STEEL AND THE ENVIRONMENT

Introduction to Sustainability and Green Building

Sustainability was defined nearly thirty years ago as 'progress that serves the needs of the present without compromising the ability of future generations to meet their own needs'.[1] Today, population growth, finite resources and recognition of climate pattern anomalies possibly resultant from resource depletion and fossil fuel combustion gases are motivating architects, builders, designers and owners to demand products that use resources wisely. This social consciousness and the financial reality of increasing energy costs has dramatically shortened payback periods for investment in sustainable alternatives, so that, put simply, it pays to be green.

To assist planning, specification, implementation and commissioning of a sustainable construction project, the U.S. Green Building Council (USGBC) and the National Association of Home Builders (NAHB) have independently developed the two most widely-recognized rating systems to gauge compliance with green building initiatives. Programs generally consist of guidelines covering special areas, like energy, resource or water conservation, for which points are awarded for employing environmentally preferential processes or materials to meet project objectives. Program references and user's guides serve as clarification of each program's intent and provide direction for implementation that are based on recognized building practices.

[1] Excerpted from the report of the Brundtland Commission to the United Nations, "Our Common Future," 1988.

Green Building Program Points and Cold-Formed Steel

Instructions covering implementation of green building guidelines have left reference to cold-formed steel (CFS) absent from program documents. Yet, steel has the highest strength to weight ratio of all structural building materials, a high recycled content and is a structural substitute for both dimensional lumber and reinforced concrete in residential and commercial applications. With these attributes, steel stands out as a structural material that will meet multiple green building program objectives. This document will fill in the blanks in these green building programs to underscore the suitability of steel as a sustainable building material.

LEED®-NC is the USGBC program that is nationally-recognized as the scorecard for green commercial buildings and the National Green Building Standard™ (NGBS) serves as a principal program model for residential green building.[2] The program overviews that follow will briefly explain how specifying steel can contribute to sustainable decisions under guidelines of each program.

[2] National Association of Home Builders (NAHB), the International Code Council (ICC) and the NAHB Research Center have initiated a process for the development of an ANSI standard for green home building construction practices based on the NGBS. The standard development process includes vetting of the NGBS by a 42-member consensus committee as well as consideration of all public comments. The process is likely to change the content and rating system significantly during the approximately one-year period of development. The timeline to standard adoption is under revision. Previously, the timeline anticipated ANSI adoption of the NGBS in February 2008.

LEED-NC

Sustainable Sites Credit 7.2: Heat Island Effect: Roof

This section allows one point for roofing that meets stated solar reflectance index (SRI[3]) criteria. Steel roof cladding can be shaped and coated to satisfy infinite architectural requirements and many of the available coatings are ENERGY STAR® rated because of their high reflectance and emissivity.

Materials and Resources Credit 2.1 and 2.2: Construction Waste Management and Reduction

The section allows points when a percentage of the project's construction waste is diverted from disposal by recycling or reuse. Steel is one of the most common structural materials that can be ordered to exact specification (eliminating waste and added labor). And, the steel industry has recycled used product for over 150 years so a dynamic global steel scrap market ensures that steel recycling is simple and profitable. (Up to 2 points are available for diversion of 75% of the waste stream.)

[3] SRI calculating tool, http://coolmetalroofing.com/elements/downloads/SRIcalc9.xls

Table 1. LEED-NC At a Glance

LEED-NC Category	Total Points	Points for Cold Formed Steel
Sustainable Sites	14	1 + 1 (partial)
Water Efficiency	5	
Energy & Atmosphere	17	
Materials & Resources	13	2 (partial) + 3 (partial)
Indoor Environmental Quality	15	
Innovation & Design Process	5	
Total Points Available	69	7
LEED-NC Certification Level	**Minimum Points**	
Platinum	52	
Gold	39	
Silver	33	
Certified	26	

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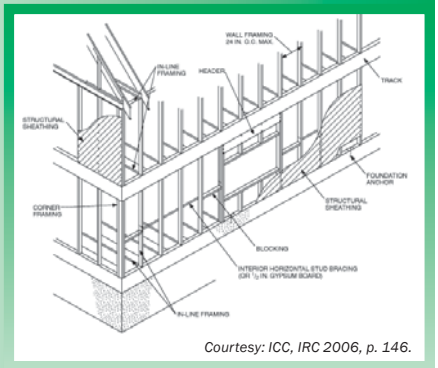
Table 2. Recycled Content of Domestic Steel

Manufacturing Process	Domestic Industry Data	Basic Oxygen Furnace	Electric Arc Furnace
2006 Annual Domestic Production (tons)	105,928,500	46,802,100	59,126,400
Percent Domestic Production by Process[A] (%)	100.00%	44.18%	55.82%
Recycled Steel Used in Production	43.08%	12,631,400	33,005,200
Recycled Content (tons)[A]	Post-Consumer	10,534,588	27,526,337
	Post-Industrial	2,096,812	5,478,863
Recycled Content (%)	**Post-Consumer**	**22.51%**	**46.56%**
	Post-Industrial	**6.19%**	**26.93%**

[A] Steel Recycling Institute, 2006 *Inherent Recycled Content of Today's* Steel.

