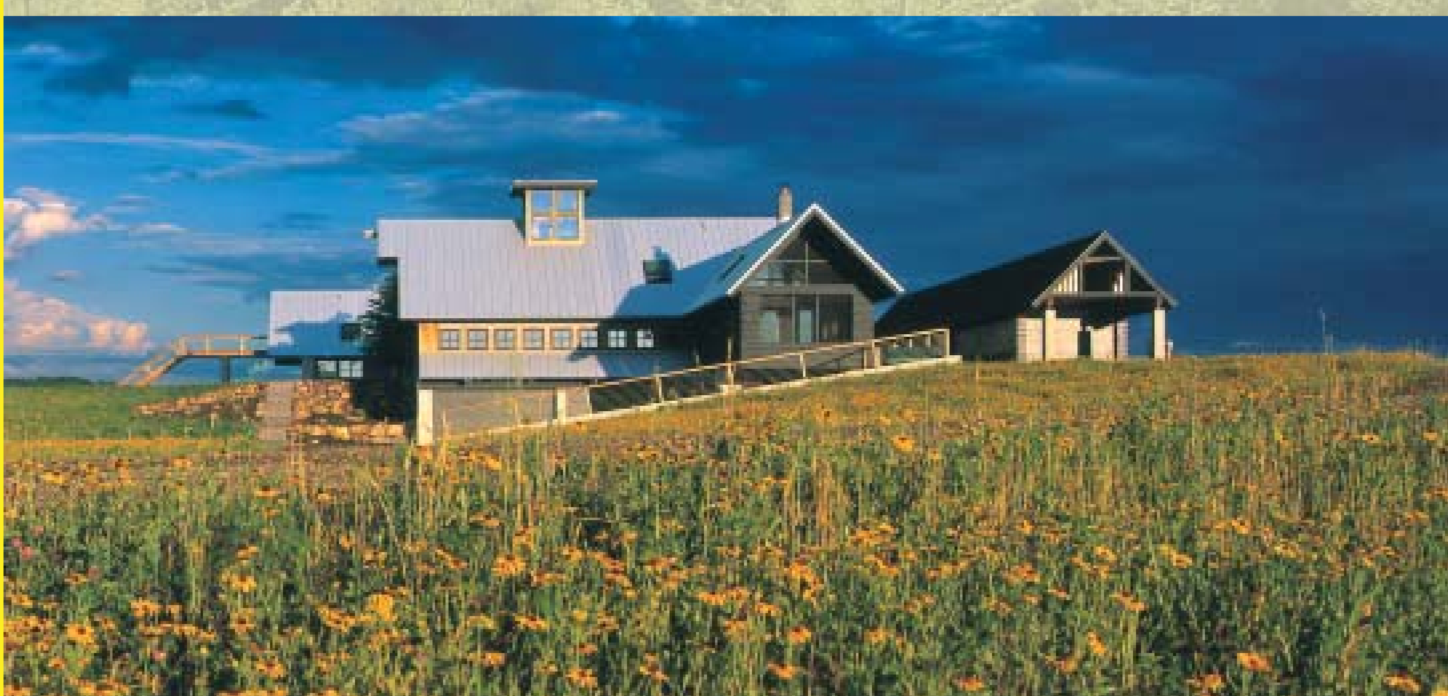
Canadian Wood Council
Conseil canadien du bois

Sustainable Building Series | **No. 1**

Energy and the Environment

IN RESIDENTIAL CONSTRUCTION



Introduction

The oil embargoes of the 1970s resulted in energy conservation guidelines and codes. National policies respond to climate change concerns and sustainability issues that arise from the burning of fossil fuels, air pollution and concerns surrounding global warming.

There are complex issues surrounding the concept of sustainability. Immediate actions to address the environmental impacts of buildings and construction focus on the reduction of construction waste and the reduction of energy consumption in buildings.

The operating energy use in buildings represents a major contributor to fossil fuel use for space heating and cooling, lighting and the operation of appliances. Fossil fuels release greenhouse gases such as carbon dioxide and nitrous oxide. For this reason, the need to save energy by reducing operating energy consumption in buildings is widely recognized throughout the world.

Less attention has been given to the need to reduce the embodied energy of structures because the amount of embodied energy is small in comparison to the amount of operating energy over a building's life cycle. Nevertheless embodied energy results in considerable emissions of water pollutants to our rivers and oceans and emissions of air pollutants contributing to air pollution and greenhouse gas emissions.

In the 1990's, the Canadian Wood Council launched "Wood the Renewable Resource", a series of publications for architects, engineers, cost consultants and clients, examining how building products affect the environment through their life cycle. Building upon this start, this publication provides new life-cycle assessment (LCA) data and offers an updated comparison study by presenting data for both the embodied energy and operating energy of three 2,400 sq. ft. single-family homes.

Sustainable Buildings

Sustainability

The relationship between the principles of sustainable development and the construction sector includes similar challenges: environmental quality, energy conservation, resource efficiency and human health.

To date, there is not one single definition of sustainable buildings or sustainable construction that is accepted worldwide and the most frequently quoted definition of sustainable development is that of the United Nations World Commission on Environment and Development (1987): "The ability of humanity to ensure that development meets the needs of the present without compromising the ability of future generations to meet their own needs."

While sustainable building guidelines and building rating systems aim to reduce the environmental impacts of buildings, none assess the total impact of a building on the environment.

