Low-impact facility sets high standard for future sustainable construction.

# Greening Steel Construction

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**THE SUSTAINABILITY MOVEMENT** has been solidly embraced within the design and construction industry in recent years. Owners and developers now frequently require new buildings to be LEED certified. On these LEED projects the majority of the sustainability focus is often placed on the operational efficiencies of the mechanical, electrical and plumbing systems. However the sustainability impact of the structural systems and the energy used in the actual construction of the structure often receive less attention and are not as well understood.

The recently completed Research Support Facilities (RSF) at the National Renewable Energy Laboratory's (NREL) campus in Golden, Colo., aims to be the prototype for the next generation of sustainable office space. The 220,000-sq.-ft, $64-million building was designed around 23 sustainability goals, including the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Platinum certification, net-zero energy usage and inclusion of visible alternative energy technologies.

The NREL RSF project challenged the design team to find creative ways of reducing the overall environmental impact of the building process as well as operation. The structural design team was inspired by the project's ambitious sustainability goals, but saw limited guidance for greening the structural steel process within the LEED framework. The project's structural engineer took this opportunity to fill a void in green building knowledge by commissioning a study with Colorado State University's Institute for the Built Environment in the Department of Construction Management to investigate opportunities for reducing the environmental impacts of structural steel design, fabrication, and erection processes. This article summarizes the research findings.

This study quantified the environmental impacts of the structural steel construction process throughout the RSF project and evaluated alternative methods or subprocesses that can be used to minimize environmental impact on future projects. The study was divided into two parts: (1) analysis of the structural steel fabrication and erection for the NREL project using environmental life cycle inventory assessment (LCIA) methodology and (2) a series of interviews with representatives of all those involved in the project design and construction that identified potential sustainability and process improvements through integrated design and delivery of structural steel.

LCIA is concerned with the energy use and environmental emissions from all life cycle phases of a product or process. Results include estimation of energy use and $CO_2$ emissions for the RSF steel fabrication and erection processes, evaluation of scenarios to reduce environmental impacts from these processes, and potential benefits from transitioning toward a more integrated structural steel delivery process. Although this study focused solely on the RSF project, the results are intended to inform the steel industry in general.

## Energy Use and Emissions

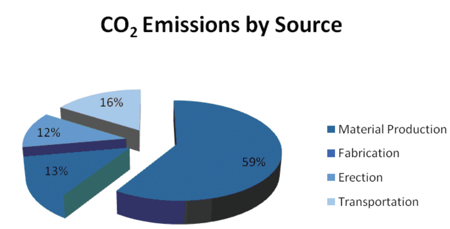
Process diagrams detailing the steps of the fabrication and erection processes were the foundation of the LCIA. These diagrams depict each process that the generic steel shapes arriving at the fabrication plant go through until they are installed as structural members in the RSF building. The materials, energy consumption, and equipment usage associated with each step were estimated using onsite observation at PVS and the NREL RSF site, discussions with team members, electricity records, and published data.

The accompanying chart shows relative contributions of $CO_2$ by source for the structural steel activities for the NREL RSF project. As a portion of total environmental impacts, the material pro-

➤ Located in Golden, Colo, the National Renewable Energy Laboratory's new Research Support Facility is designed to become a model for building efficiency and net-zero design, in part through the use of natural daylight and ventilation but also by using reclaimed and recycled materials in the construction process.

➤ The lazy H configuration of the NREL's new 220,000-sq.-ft Research Support Facility is conducive to minimizing energy use while providing top-notch serviceability and occupant comfort.

duction category dominates at 59%. However, the contributions from fabrication (13%) and erection (12%) are still significant in absolute terms. For instance, erection activities generated 342,000 kg of $CO_2$ which is equivalent to the emissions from 30 average homes or 65 cars in one year.

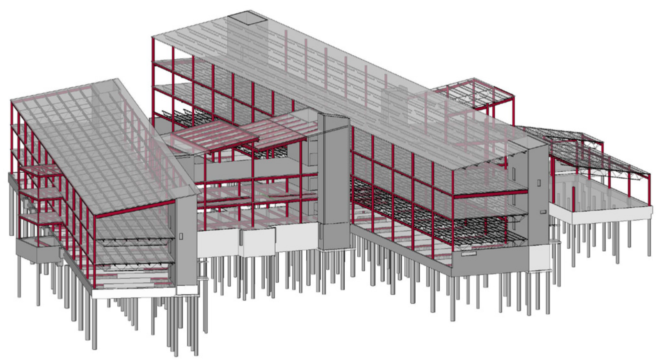



To evaluate how these impacts could be reduced, alternative scenarios were investigated for the material production, fabrication and erection phases.

