

Carbon-Neutral McCall:

Developing a zero energy campus in McCall, Idaho

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ABSTRACT: At the University of Idaho an interdisciplinary group of faculty and students has created a design-build workshop sequence focused on the development of a carbon-neutral learning environment at one of the university's field campuses in McCall, Idaho. 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 at the campus. The inaugural design workshop in the sequence began this semester. This paper will focus on a number of critical issues regarding the inaugural design-build workshop experience. First, it will present student findings as to the carbon-neutral material and building technology possibilities in this region. Next, it will outline our findings regarding carbon-neutral building performance, with an emphasis on passive techniques, for the intermountain west region. Finally, the paper will give an overview of the interactive process and compromises that take place when client's needs and desires are measured against material and formal needs with regard to carbon-neutral construction and performance.

Keywords: energy, carbon-neutral, zero energy, design-build

PROJECT INTRODUCTION

In 2006 an interdisciplinary design studio was formed at the University of Idaho that focused on the construction of a carbon-neutral field campus in McCall, Idaho. The field campus is currently 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. The studio included students from the departments of Architecture and Interior Design as well as collaboration and support from faculty members in various disciplines including Architecture, Interior Design, Landscape Architecture, Bioregional Planning, and Conservation Social Sciences. In addition to involvement from the University of Idaho students and faculty, a number of community stakeholders were involved. Among the community groups were the McCall Outdoor Science School, Palouse Clearwater Environmental Institute, Idaho Department of Parks and Recreation, and the City of McCall. Professional involvement included support from Epikos Architecture and Engineering, and Sesech Engineering. The 2006 studio concentrated on major site development issues (*Figure 1*) and preliminary schematic designs of a variety of building types that will eventually populate the campus. In fall, 2008 a second carbon-neutral studio was conducted that focused on the design of a single, carbon-neutral living facility at the McCall Field Campus. The goals of the

2008 studio were to design a living facility that housed 16 people, embodied principles of fire-wise construction, used underutilized materials, obtained carbon-neutral performance, and acted as a learning instrument for the students who were to occupy it. We are currently in the midst of a continuation of the project in the form of an interdisciplinary workshop in which a team consisting of architects, mechanical engineers, and structural engineers will attempt to refine the design and material decisions made during the 2008 carbon-neutral studio. This paper will focus on the work of the fall 2008 studio, describing building type research and preliminary energy calculations for the living facility.

CARBON-NEUTRAL STUDIO STRUCTURE

The fall 2008 studio was carefully structured as there were a number of issues that had to be addressed before schematic design could begin. We were limited on time as the studio had to result in a complete set of construction documents and energy models for the building. During the first week of the studio we focused on three areas of precedent research: carbon-neutral design, design-build, and building types. The class was divided into three teams of five students each and each team was asked to choose one of the three areas of research focus.



Figure 1: Final Site Development Plan, Fall 2006 Carbon-Neutral Studio (Source: Bruce Haglund).

The second week of the studio was dedicated to site analysis. We took two field trips as a class during this week. One of the trips was to Islandwood, an educational campus on Bainbridge Island, Washington, whose mission is to teach young people about stewardship of the environment and sustainable practices. Our second trip was to the McCall Field Campus, where our building will eventually be located. The trip to McCall allowed the students to draw inspiration from the site and gave us an initial indication of the best site location for the living facility.

The third week of the studio was dedicated to plan diagramming, which was done on an individual basis.

The fourth week was dedicated to construction type research. This was another team effort where the students were divided into three groups: cordwood, rammed earth, and straw-bale. We chose these three construction types as a specific response to the goal of using underutilized materials and as an accentuation of the building as learning instrument.

Following these preliminary research exercises the students spent the next couple of weeks on Phase I Schematic Design. For this phase the students were divided into teams of three students each. Each team was asked to select a construction type they were interested in pursuing and complete a schematic design of the living facility using the chosen construction type. After a review, which included the client and a number of employees from the field campus, the students were asked to refine their schematic designs over the next couple of weeks. (Figure 2)

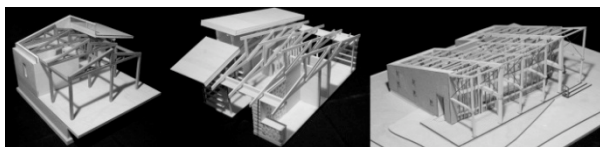


Figure 2: Site Model, Fall 2008 (Source: 2008 University of Idaho, Carbon-Neutral Studio).