Decision makers need reliable data for the development of policies and performance-based standards that will become the benchmark of environmental values. With scientific measurements, such as life cycle assessment, one can move from prescriptive-based thinking to performance-based criteria. By creating performance-based criteria, we can create a sensible road to sustainability.

Operating and Embodied Energy

According to the International Energy Agency, comprised of 22 countries that include both the United States and Canada, on average, one-third of operating energy usage in the developed world goes for heating, cooling, lighting and the operation of appliances in non-industrial buildings such as homes, offices, hospitals and schools. These estimates do not take into account the amount of embodied energy in building products and its impacts on the environment.

Operating energy efficiency in residential and commercial buildings is greatly enhanced in highly insulated and airtight building envelope systems, high performance windows, high-energy efficiency heating, cooling and water heating equipment, low energy lighting and energy efficient home appliances.

Increased insulation in foundations, walls and attics, and insulated doors and windows reduces the operating energy in buildings. However the need for insulating products contributes to higher embodied effects.

Wood is a good and natural insulator. Due to its cellular structure, wood traps air resulting in low conductivity and good insulating properties. Steel conducts heat 400 times faster than wood. High conductivity causes thermal bridging leading to increased energy use for heating and cooling. Because steel and concrete must overcome lower R-values due to thermal bridging, there is a need for additional insulation.

Understanding the need to reduce operating energy in buildings and the importance of the embodied energy of structures leads to a more rigorous approach to sustainability. While it is easier to focus solely on the conservation of operating energy, the effects of embodied energy in structures, such as global warming potential, solid wastes, air and water pollution, are significant. Of the major building materials, wood requires the least energy to produce.

The initial embodied energy in buildings represents the energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to the site, and construction. The initial embodied energy has two components. The direct energy, that is the energy used to manufacture and transport building products to the site and to construct the building. The indirect energy is the energy use associated with processing, transporting, converting and delivering fuel and energy to its point of use.

The recurring embodied energy in buildings represents the non-renewable energy consumed to maintain, repair, restore, refurbish or replace materials, components or systems during the life of the building.

As buildings become more energy-efficient the ratio of embodied energy to lifetime operating energy consumption becomes more significant.

Life-Cycle Assessment (LCA)

Life-cycle assessment (LCA) is the recognized international approach to assess the environmental merits of products or processes as set out in the ISO 14000 series of standards.

LCA includes the entire life cycle of a product, process, or activity, from extracting and processing raw materials to manufacturing, transportation and distribution, use, maintenance, recycling and final disposition.

It includes environmental impacts such as acid rain, air pollution, ecological toxicity, fossil fuel depletion, global warming, habitat alteration, human health, indoor air quality, ozone depletion, smog, and water intake (current cradle to grave system). Based on LCA, wood products have proven to be one of the most environmentally responsible building products.

In the concept of cradle to cradle, where materials are designed to be returned safely to the soil or to flow back to industry to be used again, wood is a material that can be recycled or reused and ultimately is biodegradable. With good forest management practices, wood is the most environmentally responsible building material.

The not-for-profit ATHENA™ Sustainable Materials Institute (the Institute), a world-leading source of life-cycle assessment data and tools, is finding answers to critical questions about the environmental impact of buildings and building products. The Institute's work has gained recognition from environmental authorities in Canada, in the United States and abroad.

Life-cycle inventory (LCI) is a cornerstone of any life-cycle assessment because it involves tracking and recording basic flows from and to nature (resources and wastes) for specific products or processes. All subsequent LCA calculations or steps are derived from or reflect basic LCI data. The lack of widely available LCI is recognized as the main reason LCA data is viewed as expensive and time consuming.

The U.S. LCI Database Project (LCI Project) is a public/private research partnership to develop and make publicly available LCI data for commonly used products and processes. Generally, access to LCI databases are restricted or protected by copyright agreements. The LCI Project on the other hand will make the information available to all and will provide an open exchange of information.

The LCI Project was conceived by the ATHENA™ Sustainable Materials Institute as a three-phase effort: Phase I was an intensive initiation and planning phase and was undertaken by the Institute in association with Franklin Associates Ltd. and Sylvatica, with funding through the National Renewable Energy Laboratory (NREL) from the US Department of Energy, the General Services Administration, and the US Naval Facilities Engineering Command. The U.S. LCI Database Project – Phase I Final Report was completed in January 2002 and is available online on the NREL website.

The Institute is now undertaking Phase II, which involves basic data collection, analysis and review as well as the development of data formats and a User's Guide.

Following is a comparative environmental impact LCA assessment of embodied and operating energy of steel, concrete, and wood residential construction. The impact assessment includes primary energy, global warming potential, air pollution, water pollution, resource use, and solid waste.

For more information please visit the ATHENA™ Sustainable Materials Institute at http://www.athenaSMI.ca and the National Renewable Energy Laboratory at http://www.nrel.gov/lci.

