

# Building learning: making a carbon neutral campus in McCall, Idaho

**Frank Jacobus, and Keith Bickford**

The University of Idaho, Moscow, Idaho

**ABSTRACT:** At the University of Idaho, an interdisciplinary group of faculty and students have created a design-build workshop sequence focused on the development of a carbon-neutral learning center at one of the university's field campuses in McCall, Idaho. Located adjacent to Ponderosa State Park, an area populated by mature Ponderosa pine trees, the field campus is managed and directed by the McCall Outdoor Science School (MOSS), whose mission is to use the outdoors as a context to teach intermediate and high school students from the state of Idaho about science, place, and community. The new sustainable design curriculum, in the form of interdisciplinary workshops, aims to design and construct buildings at the field campus that will eventually embody the sustainable values taught by MOSS. The inaugural design workshop in the sequence began this semester with construction scheduled to begin in the summer of 2010. The intent of the design-build workshop sequence is to redesign and rebuild the field campus over a period of several years using carbon neutral design as an overriding goal. Passive design, in lieu of using heavily embedded technologies, will be a teaching focus in an effort to achieve the workshop and campus objectives. Because of the alpine forest campus location the workshop will have an additional focus on issues of fire-wise construction, snow management, and a use of underutilized materials in the built work. In addition to these aims, and in accord with the MOSS mission of using the outdoors as a teaching tool, the buildings themselves will act as 'learning instruments' for the young visitors, making explicit the sustainable principles embedded within. The eventual goal is that the entire campus will attain carbon-neutral performance and will set an example for future learning environments around the globe.

Conference theme: Building performance studies, zero energy, and carbon-neutral buildings  
Keywords: carbon neutral, design-build, zero energy

## PROJECT BACKGROUND

In 2006 an interdisciplinary group of faculty at the University of Idaho collaborated on a carbon neutral design studio. The design studio's goal was to redesign and eventually rebuild the University of Idaho McCall Field Campus in an effort to make it carbon neutral in terms of its annual energy consumption. The McCall Field Campus is operated by the McCall Outdoor Science School (MOSS), whose mission is to use the outdoors as a context to teach intermediate and high school students from the state of Idaho about science, place, and community. A number of building types were looked at during this studio and a new campus site plan was developed. It was determined that a central biomass co-generation plant would be constructed, providing the heat and electricity for the campus. This strategy was based in large part on the abundance of available wood from the continual clearing of undergrowth in nearby Ponderosa State Park. As a result of the work of this studio, in the Fall of 2007, an EPA P3 grant was awarded to the University of Idaho. In April of 2008, P3 honourable mention was

awarded to the McCall Campus design team at the EPA P3 Expo in Washington D.C. As a continuation of the 2006 studio effort, a carbon neutral design-build studio was formed in the Fall of 2008. The design-build studio's task was to design a single living facility that would house up to 16 students.

This paper will outline the work of the Fall 2008 studio, addressing the studio structure and approach, and will describe the studio findings with regards to design approaches and preliminary energy calculations for the building.

## 1. THE DESIGN STUDIO

### 1.1. Introduction

We began the Fall 2008 carbon neutral studio by conducting precedent research in three areas: carbon neutral design, design-build, and building types. We divided the class into three teams of five students each, dedicating approximately one week to these preliminary research efforts.

The students on the carbon neutral research team focused on definitions of carbon neutrality, means of

carbon neutral certification, examples of embedded and passive systems, and methods of measuring carbon neutrality during the life cycle of a building. This team also looked at several carbon neutral building precedents such as the Aldo Leopold Foundation Center, designed by Kubala Washatko Architects, The Lighthouse, by Sheppard Robson Architects, and The Beddington Zero Energy Development (BedZed), by Bill Dunster Architects. We understood from day one of the project that many of the embedded systems employed in the aforementioned projects were not going to be possible at the McCall, Idaho campus due to the natural solar shading and wind block in the Alpine Forest landscape. However, there were other passive methods employed in the precedent projects that we were able to learn from and implement into the new bunkhouse design; we will focus on these in more detail later in the paper.

