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Reducing Environmental Consequences of Residential Construction through Product Selection and Design

Lucy Edmonds and Bruce Lippke

In recent years, members of the public and the building industry have shown increased interest in reducing environmental impacts through residential building design. The response to this has largely focused on designs that attempt to reduce heating and cooling requirements over the course of a building's lifetime. Often overlooked, however, are opportunities to reduce fossil fuel use and other environmental impacts at earlier and later stages in the building design process. Product selection and design provide substantial opportunities to reduce environmental burdens.

CORRIM, the Consortium for Research on Renewable Industrial Materials, (www.corrim.org) illustrated the presence of significant differences in energy consumed and environmental impacts associated with resource extraction, materials production, transportation, and disposal among homes built using different materials and processes. The 2004 CORRIM study showed that the energy consumed during the production of a representative steel framed house in Minneapolis is 17% larger than for a wood framed house.

A more recent report extends the CORRIM findings by assessing the environmental burdens of each component used in the wall and floor subassemblies in the construction of a house. Evaluating the environmental impacts of each component in the design of a subassembly clarifies which components and configurations contribute the greatest environmental burden and provides specific information on how one might change products and/or processes in residential building design to substantially reduce environmental burdens.

ATHENA™ Environmental Impact Estimator (EIE), a software package designed to assist architects in evaluating the environmental burdens of buildings (www.athenasmi.ca), was used to design wall and floors subassemblies and to calculate the energy and environmental impacts associated with the different materials included in each of the designs. Included in the data produced by EIE were impacts associated with material extraction (e.g. mining iron and coal for steel or harvesting wood for lumber), production (e.g. process energy for steel and or lumber production), transportation (both to the manufacturing facility and from the manufacturing facility to the construction site) and disposal (e.g. demolition and disposal).

Global warming potential, air and water pollution and solid waste are all considered important environmental burdens and all are covered in the CORRIM study however fossil fuel consumption tends to be the most important single indicator and will be the focus of this fact sheet. The following tables demonstrate the extent to which fossil fuels consumed during the processes leading up to a home's occupation as well as its eventual disposal can differ dramatically among different exterior wall and floor designs.

Table 1 shows the fossil fuel energy per square foot consumed by three different exterior wall designs for a cold climate home. Figures in Table 1 were arrived at by using Athena EIE software to design 2,000 square feet of exterior wall area under three different design scenarios. Two thousand square feet of exterior wall area is considered average for a home in Minneapolis – which is taken as the representative cold climate locale. Each of the exterior wall designs are built to Minneapolis local code (R19 insulation).

Columns two through four in Table 1 represent the wall designs. The final row, "TOTAL", contains the total mega joules of fossil fuels per square foot (MJ/ft^2) consumed by each design. The three preceding rows, "Structural", "Insulation", and "Covering" represent categories of building materials that, when added up for each design, amount to the Total MJ/sq ft for that design.

Table 1. MJ/ft^2 of fossil fuels consumed by three exterior wall designs in a cold climate home.

	Exterior wall designs for cold climate home		
	Lumber wall (MJ/ft^2)	Steel wall (MJ/ft^2)	Lumber wall with additional wood product substitutes (MJ/ft^2)
Structural [a]	9.54	15.22	4.82
Insulation [b]	12.63	21.02	5.45
Covering [c]	22.42	22.42	2.91
TOTAL [d]	**44.59**	**58.66**	**13.18**

[a] Includes studs and plywood sheathing. For the third design, Lumber wall with substitutes, lumber and plywood are produced with higher than average levels of biofuels.

[b] Includes fiberglass (Lumber wall and Steel wall designs), extruded polystyrene (Steel wall design only), and insulation created with recycled paper products (Lumber wall with substitutes). All three designs include a six mil polyethylene vapor barrier.

[c] Includes interior and exterior wall coverings. Exterior wall coverings for Lumber wall and Steel wall are vinyl cladding and interior wall coverings are gypsum. Half-inch thick plywood (produced with higher than average levels of biofuels) serves as the exterior wall covering for Lumber wall with substitutes. Quarter-inch thick plywood (produced with higher than average levels of biofuels) replaces gypsum as the interior wall covering for the Lumber wall with additional substitutes.

[d] Includes subtotals from Structural, Insulation, and Covering categories.

The first exterior wall design in Table 1, "Lumber wall", represents a typical wood-based exterior wall frame design. The Lumber wall design uses 2X6 kiln-dried lumber studs, vinyl siding, gypsum covering, fiberglass insulation, and plywood sheathing. "Steel wall", represents a typical steel-based exterior wall design. The Steel wall design uses 2X4 steel studs, vinyl, gypsum, fiberglass and extruded polystyrene insulation and plywood sheathing. While the Lumber wall uses a wider stud to house the fiberglass insulation, the narrower steel design requires a layer of extruded polystyrene to achieve the same thermal rating. The designs' different studs and insulation creates a significant difference in the amount of fossil fuels required. Selecting the Lumber wall instead of the Steel wall achieves a 24% reduction in fossil fuel consumption per square foot.