Comparative Environmental Impact Assessment

Prepared for the Canadian Wood Council by the ATHENA™ Sustainable Materials Institute

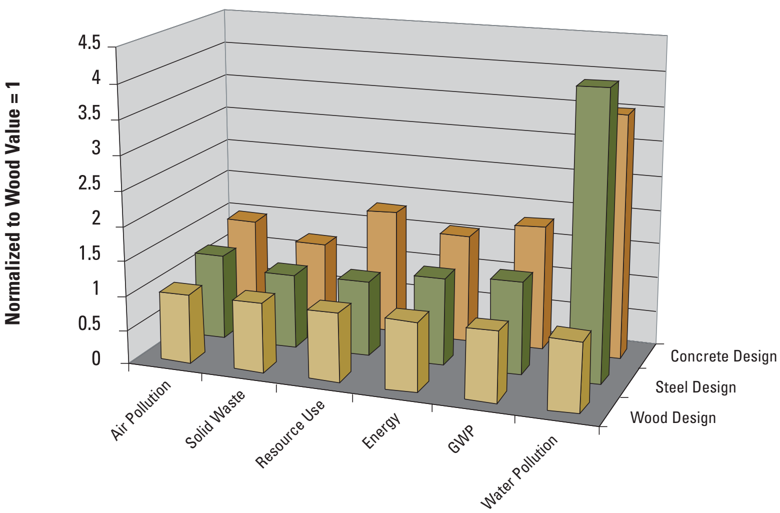


Figure 1: Embodied Effects Relative to the Wood Design across all Measures

Objectives of Assessment

The Canadian Wood Council (CWC) commissioned the ATHENA™ Sustainable Materials Institute (the Institute) to update and expand on an earlier 1999 CWC study completed by the Institute which contrasted the initial environmental impact of wood, steel and concrete single family home designs.

At the time of the first study, the Institute's Environmental Impact Estimator (EIE) software could only simulate the environmental implications of structural systems and hence, all the building envelope components were assessed through calculations using life cycle inventory (LCI) data that had not been entered in the software.

Since that original study, all the Institute's life cycle databases have been updated and expanded to include envelope materials, and other systems have been added. The original study included a very preliminary quantity take-off for insulated concrete forms (ICF) – a key assembly in the concrete design. ICFs are now fully integrated into the software. In the original 1999 study, the effective R-value of the wall envelope systems was different for the three designs and the effects of varying R-values were not included in the results.

Operating energy differences between the designs are now explicitly considered in this study. And lastly, in the earlier study all the common elements (e.g., cladding, windows, roofing, etc.) shared among the three designs were excluded from the analysis to underscore the differences across the three design scenarios. However, in this present study these common elements are included in the analysis as they have a direct bearing on operating energy use calculations and modeling.

This updated study addresses all the aforementioned factors, providing a more thorough environmental assessment of the three alternative material designs (structure and envelope) for a 2,400 sq. ft. single-family home built in the Toronto market over the first 20 years of its lifespan, the average lifespan being 70 years.

While the three homes are similar in outward appearance, square footage and divided living area, they are markedly different in terms of the structural materials used to achieve the final design. One is designed using softwood lumber and engineered wood I-joist framing, the second design incorporates light frame steel for its structure, and the third design uses insulated concrete forms (ICF) and a composite concrete slab on steel joist (HAMBRO™) floor system.

Because sheet metal and concrete roof-framing methods are not readily available or in common use, the decision was made to use wood trusses for all three designs to reflect current building practices.

The assessment results are summarized into six key measures covering total primary energy (operating and embodied energy, where embodied energy includes the direct and indirect energy associated with extraction, manufacturing, on-site construction and maintenance and repair activities during the first 20 years of operating these homes, including all transportation energy within and between these activity stages), weighted raw material use, greenhouse gas potential, measures of air and water pollution, and solid waste emissions. See Figure 1.

LCA Methodology

A full life cycle assessment (LCA) is a formal process of examining the environmental impacts of a material, product or service through its entire life cycle, from raw resource or material acquisition through manufacture and use to waste disposal. Instead of a single-attribute analysis of a material's environmental impact, such as its recycled content, LCA takes a "holistic" approach to the possible impacts of material choices throughout their respective life cycle.

The life cycle inventory (LCI) is fundamental to an LCA. As the name implies, the LCI involves collecting and documenting data on the relevant environmental flows or burdens associated with the various life cycle stages, including transportation within and between stages and the upstream effects of energy use (i.e., the energy and emissions associated with producing and moving energy). Once the LCI is in place, the potential environmental impacts of a material, product or system (e.g. a house) can be characterized in terms of several internationally recognized measures of environmental loading, such as the following:

- acidification
- global warming
- smog formation
- solid waste.

While LCI/LCA has been around in various forms since the early 1960s, it was only in the mid-to-late 90s' that the protocol for completing such studies was standardized by the International Organization for Standardization (ISO14040-42). The Institute subscribes to this international protocol and over the years has adjusted its own methodology to be in step with the ISO protocols governing the application of LCA.

Currently, the Athena™ Environmental Impact Estimator (EIE) software (v3.0) encompasses LCI profiles for steel, wood and concrete structural products and assemblies, as well as a full range of envelope components (e.g., cladding, roofing, insulation, glazing. etc.). It covers a building's life cycle stages from the "cradle" (natural resource extraction) through to its "end-of-life" (grave). Specifically the model encompasses the following building life cycle stages:

Product manufacturing: includes resource extraction, resource transportation and manufacturing of specific materials, products or building components.

On-site construction: includes product/component transportation from the point of manufacture to the building site and on-site construction activities.

Maintenance and replacement: includes life cycle maintenance and replacement activities associated with the structure and envelope components based on building type, location and a user defined "design life" for the building.