The remaining nine weeks of the studio were dedicated to devising a final design from the information we had received from the client and other team members during the course of Schematic Design Phase I and II.

FINAL DESIGN

During the final design phase the students were asked to sign up for teams in the following categories: design development, construction documentation, physical model making, digital models / presentation, and energy analysis. The goal of the design development team was to locate local material vendors, help determine product feasibility, and establish costs for each product. The construction document team was responsible for all 'hard-line' drawings during the process of redesign, title blocks, code information, and the final construction document set. The physical model team was responsible for constructing schematic models as the class underwent the process of redesign, and constructing the final models which would be detailed scale replicas of the final building design. The digital model and presentation group focused on the creation of a book of studio work, and all final renderings and boards. The energy team tested the building during the process of final design in various energy modeling programs such as HEED, Autodesk Revit, and VE-Ware. Throughout this process it was understood that there were a number of design issues that still needed to be resolved and that members from each team would be responsible for rejoining as a larger group and solving the design issues as they arose.

SITE AND FOUNDATION

It became clear to the class after visiting the field campus that the Alpine forest environment was going to present additional design challenges, as the ability to garner natural light during the winter months is reduced on our site by large Ponderosa Pine trees. (Figure 3) The heavily wooded site also makes it difficult to generate wind energy at a significant enough level to aid in building operation. These particular characteristics of the site limited our possibilities for building placement such that it became fairly evident early on where the general location of the building would have to be. The abundance of shading on the site will make future building location strategies a huge part of the overall problem to solve in relation to creating a building that minimizes its energy needs.

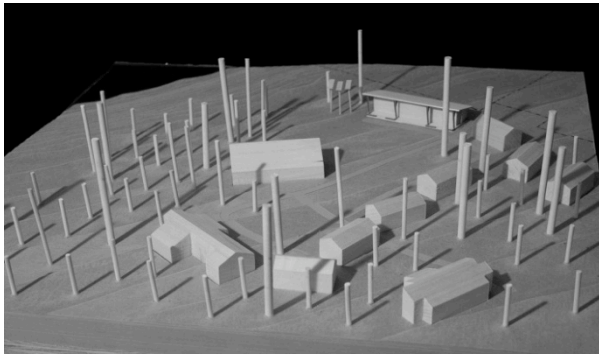


Figure 3: Site Model, Fall 2008 (Source: 2008 University of Idaho, Carbon-Neutral Studio).

After discussing foundation options as a group and consulting with several contractors in the McCall area we opted to design an insulated slab on grade with high fly ash content. The foundation is designed to have 2" of rigid insulation beneath the slab and aligning the inside and outside surface of the grade beams. Integral piping in the slab will deliver radiant heat throughout the building. The radiant heat from the slab will be the only mechanical heat source in the building. A stem wall at the perimeter of the north, east, and west sides of the slab 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. The current McCall workshop is interrogating this foundation system to see if a lower impact foundation may be employed. The driving force from a design-build perspective of using a traditional foundation system is the fact that we can have licensed contractors pour the slab and have it ready to house building elements when we arrive at the site. Due to our 10 week build schedule we are looking at several areas of the building whose construction can be farmed out to licensed contractors. Our research in this semester's workshop should help us determine whether there are better (more sustainable) foundation alternatives, which meet our time constraints.

BUILDING ENVELOPE

Our research for the building envelope focused mainly on rammed earth, cordwood, and straw bale, and what I labeled for the students "alternative contemporary" construction types (these included products such as SIPS and ICFs). Crystal Van Horn, an M.S. Arch student at the time, did an in depth analysis on the first three of the aforementioned building types as part of her master's thesis. Her study was in part an attempt to determine feasibility and carbon costs for the use of these materials in our region.



Figure 4: Bay Model (south side), Fall 2008 (Source: 2008 University of Idaho, Carbon-Neutral Studio).

