Is Super-Insulation Worth It?

By

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In April, 2007 a report entitled "The Insulation Dilemma: R-Value vs Real Value" by Icynene Inc., in the magazine, Home Builders was published. This report set forth the argument that super-insulating beyond current code for exterior walls was not worth the extra cost. Additional costs would not be recovered through lower fuel bills in the number of years that people normally occupy a particular residence building. At first this appears unbelievable because super-insulated passive solar houses have been built and are quite energy efficient (Shaw 2005). Many others have built similar houses and the recent Riverdale Netzero House (www.riverdalenetzero.ca) sets a new super-insulation level with R56 walls and R100 ceiling for the exterior envelope.

Single and two story houses were simulated with different levels of insulation in walls and ceiling in Hot 2000™, version 9.33 to test the argument set forth by Icynene Inc. The current and double costs of using natural gas from Direct Energy in Edmonton, Alberta were used in the simulations.

The report by Icynene Inc uses the premise that "In reality, R-8 insulation already controls 90 per cent of potential energy loss through a material". Upgrading the insulation from R-8 to R-12 or R-20 would cost $1200 and $3200, respectively. The annual savings would be $22.50/yr and $45/yr, respectively, and take 53 years and 71 years, to recover the extra cost. From this one might expect upgrading from R-12 to R20 (a more common upgrade at present) might take 18 years at an annual savings of $22.50. Attributes of the building and its environment, such as furnace efficiency, air changes per hour of the house air mass, etc were not given in the report.

On the Icynene Inc website (www.icynene.com) the Design Note (The Economic Thickness of Thermal Insulation) has more detail and appears to be the basis of the Home Builders report. In this Design Note (DN) conductive heat flow (kBtu's) through a wall of 1000 sq ft is plotted against the thickness of insulation, disregarding convective and radiant heat movements in the wall. The valid assumption is that the wall(house) has a good vapour barrier to stop convective and radiant heat movements. The percentage of the heat flow blocked by each inch of insulation with an R value of 3.6 is placed at the top of the bar for each inch of insulation. The first bar for the zero inches of insulation (= boundary surfaces) shows 100%, but is clearly slightly below 45000 Btu, a representative heat flow. The wall without insulation would still have outer and inner surface boundaries with R values of 0.2 and 0.7, respectively. Table 1, 23.3 (ASHRAE 1985) describes the boundary R value to vary at least 10 fold in relation to reflectivity of the surface and amount of air movement. Pink fiberglass insulation has valid R values/inch from 3.6 to 2.97(Alberta Agriculture, 1983; some googled websites on the internet). Such laboratory determined R value ratings are usually all legitimate because the methods of determination are governed by standard's organizations in Canada and the United States.

Table 1 shows a basis for the computation of the figure 1.1(DN). This table was produced in Excel software and is repeated here except for the deleted boundaries row of Fig 1.1(DN). The standard equation for Q (heat flow); ie, Q=Area x ΔT/R was used. The value for ΔT is a reasonable design differential between average outside and constant indoor temperature in winter. The calculations are done in the same units used for Fig 1.1(DN). The last column of Table 1 is the same as Fig. 1.1 (DN).

Table 1
Percent Conductive Heat Loss from Increased Insulation (R=3.6/inch as per Fig. 1.1 DN)

Inches	Area:sqft	ΔT	R	Sum R	Q:kBtu	Heat Saved	%	%Heat Loss
1	1000	40		3.6	8.910	36.089	80.2	19.8
2	1000	40		7.2	4.945	40.055	89.0	11.0
3	1000	40		10.8	3.422	41.578	92.4	7.6
4	1000	40		14.4	2.616	42.384	94.2	5.8
5	1000	40		18.0	2.118	42.882	95.3	4.7
6	1000	40		21.6	1.779	43.221	96.0	4.0
7	1000	40		25.2	1.533	43.467	96.6	3.4
8	1000	40		28.8	1.347	43.653	97.0	3.0
9	1000	40		32.4	1.202	43.798	97.3	2.7

However, the calculation for boundary considerations was deleted because it does not change the conclusion to which they came, but will lead you into trying to understand the weird anomaly of negative "Heat Saved" values when exploring variation in boundary R values. Only changes in insulation type and its R value, ΔT and reasonable variations from 45 Kbtu could lead to other useful conclusions.