Building "end-of-life": simulates demolition energy and final disposition of the materials incorporated in a building at the end of the building's life.

The software converts operating energy to primary energy and emissions to allow users to compare embodied and operating energy environmental impacts over the building's life. The operating energy calculator requires a separate estimate of operating energy as an input to the model. HOT2000 annual fuel consumption simulation results by fuel type for each of the design scenarios were entered in the EIE software. The software then estimated the regionally applicable emissions to air, water and land associated with the type and quantity of fuels used for each of the three house designs over a 20 year period.

HOT2000 is an operating energy analysis program for residential buildings developed by Natural Resources Canada and freely distributed via the web (www.buildingsgroup.nrcan.gc.ca).

It is a versatile whole house operating energy simulator and is used to evaluate new housing designs for the R-2000 program on a regional basis.

R-2000 is a program offered by Natural Resources Canada's Office of Energy Efficiency that encourages and certifies the building of energy efficient houses that are environmentally responsible and healthy to live in, according to certain criteria. (Another program sponsored by the Government of Canada is the Super E® House Program for countries other than Canada, supported by Canadian technology, expertise and training.)

The HOT2000 software program has been in use for over 15 years across Canada and around the world. Version 9.01 of the program was used in this project. Morrison Hershfield completed the HOT2000 simulations for the three alternative material designs.

In terms of results, the EIE software provides a detailed environmental life cycle inventory of the embodied effects associated with the building as well as a set of six summary measures. These summary measures include total primary (embodied and operating) energy and raw material use; greenhouse gas potential (both fuel and process related); measures of air and water pollution; and solid waste emissions.

The software and its embedded databases are North American in scope, representing average or typical manufacturing technologies and appropriate modes and distances for transportation. The model simulates 12 geographic regions represented by Vancouver, Calgary, Winnipeg, Toronto, Ottawa, Montreal, Quebec City, Halifax, Minneapolis, Atlanta, Pittsburgh and a US Average. This study drew on the software's Toronto regional database.

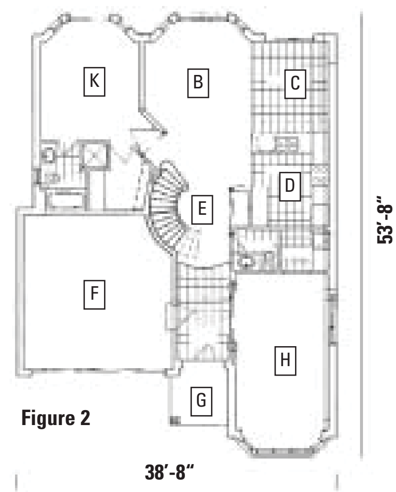


Figure 2

Building Design and Energy Simulation Considerations

CWC's design team [Peter Gabor (Architect) and Raymond van Groll (Structural Engineer)] provided the Institute with structural and elevation drawings, Figures 2 and 3, and envelope details for each of the three designs.

With the drawings and envelope details in hand, the Institute retained the services of Morrison Hershfield's Buildings Group to review the drawings and material lists for accuracy, gauge the comparative "fairness" of the alternative designs and assist in entering assembly and material data into the ATHENA™ EIE model.

Morrison Hershfield also completed the operating energy simulation for the three material designs.

The focus of the energy simulations was to determine the influence of the varying wall envelopes on operating energy, specifically, space heating and cooling. To this end, the simulations assumed a high-efficiency natural gas-fired, forced-air furnace and a 3-ton conventional air conditioner for all three material designs assuming Toronto climatic conditions. Plug-loads and domestic hot water heating were deemed to be the same for all three material designs and were excluded from the assessment.

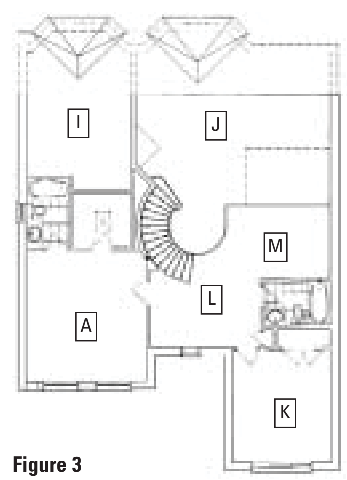


Figure 3

A Master Bedroom
B Family Room
C Dinette
D Kitchen
E Hall
F Garage
G Entry
H Living/Dining
I Attic
J Open to Below
K Bedroom
L Upper Hall
M Den

Assumptions

The ATHENA™ model is a conceptual design tool and in working with final engineering designs requires a number of assumptions to permit modeling of these detailed designs. This section briefly describes assumptions and substitutions made during the course of the analysis.