Table 3. Threshold Point Ratings for Green Buildings

Green Building Categories	Performance Level Points*			
	BRONZE	SILVER	GOLD	EMERALD
Lot Design, Preparation, and Development	37	59	85	114
Resource Efficiency	31	66	101	136
Energy Efficiency	30	70	100	120
Water Efficiency	20	25	30	40
Indoor Environmental Quality	53	63	78	103
Operation, Maintenance and Building Owner Education	8	10	11	12
Additional Points from any Category	100	100	100	100
Total Points:	**279**	**393**	**505**	**625**



Courtesy: ICC, IRC 2006, p. 146.

Materials & Resources Credits 4.1 and 4.2: Recycled Content

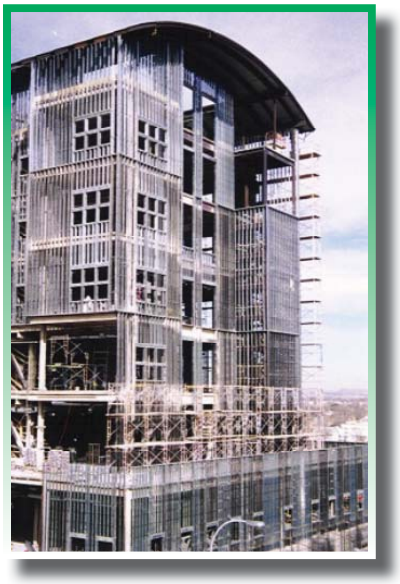
These sections allow one point if a minimum of 10% of a building's materials have post-consumer recycled content and another point if total recycled content reaches 20%, respectively.[4] Specifying cold-formed steel building components can contribute significantly toward earning these recycled content points because of its high recycled content. (See Table 2.)

There are essentially two methods of steel manufacture – basic oxygen furnace (BOF) or electric arc furnace (EAF). Each process requires different levels of energy and recycled material input. The continuity of the steel product manufacturing infrastructure and the high reclamation rate (69% of all products and nearly 98% of structural construction products are recycled[5]) make each of the two processes interdependent.

Using industry data reported in U.S. Geological Survey's (USGS) *Mineral Summary Report for Iron and Steel Scrap* and *Iron and Steel*[6] as a cogent alternative to locating the manufacturing source of the steel, a 3-story 22,500 square foot apartment building was analyzed. Using LEED's recycled content formula and statistics for BOF steel, a conservative approach that is estimated in Table 2, steel contributes about 2.6% of the recycled content of the materials in the building when accounting solely for steel open web floor and roof joists, ribbed metal decks, and steel studs in partition walls that would typically be specified in a $2.9 million project of this scope.[7] In this example, the steel materials represent less than 10% of overall building material cost yet contribute 25% to the available point.

Using cold-formed steel can facilitate point award under *SS 1: Activity Pollution Prevention* because steel's light weight minimizes footing excavations and size. Projects involving structure remodel and space repurposing will gain assist with steel components that can easily be dis- and re-assembled in section *MR 3.1: Materials Reuse.* Steel is inert so it will not release terpenes (hydrocarbons found in the essential oils and resin of wood) to the indoor air or provide a food source for mold, bacteria or insects which facilitates the goals of qualifying for the point in section EQ 3.1: *Construction IAQ Management Plan: During Construction.*

[4] Cost of material is weighted by percent of post-consumer recycled content (and ½ pre-consumer/post-industrial recycled content) as a percentage of overall building material cost.
[5] The Steel Recycling Institute, 2006, http://www.recycle-steel.org/PDFs/2006RatesRelease.pdf
[6] The USGS *Mineral Resources Program (MRP)* provides scientific information for objective resource assessments and unbiased research results on mineral potential, production, consumption, and environmental effects. The MRP is the sole Federal source for this information and is based on responses from about 56% of the companies surveyed that manufacture pig iron and semi-finished steel products, which represent about 48% of the total scrap consumption in those sectors. *Iron and Steel Scrap,* http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel_scrap/fescrmcs07.pdf and *Iron and Steel,* http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/festemcs07.pdf are two excerpts from the MRP.
[7] Calculations are based on *RS Means Light Commercial Cost Data, 26th Annual Edition, 2007, Apartment, 1-3 Story.* Recycled content and origin figures from U.S. Geological Survey, 2006 statistics (Table 2).