**Material Production:** The primary source of the energy use and $CO_2$ emissions is from the material production phase. The steel manufacturing industry has seen a reduction in energy consumption of 33% per unit volume in the period between 1990 and 2007, but this process is still the dominant part of the overall production. This study found two possible ways that raw material production energy use and environmental emissions can be reduced for a given project: material salvage and reuse, and waste reduction in fabrication. Salvaged oil and gas piping was used for the majority of columns on the NREL RSF project, as described in the article "Reclaimed Structural Steel and LEED Credit MR 3—Materials Reuse" in the May 2010 issue of *MSC* (available at **www.modernsteel.com/backissues**). Of the 560 tons of structural steel that went into the project, 107 tons of reclaimed piping was used for pipe columns.

This salvaged material saved 69% of the $CO_2$ emissions and 68% of energy consumption as compared to newly manufactured equivalent structural sections.

**Fabrication:** Electricity for fabrication processes and operations is a primary input to the steel delivery process. In exploring opportunities to reduce the environmental impacts within the control of steel fabricators, this is the obvious starting point. Interestingly, shop lighting is one of the larger consumers of electricity.



➤ Reclaimed material used in the perimeter columns and elsewhere is colored red in this computer model of the NREL Research Support Facility.

The fabricator for this project currently uses high-pressure sodium and metal halide fixtures for shop lighting. However by changing to fluorescent fixtures with equivalent lumen output the energy consumption could be reduced by 56%. This would translate into a $55,300 annual savings, an annual reduction of 405,000 kg of $CO_2$, emissions, and a simple payback period of three years for the anticipated cost of the lighting change.

**Erection:** The environmental impact of the erection activities is dominated by the transportation of workers to and from the site. Increased carpooling and a work week of four 10-hour days generated some of the most significant savings. The magnitude of the

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Some of the 107 tons of reclaimed natural gas piping that was used for the columns on the NREL Research Support Facility project.

erection impact also is directly related to the duration on site. In the case of RSF, the erector estimated that the erection duration could have been reduced by three weeks with a larger staging area and preferred crane. If these requests could have been accommodated an estimated 21,900 kg of $CO_2$ emissions would have been eliminated.

## Interviews and Focus Groups

Several opportunities for improving the structural steel delivery process on future projects emerged as a result of individual interviews and a focus group session with those involved in the project. These include: (1) establish direct lines of communication among the structural steel team members, (2) ensure early involvement of the erector and fabricator in the steel design process, and (3) utilize appropriate technology in the planning process. Adopting an integrated steel delivery model (where one firm is responsible for all aspects of the design, detailing, fabrication and erection) could positively impact the team's communication, improve overall design efficiency, reduce the need for RFIs and shorten response times for questions. As demonstrated in the LCIA portion of the study, reductions in waste and project schedule have measurable environmental benefits.

## Conclusion

The structural steel industry has made great progress in reducing its environmental impact which has resulted in steel being one of today's most sustainable building materials. Steel mills are using new processes to minimize the energy required to produce steel shapes. Fabricators and erectors downstream from production facilities have realized process efficiencies through technological advancements such as computer-controlled equipment that minimizes waste. However, opportunities for improvement still exist at the project level. The ability to capitalize on these opportunities rests with the ownership, design and construction team. By reducing inefficiencies in the design and fabrication process, the total amount of material consumed can be reduced. By repurposing salvaged material, the designer can significantly reduce the environmental impacts attributed to the manufacturing process for the materials that are used. Through an integrated steel delivery process the needs of the fabricator and erector can be better addressed during the design phase resulting in decreased durations and waste during construction. All of these opportunities have quantified environmental benefits and are possible to implement on today's projects if they are approached as an integrated team. MSC

**Project and Study Participants**

As an integral part of this study, CSU researchers conducted individual interviews as well as a focus group session to gather input from stakeholders. The purpose was to determine the level of integration the steel stakeholders used on the project and to allow participants to discuss any inefficiencies and/or opportunities for improvement for the steel delivery process based on their experiences on the NREL RSF project.

Representatives participated in both individual interviews and the focus group on behalf of all those involved in the steel portions of the project. They included the owner, the National Renewable Energy Laboratory; the architect, RNL, Denver; the structural engineer and steel detailer, KL&A, Loveland, Colo.; the fabricator, AISC member Paxton & Vierling Steel Company, Carter Lake, Iowa; and the erector, AISC member LPR Construction, Loveland, Colo. Representatives of the American Institute of Steel Construction (AISC) also took part.

This project has been named a National Award Winner in AISC's 2011 IDEAS$^2$ program. To read more about the design and construction of the NREL Research Support Facility, turn to the IDEAS$^2$ awards coverage on page 32 in this issue.