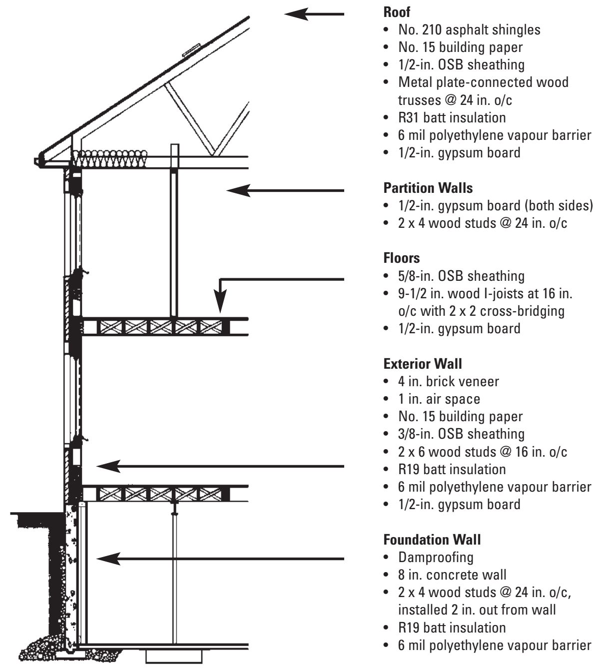


Figure 4: Wood House Cross-section

The assumptions and substitutions are described below in terms of global variables as well as specifics concerning each material design scenario. Otherwise all design inputs were as per specified in the drawings (see cross-section component detail drawings for specifics, Figures 4, 5 and 6).

Global assumptions across all three material designs

- clay brick exterior cladding finish;
- all windows operable double glazed units with PVC frames, low "E" tin, and Argon filled;
- interior finish limited to painted gypsum board finishes on ceilings and walls;
- anything exterior to the building (e.g., landscaping, sidewalks, driveways, etc.) excluded from the assessment;
- all interior finishes (e.g. floor coverings, doors and wall finishes) excluded;
- optional basement bath and laundry room excluded, but fourth second floor bedroom and bath included in all three material design scenarios;
- all three roof framing designs use wood trusses;
- roof framing: combination of roof rafters and light frame wood trusses, insulation (R31 fiberglass batt) and asphalt shingles;
- strip footings under foundation walls modeled as 8" thick and square footings under column locations as 12" thick.

Wood design assumptions

- basement exterior wall vapour barrier included with use of fiberglass batt insulation;
- spacing of studs at 2' o/c for non-load bearing interior partition walls and perimeter of livable basement area;
- i-joist web 3/8" OSB and flange 2.5"x1.5" lumber.

Steel design assumptions

- basement exterior wall vapour barrier included with use of fiberglass batt insulation;
- exterior above grade walls finished in 5/8" gypsum to provide racking strength;
- interior steel stud spacing 2' o/c for non-loading partition walls and perimeter of livable basement area;
- rigid insulation on above grade walls (extruded polystyrene (XPS));
- no building paper required behind brick cladding.

Hybrid Concrete design assumptions

- foundation footing width as per Ontario Building Code for above grade concrete structures;
- exterior above grade ICF walls finished in 5/8" gypsum;
- 10M rebar 3' long reinforcement around window openings in ICF wall system;
- 10-2' stirrups at each stirruped opening;
- ICF constructed using expanded polystyrene (EPS) and polypropylene form ties.

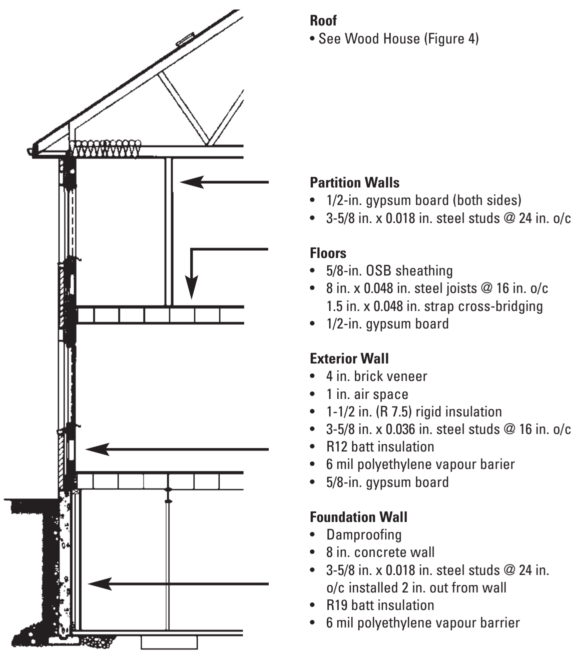


Figure 5 – Sheet Metal House Cross-section

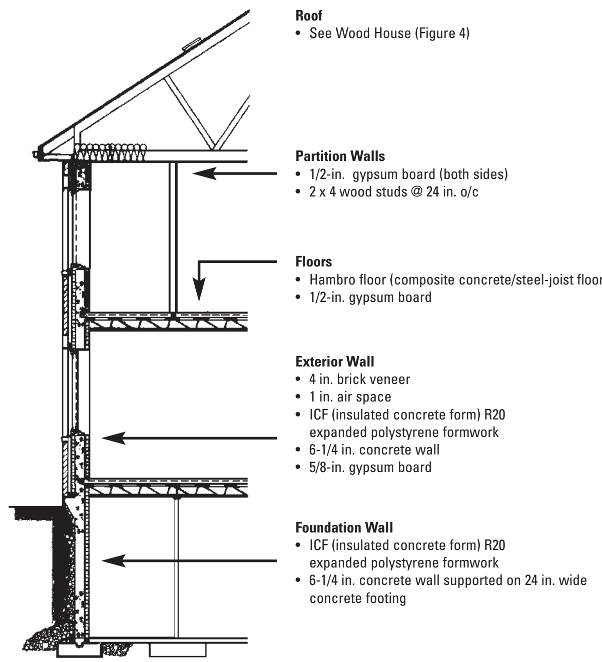


Figure 6 – Concrete House Cross-section

Results

Hot 2000 Simulation Results

While all three house-designs met energy code requirements, their respective effective R-values were not equivalent. Table 1 sets out the insulation material R-values and the estimated average effective R-values for the exterior walls for each of the three home designs.

