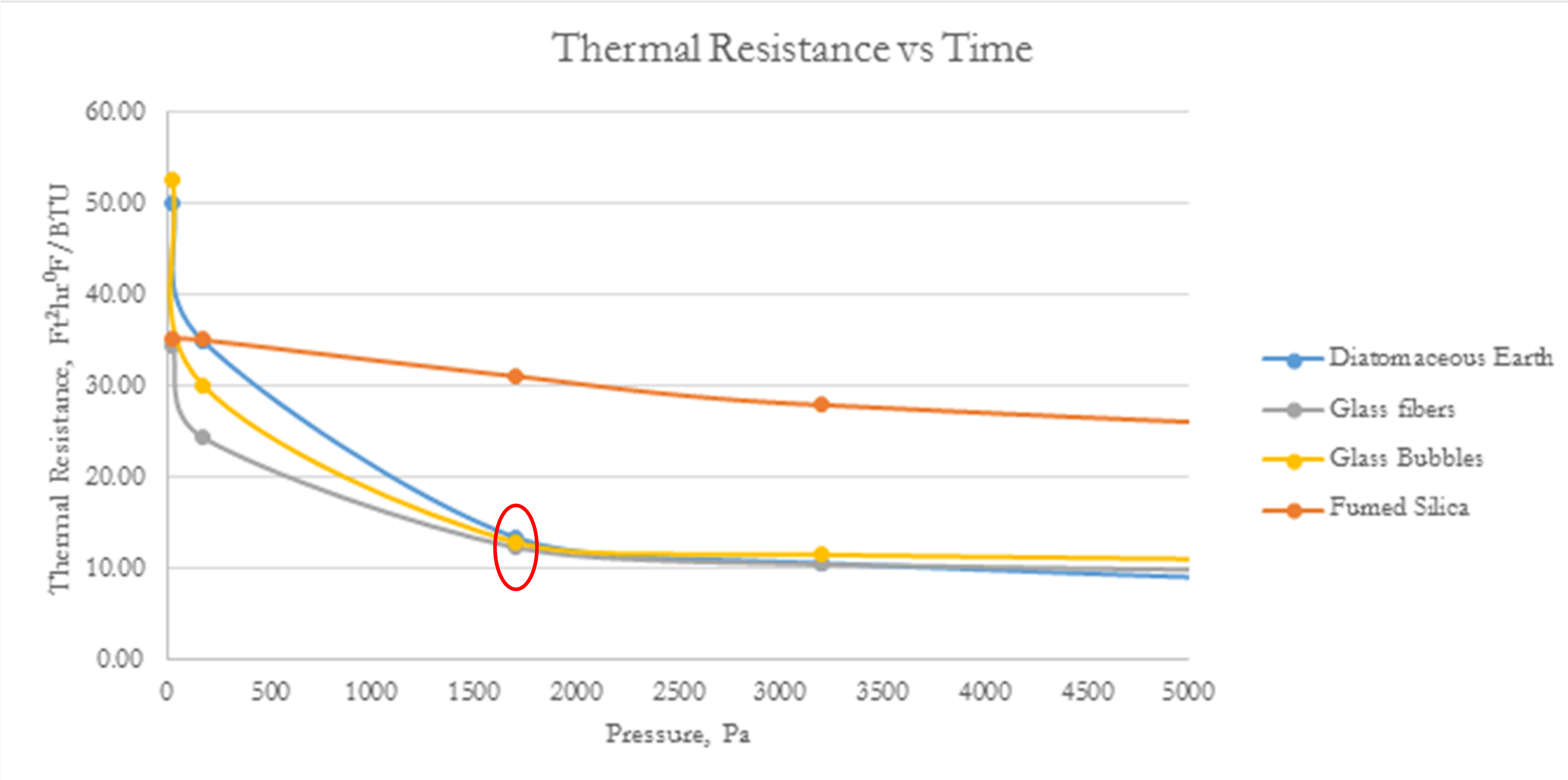
Increase in thermal conductivity within a pressure range corresponding with expected values over 50 years

Time vs Pressure



Increase in pressure over time based upon the model proposed by (J. Fricke 2007)

THERMAL RESISTANCE vs TIME



Resulting decrease in thermal resistance over a period of 50 years due to pressure increase

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