### 1.2. Design-build research

The design-build team focused their research on academic design-build groups such as Studio 804, The Rural Studio, Parsons Design Workshop, Yestermorrow Design/Build School, and the Tulane GreenBuild Studio; all of whom have produced successful projects that meet timelines dictated by the academic calendar. The particular areas of focus for the design-build research team dealt with issues such as number of students participating in each design and build effort, length of design time, length of build time, average building size, and average building cost. Being that this was the first time a major design-build effort was being undertaken by the University of Idaho as a part of a studio sequence it was necessary to establish precedence for how the entire effort would be structured using models that had proven to be successful in the past. We found most of the projects to be between 800 and 1,200 square feet; though the largest projects were 1,900 to 2,000 square feet. There was anywhere from 11-17 students involved with both the design and build phases of these projects with a construction schedule that ranged from 10 summer weeks to a full academic semester. This information paired with our knowledge of the requirements of the building program helped us determine that we should keep the building footprint to a range of 1000-1200 square feet.

### 1.3. Building type precedent research

The Building Type Precedents group looked at Eco Shed, a 280 square foot house located in Vancouver, British Columbia, and a materials testing facility designed by Bisby and Associates, also located in Vancouver. The group also studied two house prototypes: Mini Home by Sustain Design Studio, and Blue Sky Mod designed by Todd Saunders. As a class we discussed each of these projects in relation to the bunkhouse program we had been assigned and continued to refer back to them throughout the semester. A number of design principles learned through precedent study helped us establish our own unique design direction based on the program at hand.

For instance, we discussed the use of FSC certified materials in Eco Mod and eventually sought out these materials when we finally reached the design development phase of the project. Studies of both Eco Mod and BedZed brought up a number of discussions about air to air exchange systems and their importance in designs that employ a tight building envelope. The size and character of many of the precedent dwellings helped us visualize how we might economize space without a loss quality of life. The precedents were a continual point of reference as we underwent design exercises throughout the semester.

### 1.4. Site analysis

The second week of the semester was dedicated to travel to two sites. The first field trip we took as a class was to Islandwood, an educational campus whose mission is to teach young people about the environment and sustainable practices. The Islandwood site had been referred to us by our client (MOSS) and was the basic model that they envisioned the McCall campus following. Our next trip was to the McCall campus itself to see the site where our building will eventually be located. The trip to McCall was essential for obvious reasons, not the least of which was that it made the students aware of how difficult it would be to design a carbon neutral building in an environment too wooded to allow for either solar or wind energy generation (at least to the extent that would provide power and heat for an entire facility).

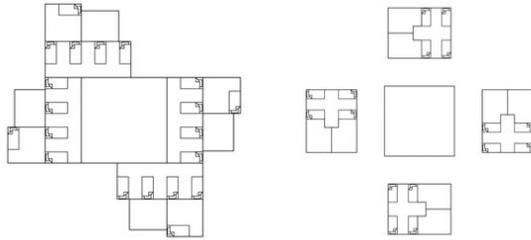


Figure 1: McCall campus site model.  
Source: McCall carbon neutral studio

### 1.5. Plan diagramming

During the third week of studio the students were asked to develop plan diagrams as individuals. Each student was asked to design five layout strategies that worked with the given program. The students were asked to list a square footage for each type of space within the bunkhouse plan. The four main spaces were the mudroom, the bunkroom, the bathroom, and the common area. It was important that we establish a goal in terms of square footage for each space for several reasons. First, as mentioned earlier, keeping the building to a minimum was vital, as we only have a ten week summer academic session to frame and dry it

in and the budget we are dealing with is very restricted. Second, we wanted to ensure that the client was aware of the size of each of the spaces and how each space fit into the overall budget. For example, there was an ongoing question as to whether the restroom area was a necessity – we took it as our job as the architect to keep the client informed of the implications of adding a restroom in terms of increased building size, increased cost, potential environmental implications, etc. When we began the project we had little sense of what it would take to accommodate the number of students that were to stay in the bunkhouse.



