Aerogel for Thermal Insulation of Interior Wall Retrofits in Cold Climates

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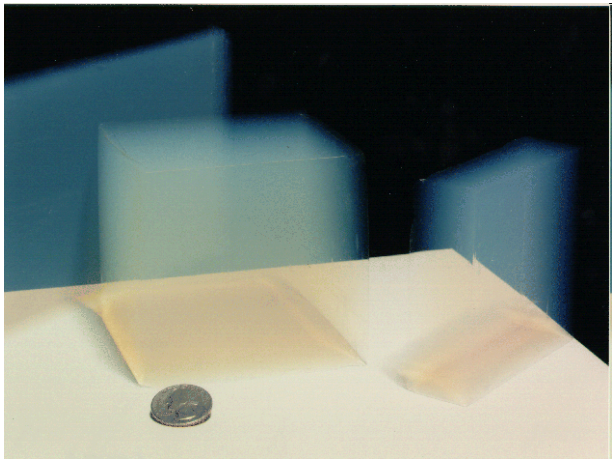
Aerogels have extreme properties

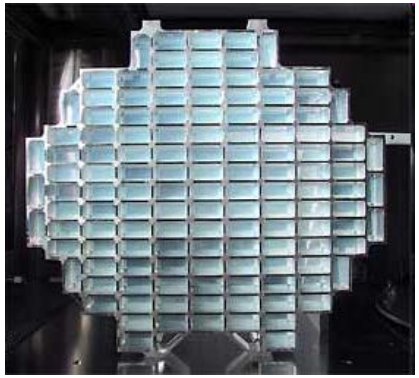
- High porosity (80–99.8%)
- Low density (~0.003 g/cm^3)
- High specific surface area (500–200m^2/g)
- Ultra-low thermal conductivity (0.02 W/m-K)
- Ultra-low dielectric constant (k = 1.0–2.0)
- Ultra-low index of refraction (n~1.05)

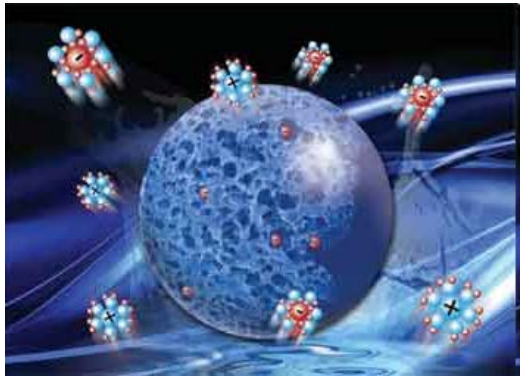


http://p25ext.lanl.gov/~hubert/aerogel/

http://www.aerogem.com/aerogel-photos-12.html

Extreme properties ➔ many applications!

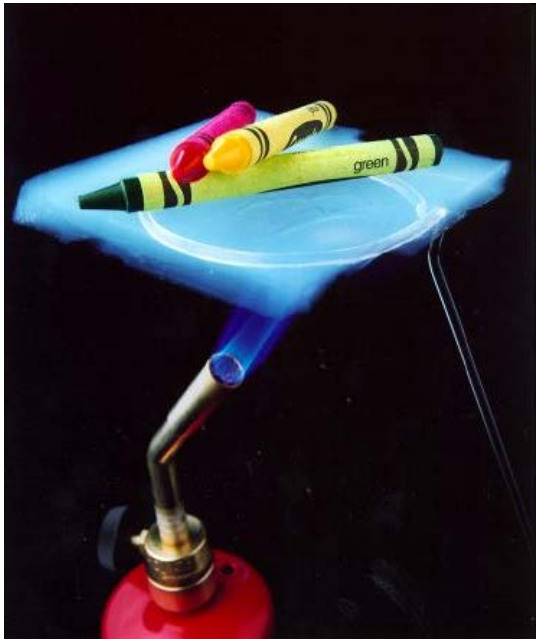




http://www.aerogel.com/products/pdf/Spaceloft_DS.pdf ,http://fullers-blog.blogspot.com/,http://berkeley.edu/news/media/releases/2006/01/10_dust.shtml,http://www.audax-speaker.de,http://www.cdiweb.com/ewave/422,http://www.physorg.com/news/2011-03-advanced-carbon-aerogels-energy-applications.html

Aerogels for building applications

- Ultra low thermal conductivity (0.02 W/m−K)
- Light weight
- Fire resistant
- Water repellent
- Non-toxic