The design presented in the fourth column of Table 1, "Lumber wall with additional wood product substitutes," represents a "hypothetical" cold-climate wall design with drastically reduced fossil fuel consumption achieved through product and process energy substitution. This design includes 2X6 kiln-dried wood studs produced using above average levels of biofuels (generally available from scraps and low valued products such as beauty bark) and substitutes ½" plywood for vinyl siding and ¼" plywood panels for the gypsum covering. Recycled paper-based insulation replaces fiberglass. The plywood used in this design, like the kiln-dried lumber, is produced using above-average levels of biofuels. The substitutions incorporated into this hypothetical wall design add up to a substantial reduction in fossil fuel consumption (70-80%) if selected in place of either of the two more traditional designs. Comparison of the three different exterior wall designs in the Minneapolis house suggests that substantial reductions in fossil fuel use and related environmental burdens are possible through product and process substitution.

Fossil fuel requirements were derived for two other cold climate wall designs not shown in Table 1. The first of these two designs was identical to “Lumber wall” except that its studs were green rather than kiln-dried. This Green lumber wall’s fossil fuel requirements were 41.09 MJ/ft^2 - approximately 8% less than for the kiln-dried “Lumber wall”. The second of these designs was identical to the “Lumber w/substitutes” design except that oriented strand board (OSB) replaced plywood in the sheathing, and the interior and exterior wall coverings. This OSB Lumber w/substitutes design required 18.16 MJ/ft^2 - about 38% more fossil fuel energy per square foot than the plywood-based “Lumber w/substitutes” design but still 60-70% better than either of the traditional designs shown in Table 1.

Fossil fuel consumption associated with two exterior wall designs based in an Atlanta house were evaluated as an example of a warmer climate. The prevalent alternative to wood in the warmer climates is concrete. The second column in Table 2, “Lumber wall”, represents the warm-climate’s wood-based exterior wall design. The major differences between the two Atlanta exterior wall designs are the Concrete wall’s use of concrete block and stucco siding versus the Lumber wall’s use of plywood sheathing and vinyl siding. Both are designed to the same R-13 insulation standard. If the Lumber wall design is selected instead of the Concrete wall, fossil fuel consumption is reduced by 60%.

Table 2. MJ/ft^2 of fossil fuels consumed by two exterior wall designs in a warm climate home.

	Exterior wall designs for warm climate home	
	Lumber wall (MJ/ft^2)	Concrete wall (MJ/ft^2)
Structural[a]	6.27	75.89
Insulation[b]	8.51	8.51
Cladding[c]	22.31	8.09
TOTAL [d]	**37.09**	**92.49**

[a] Includes studs and plywood sheathing for the Lumber wall design and concrete blocks and studs (used in a furred-out wood-studs wall) for the Concrete wall design.

[b] Includes fiberglass and six mil polyethylene vapor barrier for both warm climate designs.

[c] Includes interior and exterior wall coverings. Exterior wall coverings are vinyl (Lumber wall design) and stucco (Concrete wall design). Interior wall coverings gypsum for both warm climate designs. .

[d] Includes subtotals from Structural, Insulation, and Covering categories.

Environmental burdens are also affected by the fact that different building assemblies favor different material properties – e.g. floors require much greater stiffness than walls. The fossil fuel requirements per square foot of floor (MJ/ft^2) shown in Table 3 were derived by designing a 768 ft^2 floor which represents the area of a home’s main level. Surface materials such as carpet, hardwood and terrazzo were excluded, as was insulation. The figures in Table 3 demonstrate the greater disadvantage suffered by steel when it is used in floor systems. The floor’s requirement for stiffness results in the use of higher gage steel than needed for the wall. Although not shown in Table 3, fossil fuel consumption was also calculated for an engineered wood product floor design with I-joists comprised of an LVL flange and OSB web. The fossil fuel requirements were almost identical to those of the dimension wood joists floor design since the savings in wood use is offset by the increase in energy needed to produce the materials used to make the I-joist. Selecting the dimension wood joist floor instead of the concrete slab or the Steel joist floor results in a reduction in fossil fuel consumption of 60% and 79%, respectively.

Table 3. MJ/ft^2 of fossil fuels consumed by three floor designs.[a]

	Floor designs		
	Dimension wood joist floor (MJ/ft^2)	Concrete slab floor (MJ/ft^2)	Steel joist floor (MJ/ft^2)
TOTAL	**9.93**	**24.75**	**48.32**

[a] Excludes any consideration for insulation.

This sampling of materials and designs is not exhaustive but suggests design, product and process changes that can improve environmental performance. The most obvious include selecting renewable wood products in place of alternative products that require greater amounts of fossil fuels, using biofuels to replace fossil fuels for the drying process in lumber and wood panel production, and using recycled materials that require less fossil energy in their remanufacture. The results also identify highly consumptive components within building subassemblies where future improvement efforts should be focused.

The availability of energy sources serving each region of the country differs as well as the production process for making products, energy sources and the processes used to handle different species. Therefore, while many of the impacts demonstrated here can be expected to be important in any region, regional differences may exist.

The findings shown here represent only a small portion of CORRIM findings. The complete report includes other environmental indices including global warming potential, and air emissions – both of which are closely linked to fossil fuel consumption; and also water emissions and solid waste.

Contacts: For more information, visit the CORRIM website at www.corrim.org, or contact Bruce Lippke or Lucy Edmonds, College of Forest Resources, University of Washington, BOX 352100, Seattle, WA 98195, (206) 543-0827, blippke@u.washington.edu.