**Figure 2:** Plan diagrams.  
Source: McCall carbon neutral studio

Originally, the objective was to use the summer session to build a space to house 30 plus students. It quickly became apparent, through the plan diagramming along with the design build precedent information discussed earlier, that we were not going to be able to accomplish the 30 plus student goal over the course of one summer with the resources that we had. The plan diagramming helped considerably in eliminating schemes that were too space intensive or wasteful and also afforded good discussion of potential plan layouts in relation to site strategies in order to maximize passive solar gain.

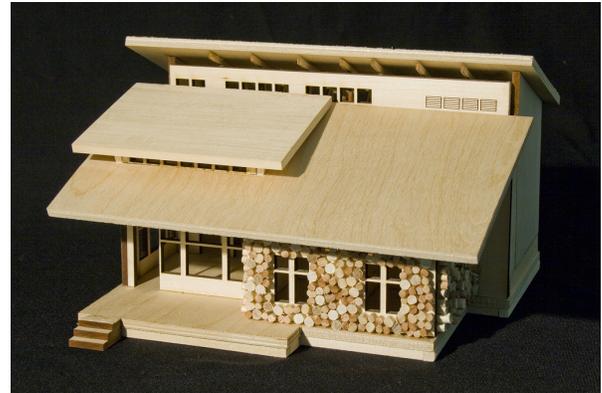
### 1.6. Construction type research

Week four of the semester was dedicated to Construction Type research. As mentioned previously the original project and studio goals were to examine 'alternative' building technologies for a couple of very specific reasons. First, we wanted to gain an understanding of which construction type worked best in the McCall environment. Second, we felt that by using alternative construction technologies we would be accentuating the building as a 'learning instrument', as it would more easily be noticed by campus visitors who are not used to seeing these building types in their daily routines. The initial discussions involved three main alternative building types: straw bale, cordwood, and rammed earth. During my preparation for the semester I began to fear that we were limiting our inquiry too much and so I added 'alternative contemporary' materials (such as SIPS and ICFs) and 'recycled materials' to the list of building types giving us a total of five material categories. The students were divided into five groups and each group was asked to study a different building type from the list. Though this

period of construction type research did not eliminate any particular types from consideration it was becoming clear that students were beginning to gravitate toward one building type or another.

### 1.7. Schematic design: phase I

For the next couple of weeks the students were asked to group themselves based on the construction types they were interested in dealing with and develop schematic designs for the bunkhouse using that particular type.



**Figure 3:** Team 1: schematic bunkhouse model.  
Source: McCall carbon neutral studio

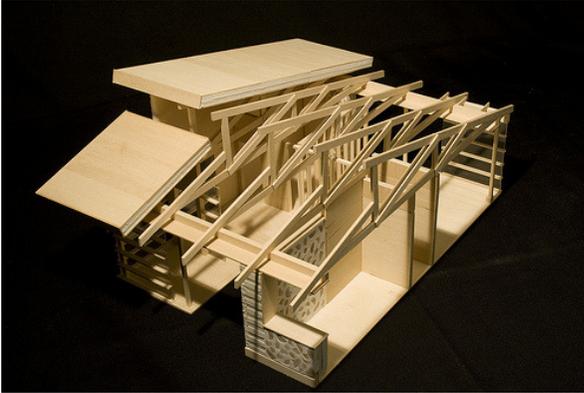
This seemed like an effective approach because it allowed the students to be involved with a material system that they felt compelled to work with and were interested in learning more about. At the end of this two week period the students had developed schematic designs that included plans, sections, perspective renderings, a physical building model, and a bay model. The review for this phase of the project was the first opportunity for the MOSS group to see and provide feedback on the five team projects.