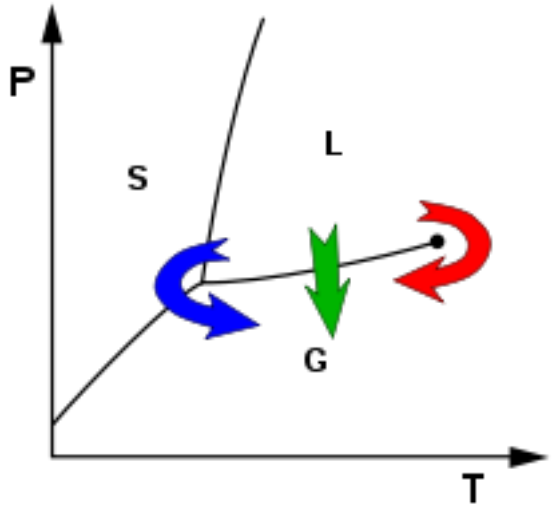
R~10 compared to the commonly used thermal insulation materials such as XPS (*R*=5), EPS (*R*=4), PIC (*R*=6.5), and PU (*R*=6).

Aerogels are expensive due to low production volume.

http://stardust.jpl.nasa.gov/tech/aerogel.html

Aerogel synthesis is a three step process

- Sol-gel process
  TMOS, TEOS, PEDS, MTES, silicon alkaoxide → Costly
- Gel Ageing
  EtOH, TEOS, H2O
  batch process → Time intensive, solvent evaporation
- Gel Drying
  supercritical drying → High capital and energy costs



- Aerogel reinforcing
  fiberglass, carbon fiber, cross-linking with polymers

↓

Undesired increase in thermal conductivity and density

Cost ~$1/cm^3 ➔ very expensive!!

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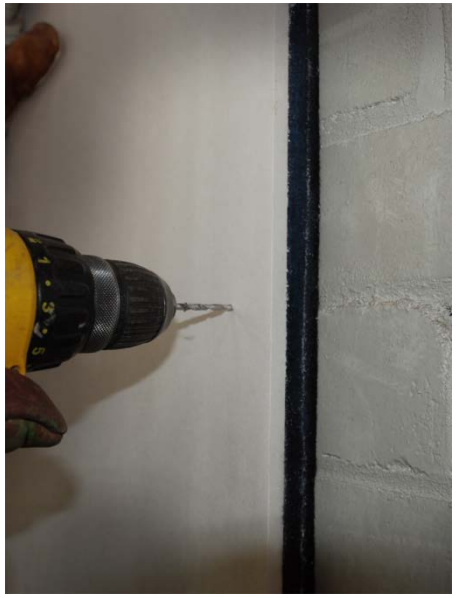
Approaches to reduce aerogel production cost

- Sol-gel process
  - cheaper and more abundant alternatives such as rice husk, clay and OSA
- Gel Ageing
  - low vapor pressure liquid
  - continuous process
- Gel Drying
  - atmospheric pressure drying
  - freeze drying
- Aerogel reinforcing
  - mechanically weaker yet cheaper and low conductivity alternatives, such as organic and biological fibers
  - using less fiber content
  - IR opacifiers, such as carbon black, titanium oxide to reduce radiative component

Building retrofit applications



- Interior wall application
- Space is premium
- Easy and quick on site installation

- Exterior wall application
- Energy efficiency improvements without any reduction in living space
- Maintains building exterior appearance
- Easy and quick on site installation

http://www.aerogel.com/markets/building.html

Aerogel blanket application on the interior surface of the wall

Target R-value	Insulation Type	Retrofit Tasks and Cost ($/SqFt)							Total Cost ($/SqFt)
Interior R-4 (vs. Interior Installation)	Rigid Insulation	Framing (2x4; OC 16) [1]	Fenestration Interior Rearrengment [2]	Insulation Installation [3]	Readjustment of electric outlets [4]	Installation of gypsum board [1]	Readjustment of Radiators [5]	Living area loss by application of 2x4 interior framing [6]	
	Fiberglass Batt[8]	$0.73	$0.24	$0.57	$0.15	$0.66	$1.04	$2.00	$5.39
	Aerogel Blanket [9]	Framing (2x4; OC 16)	Fenestration Interior Rearrengment	Insulation Installation (labor & equipment) [7]	Readjustment of electric outlets [4]	Installation of gypsum board [1]	Readjustment of Radiators	Living area loss by application of 2x4 interior framing	
	Aerogel	-	-	$3.26	$0.15	$0.66	-	-	$4.07

[1] According to RS MEANS Building Construction Cost Data 2011.

[2] Includes interior trim and casing and estimated based on RS MEANS Building Residential Cost Data 2011.