Through a combination of Crystal Van Horn's graduate thesis work and our studio research effort it was determined fairly early in the process that rammed earth was not a suitable form of construction in our location. Some of the advantages of rammed earth are its ability to resist fire, which met our goal of fire-wise construction, and the reduction of wood used in the rammed earth construction process (assuming the use of slip forms and a reuse of the formwork in other areas of the building). (Chiras, pg. 47-52, 62) The general disadvantages of rammed earth include a labor intensive construction process (which had an impact on us due to our build time constraints), the special skill needed to create load bearing rammed earth walls, the difficulty of moisture protection, and the general expense of the process. (Chiras, pg. 62-63) We would have been unable to use earth from the site, so rammed earth did not provide an advantage in terms of the carbon cost of material delivery. There are regional disadvantages to rammed earth as well. In the Intermountain West region it is paramount to create an envelope with a high insulation value. Our goal was that our northern building envelope would be an R-33 construction or greater. In order to achieve an R-33 envelope in rammed earth it was determined that the wall would consist of two 8" wythes of earth with an 8" layer of rigid insulation sandwiched between. This not only increased the difficulty of building with rammed earth but it would have resulted in a tremendous increase of rigid insulation used in the project. 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 construction has a number of advantages in our region, and specifically in our local Alpine forest location. Because nearby Ponderosa State Park currently has undergrowth cutting programs in place, it would most likely be possible to use the waste materials from those programs as the harvested product

for a cordwood dwelling. This would drive the cost of the dwelling down considerably. Our ability to use the undergrowth from nearby Ponderosa State Park would also result in low embodied energy for the material, as it would be delivered from less than a mile away. Although low cost, material availability, and low embodied energy are advantages to cordwood construction 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 (DayCreek Journal). The cordwood envelope that would have to be constructed to achieve an R-33 insulation value is similar to the rammed earth envelope makeup discussed above: 2, 8" wythes of cordwood with an 8" layer of rigid insulation sandwiched between (Roy, pg. 39). Perhaps the biggest disadvantage of cordwood for the needs of our project is that it requires wood that has been air dried for up to three seasons (Roy, pg. 22). For these reasons it was determined that cordwood is a viable future option but that it was not suitable for this year's project.

There are a number of advantages to using straw bale construction in the Intermountain West region. First, it is a widely available material and highly renewable resource. Second, straw bale has a low embodied energy and it meets the requirements for fire-wise construction, and for the use of an underutilized material (as much of the straw used in straw bale construction would be burned in stockpiles if not used in other construction applications). Third, the bales in straw bale construction have somewhere between an R-27 and R-35 insulation value which reduces (if not eliminates) the need for standard insulation materials in the building envelope. (King, pg. 187) Lastly, straw bale allows for a relatively quick construction time as the bales are stacked like brick and each bale takes up a large portion of wall area. Straw bale construction is not without its disadvantages however. It is essential that straw bale walls are protected from moisture, this results in additional roof framing so that long building eaves can help keep moisture off of the wall surfaces (King, pg. 20). Straw Bale walls also require an applied stucco surface which results in an increased embodied energy for the envelope as a whole.

Of the 'alternative contemporary' systems that were looked into SIPS proved to be the most ideal for our area due to its high R-value in relation to its width and due to the relative ease of construction for a design build team consisting mostly of untrained laborers. 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 as a type that would be more recognizably different than what the building inhabitants were used to experiencing on a daily basis.

After much deliberation we determined that straw bale was the best material option for our needs. The north building envelope and approximately half of the east and west building envelopes will be constructed with straw bales.

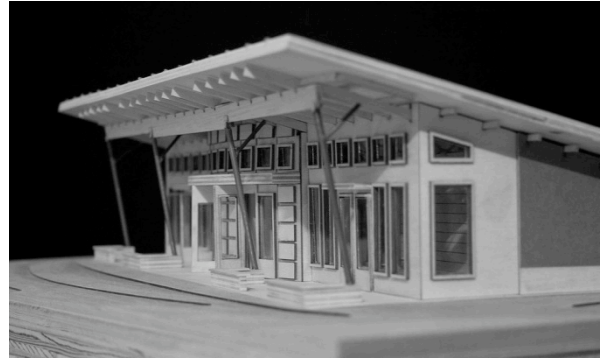


Figure 5: Final Model (southeast corner), Fall 2008 (Source: 2008 University of Idaho, Carbon-Neutral Studio).