**Figure 4:** Team 3: bay model.  
Source: McCall carbon neutral studio

### 1.8. Schematic design: phase II

Following the first schematic design review we spent another two weeks modifying the team designs based on the comments from the MOSS group. Part of our time during this period was spent dealing with issues that we realized we had neglected during phase I of the schematic design. Items such as mechanical room size, specific handicap accessibility issues in the restrooms, and detailing and construction issues that had not been given enough attention were looked at more carefully during this phase.



**Figure 5:** Team 1: schematic bunkhouse model.  
Source: McCall carbon neutral studio

We then had a second schematic design review and received additional feedback from the MOSS group. This was a critical review in that it was understood that a single design was to be chosen by the client for the class to then pursue for the remainder of the semester. Following the review and after a discussion with the MOSS group it was determined that there were aspects of several schemes that were preferred and that no single scheme had yet solved the problem entirely. Immediately following my discussion with the MOSS group the class got together and began to unify the schemes based on the client's comments. A general parti was established and we then divided up to work on specific aspects of the project making overall design refinements over the next few days.

## 2. FINAL DESIGN

Once we had established a single design the students were asked to sign up for teams in the following categories: design development, construction documentation, physical model making, digital models and presentation, and energy analysis. The design development team was charged with locating materials and vendors, figuring costs, and determining product feasibility.

The construction document team organized all of the CAD files, dealt with all code issues, and developed the title blocks and construction document set. The physical model making team was responsible for four models: a site model, a framing model, a full building model, and a bay model. They were also responsible



**Figure 6:** Final design: bay model.  
Source: McCall carbon neutral studio

for any schematic modelling exercises that were going to take place before the final models were started. The digital models and presentation group was responsible for all digital models and renderings, as well as the studio book layout. The energy team was responsible for testing the building in various energy modelling programs such as HEED and Balance Point. It was understood that there were still a number of design issues that needed to be resolved and that we would all work together as a team to get the issues addressed. The students from each group were asked to keep the other groups informed of any information that could have an effect on their work.

### 2.1. Foundation

The foundation system that we opted to employ is an insulated slab on grade with high fly ash content. There will be 2" of rigid insulation beneath the slab and aligning the inside and outside edges of the grade beams. The slab will have integral piping to deliver radiant heat throughout the building. Radiant heating will be the only mechanical heat source in the building. The perimeter of the north, east, and west sides of the slab will have a stem wall that rises 2' above grade to help protect the building's straw bale envelope from moisture penetration. The slab will be poured on site by an outside contractor and will be in place and ready to build upon when the students arrive in May.

### 2.2. Building envelope

When designing the building envelope we looked closely at rammed earth, cordwood, and straw bale construction. In conjunction with our efforts, Crystal Van Horn, an MSArch student at the time, was looking in more detail at the three construction types and their feasibility and carbon costs for our region. Though this paper will focus only on the general criteria that helped us determine the most appropriate construction type for our project, each construction type was looked at in great detail.

It was determined fairly early in the process that rammed earth was not a suitable form of construction in our region for a variety of reasons. While rammed earth provides excellent thermal mass properties it was

determined that, because of our particular climate, our priority should be to design a building envelope with the highest possible insulation value. Strategies were explored wherein we experimented with two 8" wythes of rammed earth with an 8" layer of rigid insulation sandwiched between. The sandwiched rammed earth envelope provided an adequate R-value but was determined to be problematic in terms of construction time and cost. In talking to several rammed earth contractors we determined that the cost of rammed earth, when constructing a structural wall built with pneumatic tamping devices, in most cases exceeds (and in some cases doubles) the cost of cast-in-place concrete. Moisture protection also becomes a critical component of rammed earth construction and the winter and spring months in McCall see an abundance of snow and rain. No calculations were made as to the carbon costs of rammed earth due to the fact that it was found to be inadequate as a construction type in our region.