[3] According to RS MEANS Building Construction Cost Data 2011; the cheapest combination of rigid board insulation thickness was assumed for the cost analysis (e.g. 9" was assumed as 3 x 3" layer instead of 4 x 2" + 1"). For PU, the thermal bridging effect was taken into account while calculating the required thickness to achieve target R-value. This cost is composed of material and labor costs. The labor cost varies from $0.43/ft^2 to $0.47/ ft^2 depending on insulation type.

[4] According to RS MEANS Building Residential Cost Data 2011.

[5] According to http://ths.gardenweb.com/forums/load/hvac/msg0219104426118.html.

[6] According to RS MEANS Building Residential Cost Data 2011, the cost per sq foot of living area of baseline house is $80.25.

[7] This cost is composed of $2.75/ ft^2 material cost and $0.51/ ft^2 labor cost. Labor cost assumed the same as 1" rigid foam board installation cost from RS MEANS Building Construction Cost Data 2011.

[8] 3 1/2" thick and R-13, according to RS MEANS Building Construction Cost Data 2011.

[9] After conversation with aerogel manufacturers and reviewing cost data, we assumed that in the short term prognosis, a cost of R-4/10mm blanket can be chosen at $2.75/ft^2.

Target of R-8 with aerogel application on interior wall

Target R-value	Insulation Type	Retrofit Tasks and Cost ($/SqFt)							Total Cost ($/SqFt)
Interior R-8 (vs. Interior Installation)	Rigid Insulation	Framing (2x4; OC 16) [1]	Fenestration Interior Rearrengment [2]	Insulation Installation [3]	Readjustment of electric outlets [4]	Installation of gypsum board [1]	Readjustment of Radiators [5]	Living area loss by application of 2x4 interior framing [6]	
	Fiberglass Batt[8]	$0.73	$0.24	$0.57	$0.15	$0.66	$1.04	$2.00	$5.39
	XPS	$0.73	$0.24	$1.82	$0.15	$0.66	$1.04	$2.00	$6.64
	EPS	$0.73	$0.24	$1.68	$0.15	$0.66	$1.04	$2.00	$6.50
	PIC	$0.73	$0.24	$1.59	$0.15	$0.66	$1.04	$2.00	$6.41
	PU	$0.73	$0.24	$1.54	$0.15	$0.66	$1.04	$2.00	$6.36
	Aerogel Blanket [9]	Framing (2x4; OC 16)	Fenestration Interior Rearrengment	Insulation Installation (labor & equipment) [7]	Readjustment of electric outlets [4]	Installation of gypsum board [1]	Readjustment of Radiators	Living area loss by application of 2x4 interior framing	
	Aerogel	-	-	$6.01	$0.15	$0.66	-	-	$6.82