NAHB's Model Green Home Building Guidelines and Emergence of the National Green Building Standard™ (NGBS)

The Model Green Home Building Guidelines (GBG) were developed by National Association of Homebuilders (NAHB) to guide residential green building. The GBG formed the first draft of a national green building standard that is in the process of consensus adoption as an American National Standard's Institute (ANSI) recognized standard.[8] This analysis is based on the *Draft Version #1,* dated August 12, 2007 of the NGBS[9] in progress. Table 3 covers the program's current proposed point system and levels of program achievement.

A CFS framed house can earn as many points (34) in the *Resource Efficiency* section as a wood framed house in areas like pre-cut floor joist packages, roof trusses, and maximizing material usage with advanced framing layouts. In fact, cold-formed steel frames have been constructed by in-line framing methods for years, and most often employ the energy efficient 24" center spacing. In addition, points can be earned for steel framing by re-using, sorting, and recycling material.

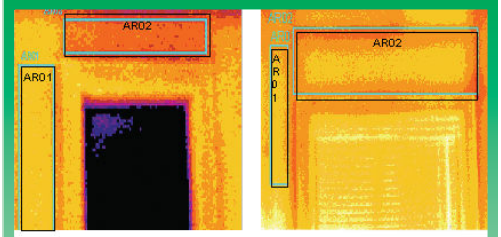
[8] http://www.nahbrc.org/technical/standards/gbfirstdraft.aspx
[9] American National Standards Institute. www.ansi.org The standard development process includes vetting of the NGBS by a 42-member consensus committee. The process is likely to change the content and rating system significantly during the approximately one-year period of development. The timeline to standard adoption is under revision. Previously the timeline anticipated ANSI adoption of the NGBS in February 2008.

Thermal Performance

In general, the effect of a structural component in an exterior wall is to act as a "thermal bridge," that is, it provides a path for conducting heat rapidly. Both wood studs and steel studs act as thermal bridges. Either type of wall can be designed to provide the desired thermal performance.

Steel is more conductive than some other building materials but it is only one of several components in a building assembly. To develop R-values for typical steel frame construction, the American Iron & Steel Institute sponsored research at the NAHB Research Center that included full scale calibrated hot box tests (ASTM C976), analysis, and thermal modeling by Oak Ridge National Laboratory. The research demonstrated that the wall R-value is not considerably affected by the thickness of the steel studs because steel stud web thicknesses are small which limits heat conduction. In climate zones where higher R-values are required, the use of an exterior insulative sheathing, such as extruded polystyrene or polyisocianurate, is an effective thermal break that will significantly increase the wall system's thermal resistance. *The Thermal Design Guide,* published by the American Iron & Steel Institute, offers the designer a series of alternative assemblies that will meet the requirements of all building and energy codes.

Designers can use building performance modeling in lieu of specifying the prescriptive insulation values in the IRC. In cooling climate zones (1-3), the approach allows substitution of continuous perimeter insulative sheathing with alternative energy efficient products, like windows or doors with low U-values, to increase the thermal resistance of the building. Whether constructed of steel or other framing materials, the overall thermal performance of the completed structure depends on the quality of the construction job. Careful attention to insulation details and air sealing any structure will assure better energy efficient performance.



Wood-Framed Home
The temperature difference between the insulation (AR01) and the window header (AR02) is 1.9°C

Steel-Framed Home
The temperature difference between the insulation (AR01) and the window header (AR02) is 0.4°C

Thermal images of a wood framed and steel framed lintel. Images were obtained from two identical homes, one steel framed one wood framed, located on the same street, and inspected on the same evening with outside temperature of -6°C, and no wind.

CASE STUDY: THERMAL MEASUREMENTS, MODELING AND ANALYSIS[8]

Infrared thermography is used as a research and investigative tool to monitor the temperature of a structure, material, or manufacturing process. In February 1997, the Canadian steelmaker, Dofasco, conducted a field study of seven steel and wood framed homes to determine their thermal performance relative to one another. The subject homes were in Toronto, Canada, and the steel framed homes were selected so that a comparable model in wood framing was available in close proximity, in most cases on the same street with the same orientation.

The infrared camera was used to collect thermal images on opaque wall surfaces, at lintels over wall opening, attic ceiling to wall connections, at the location of multiple members and at the floor-to-sill plate connection. These were identified as the locations where the effects of the framing on heat transfer would be most prevalent. All homes were occupied, with the thermostats set to 68°F (20°C). Outside temperatures ranged from 21°F (-6°C) and 10°F (-12°C) with no wind.