House simulation with Hot2000™ was chosen to examine the argument against super-insulation. Hot2000™ software (www.sbc.nrcan.gc.ca/software_and_tools/) is a residential house simulator which is continually upgraded and has been validated (Haltrecht and Fraser 1997, Shaw 2005). Three each of single and two storey houses (40 ft [South side] x 25 ft, interior side of exterior wall) with basement (BCEA_4, R 15 walls and floor) were modeled. Each wall had one (two for two storey house) clear triple pane square window (16 ft^2, R-2.49). The north side had one standard door (R10). Only, the R value of walls and ceiling were varied between simulators (Table 2). Air Tightness level of 1.5 ACH at 50 Pa, a heat return ventilator and a 90% steady state efficient, condensing furnace were used in all simulations. Default values provided by the software were used for other energy using aspects such as air conditioning. The indoor temperature of the main floor was set at 72 degrees F.

Only a few effect data for the two storey simulators are shown (Table 2).

Table 2

Annual Effects of Wall & Ceiling R Value: Input and Output Data for Hot2000™ Simulators

Variable	Base R House 1	+ R wall House 2	% Reduction	++ R ceiling House 3	% Reduction
R (W/C)	20/40	60/40		60/80	
% HeatLoss-W	20.3	7.8	12.5	8.9	11.4
% HeatLoss-C	8.02	9.3		5.5	2.5
% HeatLoss –M	39.4	29.9	9.5	29.1	10.3
% HeatLoss –B	32.4	37.4		33.2	
% HeatLoss –V	28.3	32.7		37.7	
DHL(Btu/hr/ft^3)	1.80 (2.32)	1.60 (1.95)	**11.1 (15.9)**	1.44 (1.88)	**20.0 (19.0)**
NG Use (Mft^3)	69.6 (91.3)	58.81(71.5)	**15.5 (21.7)**	50.43 (68.3)	**27.5 (25.2)**
GGemission(t/yr)	10.31	9.73	5.6	9.21	**10.7**
Electricity(kWhr)	12208	12184		12041	
Cost NG at 8$/Gj	*792 (974)*	*700 (807)*	12 (17)	629 (780)	**20.4 (20)**
Cost NGat16$/Gj	*1283 (1648)*	*1100 (1314)*	14 (20)	959 (1261)	**25.2 (24)**
Cost Electricity	1402	1400.0		1386.4	

W: wall, C: ceiling, M: main floor, B: basement, V: ventilation, DHL: winter design heat loss at -25.6 F, NG: natural gas, GG: greenhouse gas, 1 storey (2 storey) values.

Just saving energy and green house gas emissions of 27% and 10%, respectively (Table 2) may be the major worth of super-insulating.

Using the values in the third and second last rows of the above table the expected cumulative dollar savings per year of increased insulation levels are shown in the following Table 3.

Table 3

Natural Gas Cumulative Cost Savings ($/Gj) per Year for House H2 vs 1 & House H3 vs 1

	←----------single storey--------→					←----------two storey--------→			
Year	$8/Gj	$8/Gj	$16/Gj	$16/Gj		$8/Gj	8$/Gj	$16/Gj	$16/Gj
Houses	2 vs 1	3 vs 1	2 vs 1	3 vs 1		2 vs 1	3 vs 1	2 vs 1	3 vs 1
1	92	163	183	324		167	194	334	387
2	184	326	366	648		334	388	668	774
skip	--------	-------	-------	-------		-------	-------	--------	--------
7	644	1141	***1281***	2268		1169	1358	***2338***	2709
8	736	1304	1464	***2592***		1336	1552	2672	3096
9	828	1467	1647	2916		1503	1746	3006	3483
10	920	1630	1830	3240		1670	1940	3340	***3870***
skip	--------	-------	-------	-------		------	-------	-------	-------
13	1196	2119	2379	4212		2171	2522	4342	5031
14	***1288***	2282	2562	4536		2338	2716	4676	5418
15	1380	***2445***	2745	4860		***2505***	2910	5010	5805
skip	-------	-------	-------	-------		------	-------	-------	-------
19	1748	3097	3477	6156		3173	***3686***	6346	7353

92=792-700 from Table 2. 644=year7*92.

The years to recovering only the cost of insulation are indicated by bolded values.