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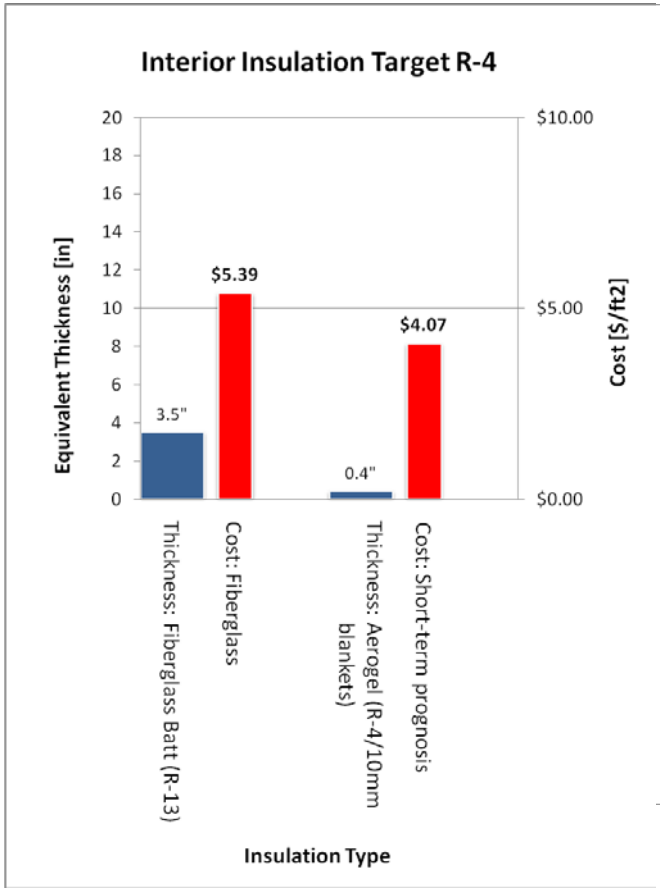
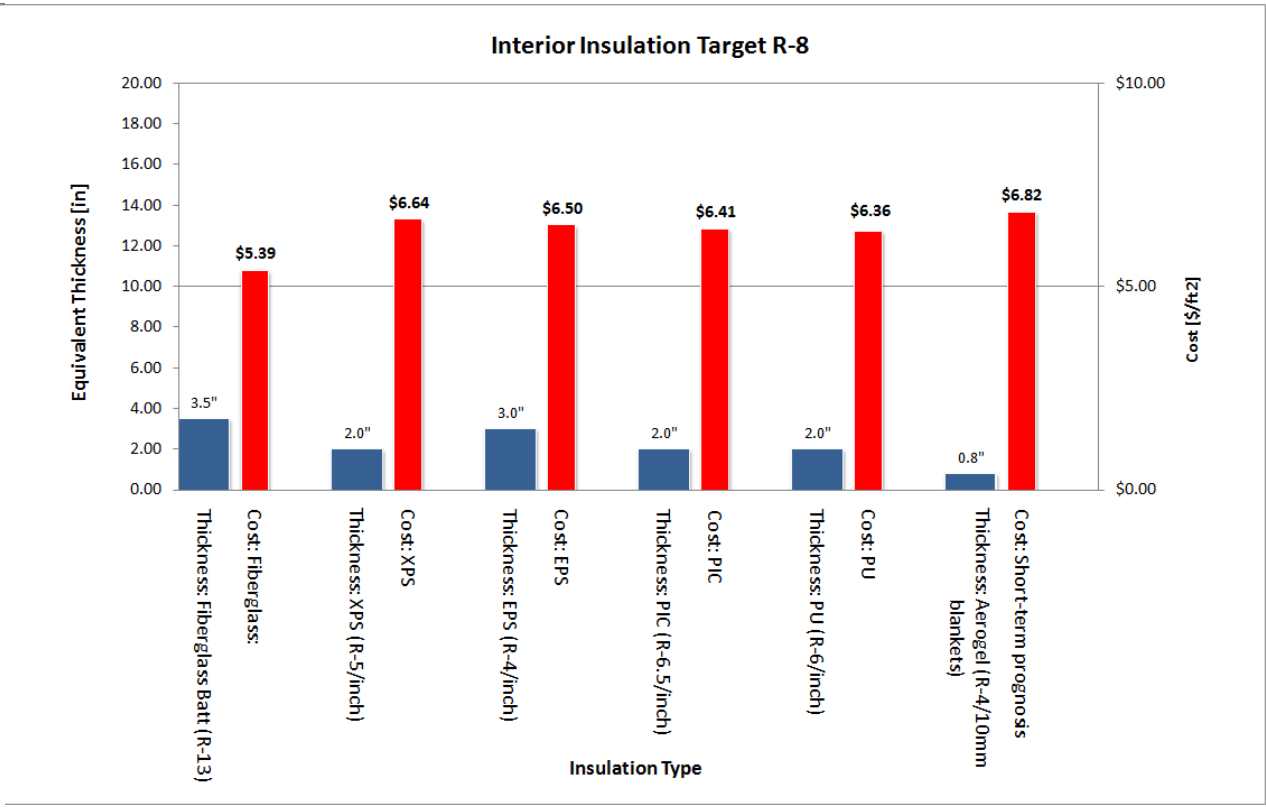
Target R-4 and R-8 with aerogel application on interior wall