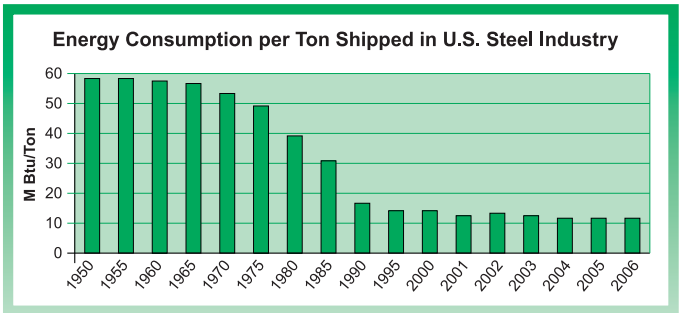
The results of the infrared tests demonstrated that the temperature differential at framing components in opaque walls, built-up members and sill connections was minor and they were comparable in both systems. Lintels in steel framed homes performed better because of the ability to incorporate a greater amount of insulation due to the shape of the steel components. Detailed with expanded polystyrene sheathing (R-5) and expanded foam insulation in the stud cavities, the steel homes used 7% less energy than their wood counterparts which were built to the same nominal R-value.

[8] DeMeo, etal., Investigation of the Performance of Steel and Wood Framed Homes Using Infrared Thermography, 1998. http://www.dofasco.ca/bins/doc.asp?rdc_id=2520

Life Cycle Assessment and Embodied Energy

To improve environmental building performance, industry design professionals explore how energy is invested over the life cycle of the building; not solely in one of the phases of its life, such as building use. Life cycle assessment, or LCA, is a tool for comprehensively measuring and accounting for the resource consumption and environmental burdens associated with a product over its life – from extraction through manufacture to use, decommission and reuse/disposal. The use of energy generated by the combustion of fossil fuels and manufacturing processes can create greenhouse gases (GHG); considered by some to be one of the most significant negative impacts on the environment. According to the Environmental Protection Agency (EPA) the U.S. steel industry has reduced process related GHGs by nearly 47 percent in the last fifteen years.[10] To benchmark GHGs resultant from manufacturing, LCA includes the energy that is used to acquire raw materials and manufacture, transport and install materials, often called embodied energy, in the assessment of a product's sustainability.

U. S. steel production uses about 3 percent of the energy consumed in the United States and more than 10 percent of that used by the industrial sector. Because energy costs represent nearly 20 percent of the total manufacturing cost of steel and the cost of energy is rising, energy efficiency in steel production is market-driven. The industry has seen innovations netting a 23% reduction in energy use per ton since 1990.[11] (See the graph titled, *Energy Consumption Per Ton Shipped in U.S. Steel Industry.*) Steel making by EAF, an environmentally clean method of steel production, grows while process improvements like scrap pre-heating, strip casting, and oxygen-injection have also improved energy conservation.[12] Today's domestic cold-formed steel contains less than13.2 MBtu of embodied energy per ton. For a home built with six tons of steel, the embodied energy represents about two thirds of the homes average annual energy use[13]; or, spread over a conservative life of 75 years, the embodied energy in a CFS house is less than 1% of the home's annual energy consumption over its expected life.



Source: U.S. Department of Energy and AISI
Courtesy of the American Iron and Steel Institute (AISI)

[10] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2004 ES5-6.* 2006
[11] U.S. Department of Energy and American Iron and Steel Institute.
[12] USGS, Flow Studies for Recycling Metal Commodities in the U.S. 2004.
[13] Based on Energy Information Administration consumption figures from 2001. (Most recent year available.)

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Dimensional Stability + Fire, Insect and Mold Resistance + Ductility = Durability

Sustainability also includes building maintenance and the associated labor, material and energy inputs. Quality construction practices and material selection assure that maintenance intervals fall farther apart which promotes durability. Materials like steel that satisfy multiple value equations simultaneously are obvious choices for the building owner. For example, the dimensional stability of steel studs eliminates interior and exterior surface irregularities caused by seasonal movement of cellulosic materials (like drywall, wood sheathing and some claddings). In exterior load-bearing walls where postponing maintenance can result in water and air intrusion, steel won't rot or provide a nutrition source for termites, bacteria, or mold. The fire resistance of steel provides an additional level of safety to structural frames in high density communities and arid climates prone to wildfires. The ductility of CFS, or the material's tendency to bend not break, satisfies criteria for seismic and high wind designs.

References and Resources

American Iron and Steel Institute (AISI)
http://steel.org

International Iron and Steel Institute (IISI)
http://www.worldsteel.org/

NAHB Research Center
National Green Building Standard
http://www.nahbrc.org/

Steel Framing Alliance
http://www.steelframing.org

Steel Recycling Institute
http://www.recycle-steel.org

U.S. Department of Energy, Energy Efficiency and Renewable Energy
http://www1.eere.energy.gov/industry/steel/pdfs/moe_steelmaking.pdf

U.S.Green Building Council
http://www.usgbc.org

U.S. Geological Survey
http://minerals.usgs.gov/minerals/pubs/commodity/iron_&_steel/

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