In June of 2008 the cost of pink fiberglass batts of insulation was obtained from a retail home builder supplier (Table 4).

Table 4
Pink Fiberglass Batt Attributes in June 2008: Single and Double Wall(DW) Construction

Batt Dimensions	4'.15".6.7"	4'.23".6.7"	DW	DW	Ceiling:House 3
Cost:#batt/bag	29.77:10	46.77	-	-	-
R (RSI) Value	20 (3.5)	20 (3.5)	40 (7.0)	60 (10.6)	80 (14.1)
Usual Cavity Depth	5.5"	5.5"	11 – 13"	16.5-20"	4 layers of R20
$ Cost/sqft	0.60	0.61	1.22	1.83	2.44

Higher R valued insulation costs more per square foot (ie R28 is $0.95). The insulation values are marked on the bags. The effective insulative value in a wall cavity will be less because of slight compression in the single wall and adjustments for thermal bridging to the extent you don't avoid it by construction techniques. The thickness of an uncompressed R 20 batt of pink fiberglass could vary from 6.7 (20/2.97) to 5.5 for batts of R=3.6/inch.

Table 5
Total Cost of Insulation ($$) for Simulator Houses 1, 2 and 3:
Insulated Areas(sqft): Walls -1071.5 or 2065.6, Ceiling- 999.9.

		←-----	1 storey	------→		←----	2 storey	-----→
House #	R Value	Walls	Ceiling	Cost		Walls	Ceiling	Cost
1	20/40 standard	654	1220	1874		1260	1220	2480
2	60/40 high	1961	1220	3181		3780	1220	5000
3	60/80 highest	1961	2440	4401		3780	2440	6220

654=1071.5*0.61 from table 4, 1260=2065.5*0.61

The extra cost of insulation alone to build house 2 compared to the standard house would be $**1307** at today's $8/Gj (Table 5, 3181-1874). Similarly, the extra cost of insulation for house 3 over the standard cost would be $**2527**. Similar figures for the two storey house would be $**2520** and $**3740**, respectively. Now go back to Table 3 to find the years closest these bolded values. For the single storey house it takes 14-15.5 years to recover the costs of super-insulating. But if gas prices double it only takes 7-8 years. Similarly, the values for the two storey house are 15-19 and 7.5-10 years, respectively.

Icynene Inc did not specify the type of insulation or its cost (Home Builder, 2007) so comparisons are not possible. But, from both their report and this paper, the conclusion is that one should plan to live in a super-insulated house many years longer than most people occupy a house (5-8 years thumb rule from a realty statistics person) in order to recover the current costs of super-insulating.

This is not the only numerical method of examining the benefit cost relationship (see RETScreen software: www.sbc.nrcan.gc.ca) nor does the method consider the costs of extra structural materials or of labor to do the additional work. To the extent that these increase the cost of super-insulating, the number of years to recover the extra costs of super-insulating will increase and perhaps double if you are not using "sweat equity" as a single retail buyer. In the residential construction industry some builders are starting to build whole wall sections in factories to lower costs and improve quality. In addition, labour and material costs undoubtedly would be lower for commercial builders than for non-trades people buying at retail outlets. So, for building a home there are many factors to consider before determining how long you must live in the home to recover the costs of super-insulating.

These methods of analyzing cost benefit relationships in the construction of buildings can be used for individual applications such as an energy star appliance vs an "old clunker". The relative performance of each should be compared in building simulation software with known bias in order to get the best estimate of potential savings.

In several countries realty valuation is beginning to include energy efficiency in the sale price of homes. Placing an 'Energy Star' or 'Energuide' rating on a house may be the way in future realty. Such a scheme would favor the earlier recovery of super-insulation costs.

Hot2000™ is a good building simulator for low-rise residences. Larger multiunit residences such as are built for apartments or retirement homes should be modeled with newer versions of "ee4" and other such software (www.sbc.nrcan.gc.ca). It may be that a builder/owner(person paying fuel bills for 25-50 years) should super-insulate. Governments and retirement home owners paying the fuel bill for such large buildings should have software output data interpreted by a knowledgeable third party on this super-insulation question before spending money on construction.

It is encouraging to see that the Alberta government adopted the LEED Silver standard (includes "high performance building envelope") for the design of new government-funded buildings (Alberta News Release, May 11, 2006).

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