

(EMBODIED) ENERGY IN RESIDENTIAL BUILDING CONSTRUCTION

A house requires energy for its operation. Keeping warm in winter or reading a book at bedtime takes oil from the tank or electricity through the meter. During the past 15 years, a lot of effort has been allotted to reducing this operational energy demand. It has been the focus of energy conservation programs worldwide. But there is another type of energy investment in buildings. It is the energy required for their construction: for the manufacture of components, their transportation to, and erection at, the chosen site. This has been called the embodied energy of a building, and it amounts to roughly the one quarter (25%) of the operational energy requirement over the life of the structure. This is quite a bundle, and the bundle gets proportionally bigger if the building is designed, constructed, and managed efficiently. Such an operationally efficient building may see more than half of its total lifetime energy requirement committed before the occupants even move in. The embodied energy therefore is a significant part of the lifetime total.

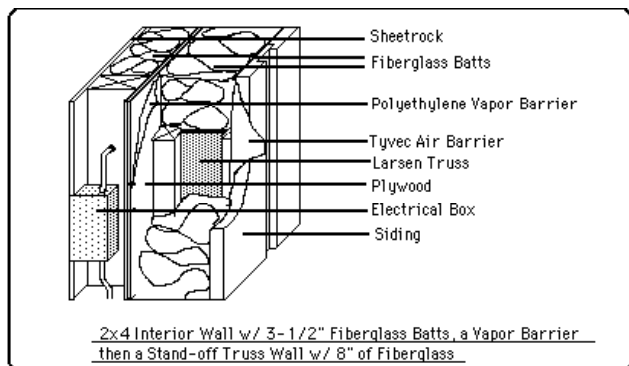
Let's look more closely at this energy vested in construction. Firstly, do not confuse embodied energy of a building component, as we are considering it here, with its potential value as fuel. Take a 2x4 stud, for example. Energy has been "embodied" in the stud through the felling of the tree, the milling, the shipping from the mill to the lumber yard and from the lumber yard to the construction site, and finally with its transformation from a stick on a pile to a functioning component of a framed structure. It also has a prorated share of the capital energy in the sawmill equipment used to mill it, and the transport system used to ship it. Furthermore, it has its share of the energy required to sustain the workers who have contributed to its evolution along the way. It is all part of the cost -the energy cost- of production which, in the case of our humble 8'0" length of 2x4, is about 40,000 Btu's. If, on the other hand, we were to burn the stud - that is to convert the biomass store of solar energy of the spruce/pine to heat - it would yield about 10,000 Btu's. Now that might be all you can do with some sticks off the lumber pile these days, but by burning them you are not retrieving their embodied energy. You are releasing a store of sunshine that was in the tree. The energy embodied in the manufacture of a building component is essentially a measure of non-renewable fossil fuel consumed.

During the 1970's a major study was undertaken using data gathered and reported by the Bureau of Economic Analysis of the U.S. Dept. of Commerce. The study identified the embodied energy requirements for over 400 different building materials and products

It is a particularly valuable store of information and has been largely neglected in the years since its publication.

To show the value of this storehouse of data, I have prepared some representative residential

construction wall sections. There are six of them. Each diagram shows a typical one square foot "core sample" through the wall and below it, values for thermal resistance, cost, and embodied energy are tabulated for each material component.



Double Stud Wall or Larsen Truss Wall with Fiberglass Insulation.

Construction	R Value/sq.ft.	\$ Cost/sq.ft.	Embodied Energy in Blg. Section (10 ³ Btu/sq. ft.)
Outside surface	0.17	-	-
Paint (2 coats oil-based)	-	0.25	2.8
Wood siding	0.87	2.00	7.3
TYVEK	-	0.04	1.0 (Est.)
Plywood sheathing (1/2")	0.62	0.70	7.7
Wood framing (2/2x4@ 24"oc)	-	2.00	6.8
Fiberglass (12")	38.0	0.79	20.5
Polythene A/v. barrier (6 mil)	-	0.06	1.5
Gyp. Board (1/2")	0.45	0.45	7.0
Paint (2 coats latex)	-	0.25	1.8
Inside surface	0.68	-	-
TOTAL	40.79	6.54	56.4

Illustration: Terry Brennan, Camroden Assocs.