Cordwood was a viable option due to the abundance of this material in our region. Its low cost was immediately cited as an advantage and our ability to use wood from the thinning of undergrowth in nearby Ponderosa State Park would result in low embodied energy for the material. Although there are many advantages to using cordwood in our region, there are a number of disadvantages as well. First, the cordwood construction process is very labor intensive and requires a great deal of wood and mortar to construct. Second, an effective cordwood envelope requires wood that has been air dried for up to three seasons. Because of this it was determined that cordwood is a viable future option but that it is not suitable for this year's project.

Alternative contemporary systems were also looked into. SIPS proved to be the most ideal system due to its high R-value in relation to its wall thickness. Ultimately, the fact that our client wanted the building to act as a learning instrument led us away from SIPS and toward straw bale construction due mostly to the latter's overtly tactile quality.



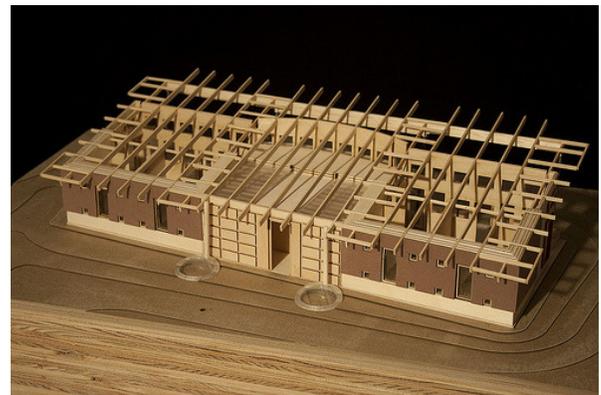
**Figure 7:** Building envelope.  
Source: McCall carbon neutral studio

After studying the potential construction types it was determined that straw bale was the best option for the summer build. Straw bale as a building material met our desire for fire-wise construction and helped us

achieve up to an R-33 insulation value. The north building envelope and approximately half of the east and west building envelopes will be constructed with straw bales. Through our precedent studies we found that, compared with a number of other building materials straw bales are relatively low in embodied energy, readily available in our region, and fairly easy to construct with inexperienced laborers. Straw bale is an abundant and renewable resource and straw bale homes require about 30 times less energy than homes with standard wood frame walls. (Chiras, 2000)

### 2.3. Roof

The roof of the bunkhouse will be constructed of 8" thick SIPS panels and will be an R-45 construction. SIPS was selected as a roof material for a few reasons. First, the panels are easy to install and can be custom ordered to any size to meet our roof framing layout. Second, we were able to achieve a high R-value relative to roof thickness and significantly limit our thermal bridging. Lastly, the SIPS panel's OSB underside provides a finished surface for the bunkhouse interior which is to remain relatively rustic.



**Figure 8:** Roof system.  
Source: McCall carbon neutral studio

### 2.4. Mechanical systems

Radiant floors that circulate hot water fed by a wood fired boiler will be the only source of heat for the bunkhouse. The wood fired boiler is paired with a solar array located nearby on site that will heat the water when it is able. When the PVs are not providing enough energy the system will automatically switch to the wood fired option.

A heat recovery ventilation (HRV) system has been specified that will ensure that the building is properly ventilated.

## 3. ENERGY MODELLING

Energy modelling was performed to predict the energy savings and green house gas emission reductions associated with replacing the existing log cabins at the McCall Field Campus with new energy efficient buildings utilizing Straw bale walls, a SIPS roof, and extensive south facing glazing for passive solar.



**Figure 9:** Final design: schematic model.  
Source: McCall carbon neutral studio

heating. These studies suggest the new building will achieve a reduction in energy consumption of 45% over the existing buildings

### 3.1. Energy modelling programs

The energy modelling procedures for the McCall campus involved computer based simulation programs to estimate energy usage and resultant green house gas emissions throughout a typical calendar year. For this project we used three computer based energy-modelling programs in an attempt to quantify energy consumption and carbon emissions of the existing and proposed structures. HEED is a standalone program developed by the Energy Design Tools Group at UCLA Berkeley (HEED). Autodesk Green Building Studio is a web-based energy analysis service that works in conjunction with Autodesk Revit (Autodesk). VE-Ware is a building energy usage and carbon dioxide emission assessment software package available from Integrated Environmental Solutions (IES).