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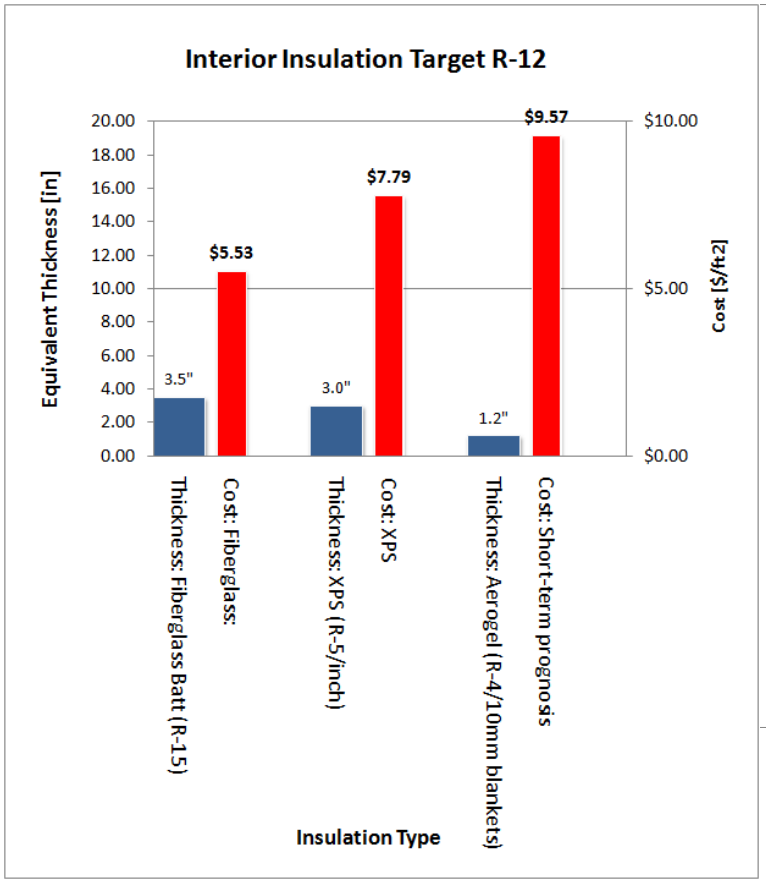
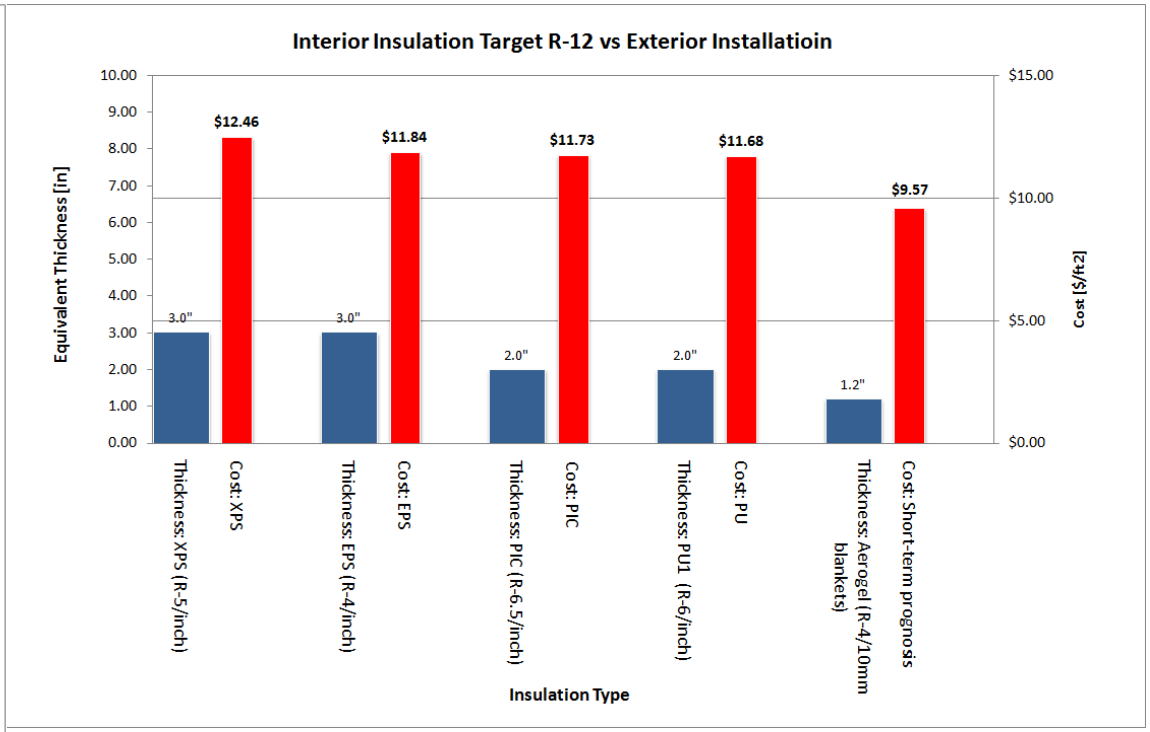
Target R-12 with aerogel application on interior and exterior wall





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Conclusions

- Aerogel production cost can be reduced by using cheaper and more abundant raw materials such as rice husk, clay, OSA etc
- Continuous batch processing and APD may be considered for further cost reduction
- Cost associated with the aerogel application in residential retrofit projects is estimated and compared to the conventional building insulations method
- Aerogel method is cost competitive for a target insulation of R-4 for both the interior and the exterior installation cases
- R-8 interior insulation is within the range of current conventional insulations prices