Both the wood and steel design effective R-values were developed using the parallel path approach as outlined and developed in the National Model Energy Code for Houses. Currently ICFs are not covered in the Energy Code and thus it was necessary to develop an effective R-value estimate for this system separately.

Because there is an ever-expanding array of ICF systems and construction details for these systems, there is also a wide variation in their effective R-values. A 2002 field study research report by Oak Ridge National Laboratory indicates an effective R-value for the ICF residential structure tested at R-16. We believe this to be at the low end of the R-value spectrum for these systems and in fact, expect some systems to attain their stated material rating. However, with the paucity of verified results for any of the ICF systems we have set the effective R-value of the ICF equal to that of the wood envelope, which is in the upper half of the range for ICF systems.

Another energy simulation issue that we wrestled with was air infiltration differences between the three systems. While wood and steel framing would typically have a similar air infiltration rate, the ICF system would tend to have a lower air leakage rate than either the wood or steel framing systems, depending on the quality of construction (e.g., around windows and at main assembly intersections). Here again we ran into a scarcity of verified air infiltration results for ICF construction and we assumed the air infiltration rate to be the same across all three systems.

Table 2 summarizes the HOT2000 fuel consumption simulation results for each of the three framing methods on a per annum basis. The values reported include all related natural gas and electricity use associated with space heating and cooling. Excluded from the results is electricity usage associated with plug loads and natural gas used to fire a domestic hot water heater, both of which were the same for all house designs.

The fuel consumption results indicate that, relative to the wood house envelope, the steel design would consume about 7% more natural gas during the heating season, but it would use 1% less electricity during the air conditioning season. Essentially the higher thermal resistance of the wood envelope design works against itself during the cooling season.

	Units	Wood Design	Steel Design	Concrete Design
Wall Insulation R-Value only	BTU/ft²hr	19.0	19.5	20.0
Whole Wall Effective R-Value	BTU/ft²hr	18.1	15.0	18.1

Table 1 – Insulation and Whole Effective R-Values by Material Design
Note: Whole wall effective R-values are for the complete exterior wall system

	Natural Gas m^3 space heating	Electricity kWh space heating	Electricity kWh air conditioning
Wood Design	1734	1456	1795
Steel Design	1852	1469	1776
Concrete Design	1753	1458	1669

Table 2 – Annual Fuel Consumption by Mode and Material Design

This phenomenon doesn't hold true for the ICF design due to the temperature moderation effect of the ICF design's greater thermal mass (primarily due to its HAMBRO™ floor system). So while the wood envelope design has a 1% natural gas use advantage during the heating season, its air conditioning electricity disadvantage is in the order of 7% due to the ICF's thermal mass advantage. The natural gas and electricity values as presented in Table 2 were entered into the ATHENA™ EIE software to calculate the total primary energy and related emissions to air, water and land associated with the use of the fuels over 20 years. [1]

ATHENA™ EIE Results

Table 3 summarizes the environmental effects embodied in the structure and envelope of the three house designs as well as their respective 20-year space heating and cooling effects.

Foundations include all reinforced concrete strip and column footings as well as the basement and garage slab-on-grade floors. The wall grouping includes all below and above grade walls as well as partition walls. The floors and roof assembly group includes the first and second story floors as well as the roof. The column and beams assembly group includes all built-up or heavy beams and jackposts.

Embodied Effects Summary[2] (for its first 20 years)

Relative to the wood design, the steel and concrete designs

- embody 26% and 57% more energy;
- emit 34% and 81% more greenhouse gases;
- release 24% and 47% more air pollution;
- discharge 4 and 3.5 times more water pollution;
- use 11% and 81% more resources from a weighted resource use perspective; and
- produce 8% and 23% more solid wastes, respectively.

Using embodied energy as an indicator, the majority of the difference between the three designs can be traced to their respective wall and floor structural framing and insulation material type differences.

Operating Energy Effects Summary

Despite the variation in the amounts of natural gas and electricity reported in Table 2, the net difference in primary energy use is less significant than one might suspect.

Relative to the wood design and over a 20-year period, the steel design

- consumes 5% more primary energy;
- emits 5% more greenhouse gases;
- emits 6% more air pollution and the same amount of water pollution;
- uses 1% more resources from a weighted resource use perspective; and
- produces 3% more solid wastes.

[1] As a sensitivity test we also ran the ICF design with an effective R-value of twenty. The difference between the R-18 and R-20 effective R-value ICF designs in electricity and natural gas usage was 0.2% and 4%, respectively.

[2] Result differences of less than 15% should be considered equal. While more work will be required to set useful tolerance limits when comparing two or more designs, relative differences greater than 15% are generally considered significant.

Relative to the wood design and over a 20-year period, the concrete design

- consumes 1% less primary energy;
- emits the same amount of greenhouse gases;
- the other four measures were also found to be either the same or tending to the negative side.

The similarity of the above operating energy results is in part a function of the various fuels used to generate electricity in Ontario, their conversion efficiency into electricity, and cleanliness relative to the natural gas heating fuel.