Of the programs evaluated, HEED proved to be the easiest to obtain and the simplest to operate. HEED uses very basic user input building parameters and a user supplied climate file unique to the region. A climate file for Salmon, Idaho was used as no climate file was available for McCall. Salmon and McCall are at the same latitude with similar temperatures, but differences in precipitation, days of sunshine, wind, etc. may substantially change results.

### 3.2. Energy modelling procedures

The greatest challenge in energy modelling using any of the evaluated programs was the absence of alternative building material information within the program, such as straw bale and cordwood and their associated thermal properties. Obtaining thermal properties for alternative building materials was also challenging, as explained below.

HEED uses various thermal properties of a building material to determine effective thermal mass and R-values for the entire structure. Two key thermal properties essential for the modelling program were difficult to obtain for alternative building materials. Time Lag is the duration of hours it takes a temperature wave to move from a building material's inner surface

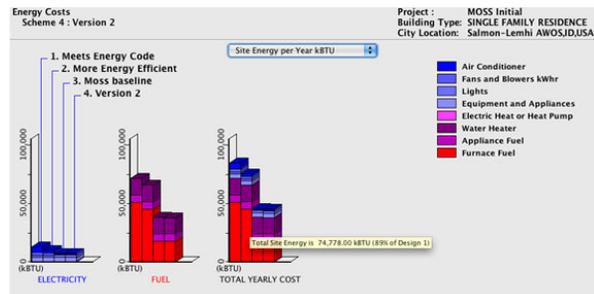
to its outer surface, or vice versa (HEED). Decrement factor is the proportional damping of temperature as it moves through a massive material (HEED). For quantifying these values, UCLA Berkeley's Energy Design Tools Group provides the program Opaque. Opaque calculates decrement factor and time lag based on several other material properties. These include: density, R-value, specific heat, conductance, and thickness.

Approximate values for the walls in the existing log cabin were obtained from Colorado Energy (Colorado). Many assumptions were made. The species was assumed to be white pine. The thickness was assumed to be eight inches and continuous (not round logs). Grout was not accounted for. Calculations based on these assumptions would make the building appear to perform better than it actually does. Therefore, actual energy savings of new structures would be greater than those predicted.

Several scientific studies have been conducted to determine the R-value of straw bale construction (Stone, 2003). This paper suggests a range of R27 to R33 for a typical straw bale wall. A conservative value of R27 was used for modelling the straw bale components of the proposed structure. Values for manufactured products were obtained through the manufacturers. These values were assumed to be accurate.

### 3.3. Energy modelling results

The existing 732sf cabin is a simple rectangular design consisting only of bunk beds. The proposed 1216sf bunkhouse is 40% larger than the existing cabin and has two ADA compliant restrooms, two common areas, and a mudroom.



**Figure 10:** HEED calculations graph  
Source: HEED software, Keith Bickford

HEED suggests an energy savings of 45% in the new bunkhouse, not considering additional energy consuming devices such as a hot water heater which the log cabins do not have. The existing log cabins utilize a separate building for showers and restrooms. It is assumed that the existing shower/restroom building will remain until all other living facilities are replaced with new buildings containing restrooms. According to HEED predictions, electricity consumption in the existing cabin is 67,767 kBTU annually, and the proposed bunkhouse consumption is 37,485 kBTU annually.