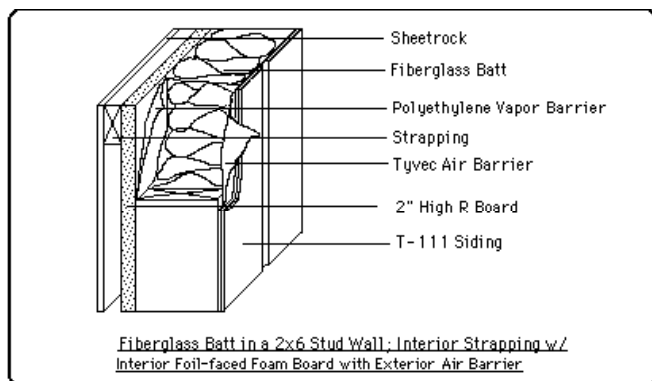


Illustration: Terry Brennan, Camroden Assocs.

Fiberglass Insulated Wood Stud Wall with Strapping and Rigid Insulation

Construction	R Value/sq.ft.	\$ Cost/sq.ft.	Embodied Energy in Blg. Section(10 ³ Btu/sq. ft.)
Outside surface	0.17	-	-

Paint (2 coats oil-based)	-	0.25	2.8
Wood siding (clapboards)	0.87	2.20	7.3
TYVEK	-	0.04	1.0 (Est)
Plywood sheathing (1/2")	0.62	0.70	7.7
Wood framing (2x6 @ 24"oc)	-	1.00	7.6
Fiberglass (6")	19.0	0.45	10.5
Polythene A/v. barrier (6 mil)	-	0.06	1.5
Rigid insulation (1" isocyanurate)	7.2	0.47	20.0 (Est.)
Aluminum foil facing both sides	-	-	3.5
Wood strapping (1x3)+ air space	1.0	0.30	2.0
Gyp. Board (1/2")	0.45	0.45	7.0
Paint (2 coats latex)	-	0.25	1.8
Inside surface	0.68	-	-
TOTAL	30.0	6.17	72.7

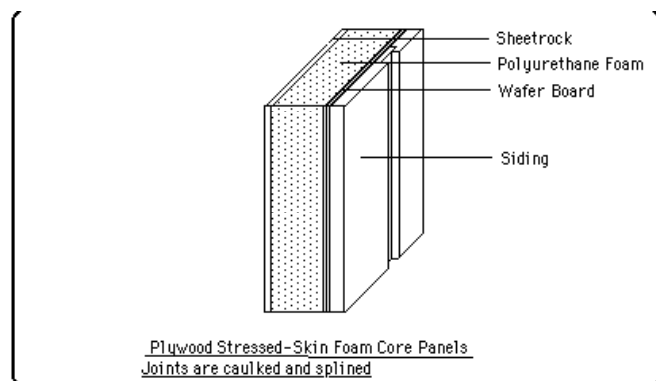


Illustration: Terry Brennan, Camroden Assocs.

Plywood Foam Core Stressed Skin Panel Wall

Construction	R Value/sq.ft.	\$ Cost/sq.ft.	Embodied Energy in Blg. Section(10 ³ Btu/sq. ft.)
Outside surface	0.17	-	-
Paint (2 coats oil-based)	-	0.25	2.8
Wood siding	0.87	2.00	7.3
Waferboard skin (3/8")	0.50	-	6.0 (Est.)
Polystyrene insulation core (6")	25.0	3.50	92.0
Waferboard skin (3/8")	0.50	-	6.0 (Est.)
Gyp. Board (1/2")	0.45	0.45	7.0
Paint (2 coats latex)	-	0.25	1.8
Inside surface	0.68	-	-
TOTAL	28.17	6.45	122.9