Design by Assembly Components	Primary Energy (Gj)	Global Warming Potential (Eq.CO_2 kg)	Air Pollution Critical Volume Measure	Water Pollution Critical Volume Measure	Weighted Resource Use (kg)	Solid Wastes (kg)
Wood Design						
Foundations	73	6474	857	3	64395	2811
Walls	687	36528	9474	3	142752	9848
Floors and Roof	287	9346	3132	8	36844	4006
Column & Beams	73	3164	411	15	7033	469
Total Embodied	1121	55512	13874	29	251024	17134
Total 20 yr Operating Energy	2192	102680	44919	3	146666	7184
Grand Total	**3313**	**158192**	**58793**	**32**	**397690**	**24318**
Steel Design						
Foundations	73	6474	857	3	64395	2 811
Walls	894	48160	12044	41	159407	10786
Floors and Roof	385	16332	3975	57	47196	4 420
Column & Beams	64	3265	389	18	6533	469
Total Embodied	1417	74231	17265	119	277531	18 486
Total 20 yr Operating Energy	2296	108020	47486	3	148387	7 396
Grand Total	**3713**	**182251**	**64751**	**122**	**425918**	**25882**
Concrete Design						
Foundations	60	5045	658	3	48198	2311
Walls	1065	65110	14248	2	304089	12247
Floors and Roof	542	26091	4934	78	93367	5871
Column & Beams	92	4167	516	19	9389	642
Total Embodied	1758	100413	20356	102	455043	21071
Total 20 yr Operating Energy	2184	102648	45067	3	142471	7069
Grand Total	**3942**	**203061**	**65423**	**105**	**597514**	**28140**

Table 3: 20-Year Environmental Results Summary (Embodied and Operating Effects)

Totals may not add exactly due to rounding.

Summary

Summing the total embodied and operating energy for twenty years for each design and then comparing these overall results relative to the wood design, indicates that both the steel and concrete designs

- embody and consume 12% and 20% more energy;
- emit 15% and 29% more greenhouse gases;
- release 10% and 12% more air pollution;
- discharge 3 and 2.25 times more water pollution;
- use 7% and 50% more resources from a weighted resource use perspective; and
- produce 6% and 16% more solid wastes, respectively.

The fundamentals of large numbers and percentage comparisons tend to indicate smaller differences. But another way of looking at these results would be to compare them on the basis of years of operating energy and related greenhouse gas releases saved by building the wood design (the lower embodied design) instead of either of the other two alternative designs.

The savings attributable to building the wood home over the steel and concrete homes is equivalent to about 2.5 years of operating energy and 3.6 years of global warming gas emissions in the case of the steel design and 5.5 years of operating energy and 8.6 years of global warming gas emissions in the case of the concrete design.