The roof of the bunkhouse will be constructed of 8" thick SIPS panels and will be an R-45 construction. SIPS were selected as a roof material for a number of 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 surfaces of the SIPS panel are constructed of Oriented Strand Board (OSB) which provides a finished surface for the bunkhouse interior, allowing us not to add any additional surfacing material.

MECHANICAL SYSTEMS / ENERGY MODELING

The primary source of heat for the bunkhouse (and the only mechanical source of heat), is provided by radiant floors that circulate hot water fed by a wood fired boiler. A solar array located near the building will be paired with a wood fired boiler to heat the water that runs through the radiant floor system. The system will be on an automatic switch such that the wood fired boiler will automatically operate when the photovoltaic panels are unable to provide the energy. A heat recovery ventilation (HRV) system has been specified that will ensure that the building is properly ventilated. After discussions with industry professionals it was determined that an HRV was necessary due to our need to tighten the building envelope, suppressing much of the natural ventilation that occurs through small voids and cracks in typical wood frame construction.

A number of energy models were tested to predict the energy savings and green house gas emission reductions associated with replacing the existing log cabins at the McCall Field Campus with the new

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

Computer based simulation programs were used to estimate energy use and green house gas emissions during a typical calendar year. This project used HEED, Autodesk Revit, and VE-Ware. HEED proved to be the easiest to obtain of the modeling programs 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.

	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 6: CO2 Emissions, calculations provided by Keith Bickford

Many scientific studies have been conducted to determine the R-value of straw bale construction (Stone, 2003). This paper suggests a range of R-27 to R-33 for a typical straw bale wall; though a conservative value of R-27 was used for this study. Values for manufactured products were obtained through the manufacturers. These values were assumed to be accurate. (Jacobus, Bickford)

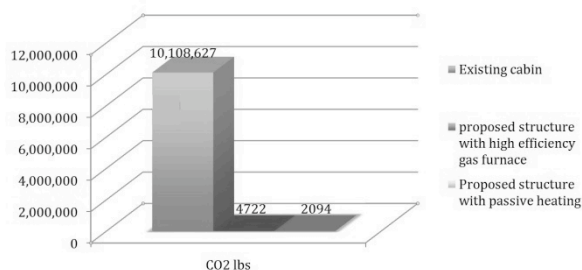


Figure 7: HEED Data, Annual CO2 Emissions, Fall 2008 (Source: 2008 University of Idaho, Carbon-Neutral Studio).

The existing 732sf bunkhouses are a simple rectangular design consisting only of bunk beds. The proposed 1,216 square foot bunkhouse is 40% larger than the existing cabin and has two ADA compliant restrooms, two common areas, and a mudroom.

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. (Jacobus, Bickford)

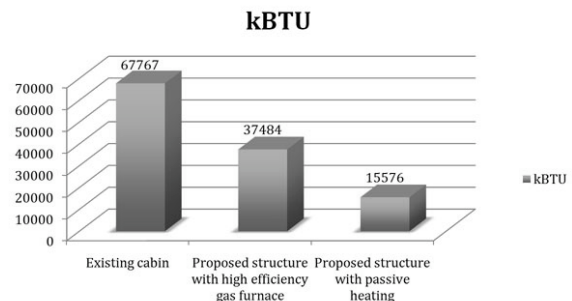


Figure 8: HEED Data, Annual CO2 Energy Usage, Fall 2008 (Source: 2008 University of Idaho, Carbon-Neutral Studio).

The 2030 Challenge as defined by Architecture 2030 (2030) requires all new buildings to reduce fossil fuel consumption by 60% by the year 2010. Our modeling suggests that our proposed bunkhouse will reduce electricity consumption by 91% when compared to the existing cabin, and by 77% when compared to an equivalent sized home that meets energy code. Our model suggests that the proposed bunkhouse will reduce natural gas consumption by 52% when compared to an equivalent sized home that meets energy code. Total CO2 emissions will be reduced by 58%. Our modeling does not account for local production of electricity with photovoltaics as planned, and our modeling does not account for utilizing a biomass burner as a primary heat source as planned.

	Proposed Bunkhouse	Equivalent size spec home, meets code	Change (typical home to bunkhouse)	% Change (typical home to bunkhouse)
Electricity (kWhr)	867.36	3,764.00	2,897	77%
CO2 from electricity (lbs) (0.92 lbs/kWh)	797.97	3,462.88	2,665	77%
NatGas (therms)	345	714	369	52%
CO2 from natural gas (lbs) (14.268lbs/therm)	4926.16968	10187.352	5,261.182	52%
Total CO2 (lbs) (electric and natural gas)	5724.14088	13650.232	7,926.091	58%

Figure 9. Comparison of energy consumption and carbon emissions between conventional home and proposed bunkhouse.