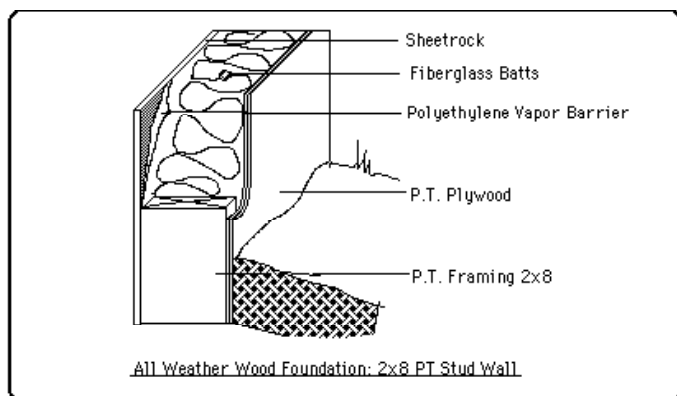


Illustration: Bruce Coldham

All-Weather Wood Retaining Wall with Fiberglass Insulation

Construction	R Value/sq.ft.	\$ Cost/sq.ft.	Embod. Energy in Blg. Section(10 ³ Btu/sq. ft.)
Outside surface	0.17	-	-
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Earth Berm			
P.T. Plywood sheathing (1/2")	0.62	0.90	7.7 (+ pres. treat.)
Wood framing (2x8 @ 16"oc)	-	1.50	10.1 (+ pres. treat.)
Fiberglass (8")	27.0	0.65	14.0
Polythene A/v. barrier (6 mil)	-	0.06	1.5
Gyp. Board (1/2")	0.45	0.45	7.0
Paint (2 coats latex)	-	0.25	1.8
Inside surface	0.68	-	-
TOTAL	28.92	3.81	42.1 (+ pres. treat.)
	(+earth berm)		

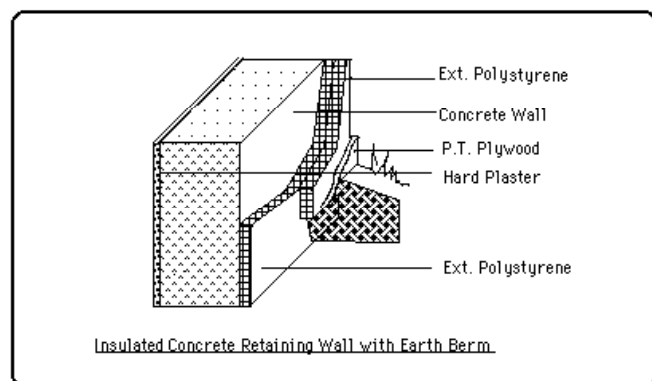


Illustration: Bruce Coldham

Concrete Foundation Wall with Exterior Rigid Insulation

Construction	R Value/sq.ft.	\$ Cost/sq.ft.	Embod. Energy in Blg. Section(10 ³ Btu/sq. ft.)
Earth Berm	-	-	-
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1/2" P.T. Plywood	0.62	0.90	7.7 (+pres. treat.)
4" Extruded Polystyrene	21.0	1.50	61.0
Concrete Wall	1.6	6.15	64.0

Plaster (1/2")	0.45	0.80	7.0
Paint (2 coats latex)	-	0.25	1.8
Inside surface	0.68	-	-
TOTAL	24.35	9.60	141.5 (+pres. treat.)
	(+earth berm)		