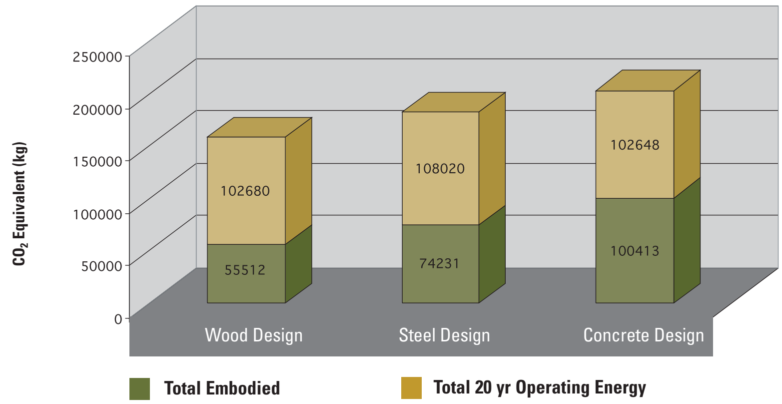


Figure 7: Global Warming Potential

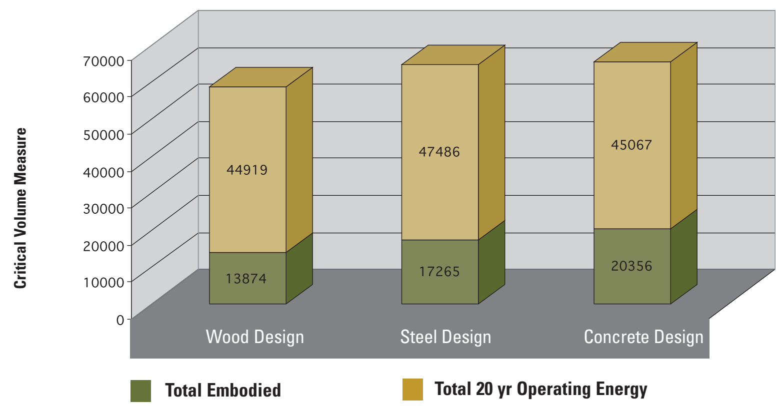


Figure 8: Air Pollution

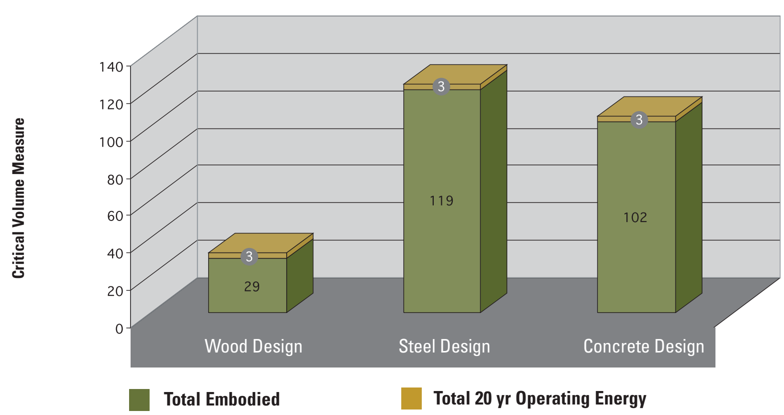


Figure 9: Water Pollution

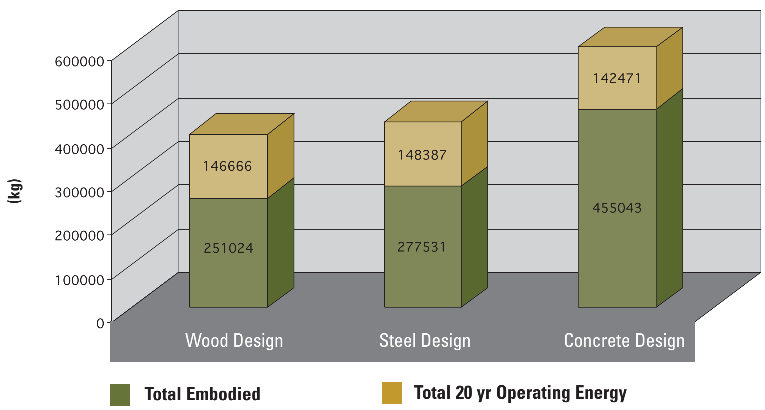


Figure 10: Weighted Resource Use

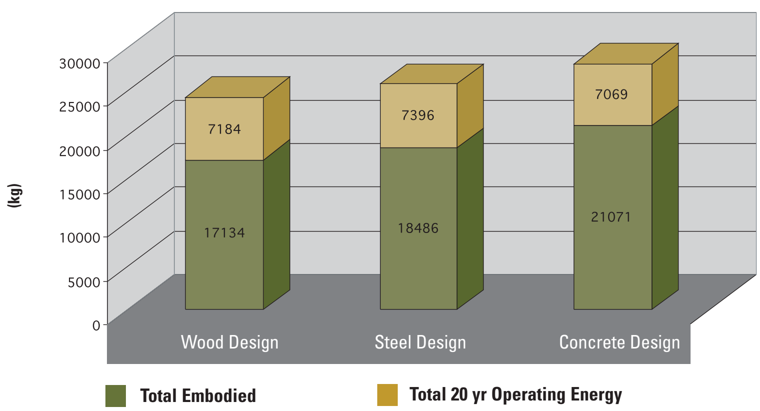


Figure 11: Solid Waste

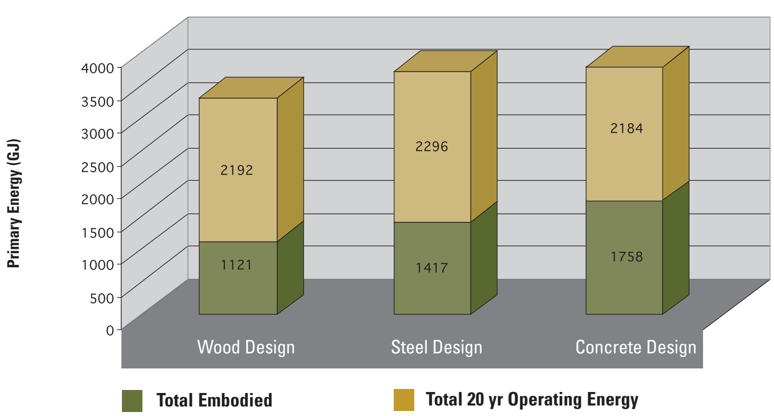


Figure 12: Primary Energy

In terms of environmental impacts, Figures 7 and 8 represent the total embodied and total 20-year operating energy of the wood, steel and concrete designs in terms of global warming potential and air pollution, respectively.

Figure 9 verifies the impact on water pollution where the water toxicity level of both the steel and concrete is considerably more significant than wood.

Figures 10 and 11 present the weighted resource use and solid waste.

Figure 12 illustrates the primary energy for all three designs, both the total embodied energy and the total 20-year operating energy.

Conclusion

To create a sustainable world a holistic approach to sustainability is needed.

Adopted by many countries, wood-frame construction is the residential building system of choice. It is strong and meets the challenges of high-wind and earthquakes. Easy to connect and insulate, wood is the only major building material that is renewable.

Wood is a high-quality material. Engineered wood products are found in houses, commercial and industrial buildings and offer tolerances in stability, consistency, and straightness. From the manufacturing of complete homes in factories, to the shipping of wall and floor assemblies at home and abroad, to the prefabrication of wall units on site, the modularization of wood-frame construction delivers cost savings and quality for builders.

In conclusion, where wood comes from well-managed forests, it is the environmental building material of choice.

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Jones Farmstead, Salmela Architect.
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Citation Award,
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Resources

Institute Reports

Demolition Energy Analysis of Office Building Structural Systems. Mar./97 Prepared by M. Gordon Engineering.

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