Summary Table				
Project : MOSS Initial A 1,216 Square Foot SINGLE FAMILY RESIDENCE in Salmon-Lemhi AWOS, ID, USA				
Scheme Name	Energy Costs			Savings Compared to Scheme 1
	Electricity	Gas	Total	
1. Meets Energy Code	\$508.48	\$776.47	\$1,284.95	
2. More Energy Efficient	\$357.89	\$705.53	\$1,063.41	17%
3.				
4. MOSS Initial	\$267.88	\$398.09	\$665.97	48%

**Figure 11:** HEED calculations summary  
Source: HEED software, Keith Bickford

HEED calculates CO2 emissions with user provided emission rates, and uses California emission factors as a default. HEED suggested a CO2 reduction of 10,107,837 lbs based on California emission factors. An external calculation was performed using the North West Power Pool's emission factor of 0.92 lbs CO2/kWh for purchased electricity and 14.268 lbs/therm according to the Greenhouse Gas Protocol Initiative (GHGP). These calculations suggest a reduction in CO2 emissions of 3,348 lbs. Data values are provided in Figure 12.

	Existing Cabin	Proposed Bunkhouse	Difference	Source
Electricity	67767.42	2959.43	64807.99	kBTU HEED
NatGas		34525.56	-34525.56	kBTU HEED
Total	67767.42	37484.99	30282.43	kBTU HEED
HEED CO2	10108627	789.69	10107837.31	LBS HEED
Electricity	9861.49	867.36	8994.13	kWhr HEED
CO2 (0.92 lbs/kWh)	9072.5708	797.9712	8274.60	lbs GHGP
NatGas		345.26		Therms HEED
CO2		2.237		Tonnes GHGP
CO2 (14.268lbs/therm)		4927.312775		Lbs
Total CO2	9072.5708	5725.283975	3347.29	Lbs

**Figure 11:** CO2 emissions calculations provided by Keith Bickford

## CONCLUSION

There were a number of areas to draw lessons from in the McCall carbon neutral studio effort. First, a great deal was learned in terms of how to structure a studio project of this magnitude. It is my belief after having directed the class that a studio project of this size and scope should be a two semester endeavour. The first semester should be spent getting students grounded in carbon neutral design principals, site and climate analysis, and schematic building design. Efforts should be made to calculate energy implications during the design process though we have not yet found a seamless way to undergo energy calculations without disrupting the flow of the material, formal, and spatial design process. The second semester should be spent with an interdisciplinary group, including at minimum Mechanical Engineers, Structural Engineers, and Architects, all working toward the same goal of minimizing (if not negating) the building's negative environmental impacts. The fact that our carbon neutral facility is slated to be built had an enormous impact on the studio structure and the time that needed to be dedicated to each task. Time spent working on construction documents could have been spent in increased energy modelling efforts. During the Spring

of 2009 we will be continuing the McCall project, working with an interdisciplinary team of capstone students from the University of Idaho and Washington State University. Our goal will be to refine the building design based on the expertise brought in by each discipline with the ultimate goal of carbon neutrality for the facility. It is our hope that in continuing to test and experiment with the carbon neutral studio we will refine our methods of inquiry into carbon neutral building techniques and eventually as architects and educators meet the goals of the 2030 challenge.

## ACKNOWLEDGEMENTS

Energy modelling charts produced by Keith Bickford using HEED software version 3.1.3. All model photography courtesy Brian Henry.

## REFERENCES

Autodesk, Green Building Studio program information available from <http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=11179531>

Chiras, D.D. 2000. *The Natural House: A Complete guide to Healthy, Energy Efficient, Environmental Homes*. White River Junction, Vermont: Chelsea Green Publishing Company.

Colorado Energy, <http://coloradoenergy.net/procorner/stuff/r-values.htm>

GHGP, <http://www.ghgprotocol.org/calculation-tools/service-sector>, Indirect Emissions (Emissions from use of purchased electricity, heat or steam), ElectricityPurchase\_ServiceSector\_v3.0.xls and Stationary Combustion Tool (Version 4.0).xls

HEED version 3.1.3, program available from <http://www2.aud.ucla.edu/energy-design-tools>, reference information obtained from help file

IES, program information available from <http://www.iesve.com/content/default.asp?page=s130>

Stone, N. 2003. *Thermal Performance of Straw Bale Wall Systems*. Ecological Building Network.