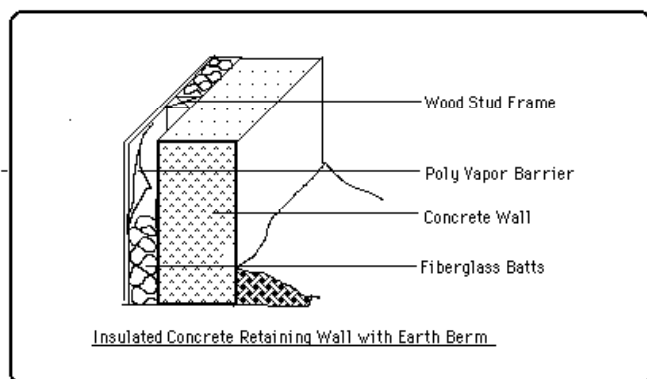


Illustration: Bruce Coldham

Concrete Retaining Wall with Interior Fiberglass Insulation

Construction	R Value/sq.ft.	\$ Cost/sq.ft.	Embod. Energy in Blg. Section(10 ³ Btu/sq. ft.)
Earth Berm	-	-	-

8" Concrete Wall	1.6	6.15	64.0
Wood framing (2x6 @ 24"oc)	-	0.80	7.6
Fiberglass (6")	19.0	0.45	10.5
Polythene A/v. barrier (6 mil)	-	0.06	1.5
Gyp. Board (1/2")	0.45	0.45	7.0
Paint (2 coats latex)	-	0.25	1.8
Inside surface	0.68	-	-
TOTAL	21.73	8.16	92.4
	(+ earth berm)		

Quite a few conclusions can be drawn from the data offered. Three stand out. First, it's clear that not all materials are created equal; some have absorbed a good deal more energy in their manufacture than others. Look at concrete for example. It has three or four times the energy content of a wood framed wall, a factor which perhaps makes a permanent wood foundation system more attractive, and, from an embodied energy viewpoint, places a primarily concrete earth sheltered house behind the eight ball.

Another look reveals that in all the wood framed wall sections, it is the insulation that comprises the bulk of the energy embodiment.

Now compare the \$ Cost/s.f. column with the Embodied Energy column: fig. 3 will help out. Notice that the three above-grade wall systems all cost about the same in dollars whereas the

double wall job has less than half the embodied energy. By the way, it also has by far the higher thermal resistance.

A third important observation can be made by comparing the first (thermal resistance) and third (embodied energy) columns of the tabulation.

The R-Value is a strong indicator of operational energy requirements since (in the Northeast at least) space heating usually comprises such a large proportion of annual residential energy consumption.

For simplicity's sake, let's consider two wall sections which are not specifically diagrammed here, but which are of simpler construction. These are a basic 2x4 stud wall with 3 1/2" batt insulation and a 2x6 basic stud wall with 5 1/2" of batt insulation. The Table below compares embodied and operational energy for the two alternative residential shells. (It is abridged from Bruce Hannon's article in Science)

	Annual Energy Demand (106 Btu/s.f.)	Energy Embodied (106 Btu)
2x4 walls with 3 1/2" insulation (roof with 5 1/2" insulation)	102	172
2x6 walls with 5 1/2" insulation (roof with 11 1/2" insulation)	77	188

Difference	25	(16)

Comparison of investment options (long term savings vs. short term savings) can be made using base units of Btu's as well as dollars. The Table shows that the embodied energy in a modest increase in insulation and wall construction is recovered in less than one heating season from savings in operational energy.

This payback is fast. The original investment is recovered within the first 1-2% of the life cycle of the structure. It is also a static determination. It doesn't fluctuate. If this energy payback was true in 1978, it is still true in 1998, and will hold into 2008 and beyond. Calculations of energy payback, and the energy investment prudence that flows from their assessment, are not made uncertain by the volatility of the commodity as are those similar calculations based upon the dollar prices of a Btu of oil or gas.

For further information consult the follow references:

Hannon, Bruce et al, "Energy and Labor in the Construction Sector" *Science* Vol. 202, 24 Nov. 1978;

Richard G. Stein et al, "Handbook of Energy Use for Building Construction" NTIS DOE/CE/20220-1 March 1981