	Existing Cabin	Proposed Bunkhouse	Change (Cabin to bunkhouse)	% Change (Cabin to bunkhouse)
Electricity (kWhr)	9,861.49	867.36	8,994.13	91%
CO2 from electricity (lbs) (0.92 lbs/kWh)	9,072.57	797.97	8,274.60	91%
NatGas (therms)	N/A	345	N/A	N/A
CO2 from natural gas (lbs) (14.268lbs/therm)	N/A	4926.16968	N/A	N/A
Total CO2 (lbs) (electric and natural gas)	9072.5708	5724.14088	3348.43	37%

Figure 10: Comparison of energy consumption and carbon emissions between existing cabin and proposed bunkhouse.

CONCLUSION

A number of lessons relating to carbon-neutral studio structure and energy analysis were learned from the McCall carbon-neutral studio experiment. The structure of the studio project became a vital determinant in the successes and failures that we faced throughout the duration of the project. Due to the necessity of delivering a complete set of construction documents we were dealing with a limited time table in relation to energy testing. A number of things could be done to mitigate the time constraints in future carbon-neutral studio efforts. Though we began the semester by focusing on a number of alternative building types, it would have saved a great deal of time to begin with a single building type and explore how the building type can be modified to meet the studio's energy needs. This would have had a couple of potential negative educational impacts however. First, the students would not have been introduced to the variety of alternative building types and therefore would have left the students without that knowledge to take into practice. Second, the chosen building type might not have turned out to be best for the region, resulting in a lower performing facility. A second issue which I believe took some time away from more energy testing was schematic design phase II which I felt wasn't as fruitful as schematic design phase I for project refinements. The alternative would have been to begin the final design process immediately following schematic design phase I, leaving more time for energy testing.

Beyond the studio structure component there were a number of successes during the fall 2008 studio. The students came away with a good understanding of alternative construction techniques that they can take into practice. The students also came away with an understanding of the implications of each design decision, whether it be roof and envelope r-value, effect of glazing type and quantity, or the environmental impacts of material choices.

A continuation of the fall 2008 studio is now underway. Four architecture students from the

2008 carbon-neutral studio are currently working with mechanical engineering students from the University of Idaho and structural engineering students from Washington State University to refine the building design such that all decisions are looked at by experts from the respective disciplines. Our hope is to conclude this spring semester interdisciplinary effort with the knowledge that all building components have been thought about at a level that insures that the living facility embodies the ideals embraced by the 2030 challenge.

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REFERENCES

1. Autodesk, Green Building Studio program information available from <http://usa.autodesk.com/adsk/servlet/index?siteID=123112&id=11179531>
2. Chiras, Daniel D. *The Natural House: a complete guide to healthy, energy-efficient, environmental homes*. White River Junction: Chelsea Green Publishing Company, 2000.
3. Colorado Energy, <http://coloradoenergy.net/procorner/stuff/r-values.htm>
4. DayCreek Journal. (2008). Cordwood Masonry. Retrieved December 2008, from DayCreek: http://www.daycreek.com/dc/HTML/DC_strawbale.htm
5. 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
6. HEED, program available from <http://www2.aud.ucla.edu/energy-design-tools>, reference information obtained from help file
7. IES, program information available from <http://www.iesve.com/content/default.asp?page=s130>
8. King, Bruce. *Design of Straw Bale Buildings: the state of the art*. San Rafael: Green Building Press, 2006.
9. Roy, Rob. *Cordwood Building: the state of the art*. Gabriola Island: New Society Publishers, 2003.
10. Stone, N. *Thermal Performance of Straw Bale Wall Systems*. Ecological Building Network. 2003
11. Jacobus, Frank. Bickford, Keith *Building Learning: Making a Carbon-Neutral Campus in McCall, Idaho*. 2009. (Energy Modeling section adapted from above)
12. Corum, Nathaniel. Goodall, Jane. *Building a Strawbale House: The Red Feather Construction Handbook*. Princeton Architectural Press. 2005.