Carbon Neutral Affordable Housing:

A Guidebook For Providers, Designers And Students of Affordable Housing

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editors

AIA

CARBON NEUTRAL DESIGN PROJECT
The Society of Building Science Educators www.sbse.org

sbse

Spinnereistrasse Affordable Housing Complex

Hard, Austria

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Click Here! CND Resources and other webistes are hyperlinked throughout this document

This guide for providers, designers and students of affordable housing is a research product of the SBSE Carbon Neutral Design (CND) Project and the CND Case Study Protocol effort- a tool that this guide serves to introduce.

The CND Case Study Protocol for Affordable Housing has been tested to date through three case studies that serve to illustrate this guide. These buildings are each in their own way striving towards carbon neutrality, though it is important to note that none of them achieve this end. They are each representative of a specific scale of construction, and each hold a host of interesting lessons to be learned.

The authors would like to thank all of the architects, experts, educators, students and residents who have participated in this effort to date, as well as those who have provided funding dedicated to the cause of affordable housing. The work continues...

The Society of
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Introduction: Carbon Neutrality as a Goal for Affordable Housing

Affordable housing organizations strive to alleviate the cost burden of housing for low-income households by subsidizing rent and home ownership financing. Costs associated with occupancy, however, are a continual source of financial stress for low-income individuals. In the US, low-income household energy bills average $1,900 per year. As energy prices continue to rise and become more volatile with time, this burden will grow. Implementing design strategies in affordable housing projects to increase energy efficiency can help extend the paycheck of a low-income family while improving their quality of life.

At the same time, fossil fuels used in buildings are a significant source of carbon emissions contributing to climate change. Extreme weather events and changing climate patterns that are predicted to occur with global climate change will disproportionately affect this demographic. Building adaptations needed to respond to these changing conditions, ranging from higher energy bills due to increased reliance on heating and cooling systems to elevating buildings to respond to rising sea levels and increased flood events will bring unexpected costs that low-income individuals may not be able to bear.

A reasonable response to these challenges is to design more energy-efficient housing. What if instead of just reducing a home's energy needs, however, we designed homes that greatly reduced occupants' utility bills, insulating them from escalating prices and reducing their negative impact on the environment? What if we designed homes that met their own energy needs on site? Carbon Neutral Design (CND) is a design approach that combines sustainable design strategies, on-site renewable energy generation, and off site renewable energy purchases, in order to both significantly reduce the energy demands of a home and eliminate the carbon impacts associated with occupying it.

Carbon Neutral Design Defined

Carbon Neutral Design (CND) is a movement focusing on creating buildings that reduce or eliminate carbon dioxide emissions throughout a building's life cycle. A typical building project generates carbon emissions throughout its lifespan. Before construction, carbon is emitted when natural resources are extracted of raw materials and are processed into building materials and products. During construction, this occurs when building materials are transported to the construction site, when the site is excavated for construction, and when equipment and tools are operated. Once construction is complete, carbon emissions are generated from the building's operation, including mechanical systems, lighting, and appliance use. Still more carbon is emitted at the end of the building's life, as the building materials are either reused, recycled or sent to a landfill.

Carbon & Greenhouse Gases

Earth's atmosphere is made up of gases, some occurring naturally and others generated by human activities. Solar energy in the form of radiation passes through the atmosphere and is absorbed by the earth's surface and then it is radiated back. Naturally occurring greenhouse gasses trap some of this radiated heat. This regulates temperatures and is part of what makes earth habitable.

Human activities have caused greenhouse gases to increase in concentration in the atmosphere, resulting in more heat being trapped. Carbon dioxide is the primary greenhouse gas growing in concentration. Fossil fuels like coal, oil and natural gas are stored carbon that has accumulated over millions of years. Combustion of fossil fuels and other industrial processed releases this stored carbon at a rate much greater than occurs naturally. Since industrialization occurred in the early 1800s, the concentration of greenhouse gases in the atmosphere has increased by 25%. Greater concentrations of greenhouse gases in the atmosphere has resulted in rising average temperatures globally and has the potential to cause more intense weather events, including storms and droughts, elevate sea levels, and shift ecosystems. There is growing concern globally about the effects these changes in climate patterns will have on daily life.

A significant amount of the carbon dioxide released to the atmosphere is attributable to energy production. In the building sector, 84% of energy comes from fossil fuels, including natural gas, oil, and coal. Fossil fuels are formed by the decomposition of organisms and have a high percentage of carbon. When burned, carbon is emitted in the form of carbon dioxide. Carbon is emitted by other forms of energy as well, including biomass combustion and biogas digestion.

CND in the Built Environment

The building sector, including both the construction and operation of buildings, is the single largest contributor of human-generated greenhouse gases in the U.S. According to the non-profit Architecture 2030, buildings are responsible for 77% of electricity consumption and 47% of carbon dioxide emissions. Most of this electricity is derived from fossil fuels. Efforts to reduce carbon emissions from the building sector will require reductions in overall greenhouse gas generation.

Typical building design aims for meeting the minimum requirements of applicable building and energy codes. These buildings may not have sufficient insulation, daylighting strategies, or energy efficient systems and fixtures to minimize the utility bills of a project by even the most conservative economic analysis. Buildings designed for compliance are the easiest to design but also have the largest carbon impacts.

Sustainability or "green" building certifications, like LEED, award points for design elements that reduce a building's environmental impact, including energy use. Many of these elements also reduce the carbon impacts of a building. However, even at the highest level of achievement for energy in these programs will not necessarily result in carbon neutrality. Of the 80 LEED Platinum projects, only one has also achieved CND – the Aldo Leopold Legacy Center in Baraboo, WI.

Carbon neutral design holistically evaluates a building's site, design, construction, and materials to minimize direct and indirect carbon impacts at all levels. CND looks at all of the components that make up a building's systems as well as its overall energy performance. The result is a high quality building that uses less energy, has lower maintenance and operations costs, and ideally has no carbon impacts – a huge step towards slowing global climate change.

CND & Affordable Housing: Design Before Technology

CND reduces carbon dioxide emissions primarily through energy reduction strategies. According to the US Department of Health and Human Services, low-income households spend an average $1,900 per month on energy costs, with over 40% of that devoted to home heating and cooling. This represents an average income burden of 14.1%, which is about twice the national average across all income levels. Reducing or eliminating the occupancy energy needs of housing will help low-income families stretch their monthly income further.

On a philosophical level, CND empowers low-income households to participate in the dialogue on global climate change. Housing with reduced climate impacts demonstrates how individuals can make a difference and that sustainability starts at home. But how do we get there? CND must be part of the project from planning and design through to construction, using energy efficient design strategies, supplemented with on-site renewable energy generation to meet the building's remaining energy needs on a net basis. If on-site energy generation is unable to meet these needs, a subsidy structure that includes renewable energy offsets should be created.

For a building project with a tight budget and a goal of significantly reducing energy and carbon impacts, the most important concept is to focus intensively on the design of the building before considering technology. It is far less expensive to design a building for efficiency and then supplement it with technology as needed than to design a conventional building that is entirely dependent on technology to address the energy concerns. The following sections will provide guidelines and recommendations for pursuing the goal of carbon neutrality in an affordable housing project.

A Provisional Standard for Carbon Neutrality: The 2030 Challenge

Architecture 2030 and the 2030 Challenge

Architecture 2030, a non-profit, non-partisan and independent organization, was established in response to the climate change crisis by architect Edward Mazria in 2002. 2030's mission is to rapidly transform the U.S. and global Building Sector from the major contributor of greenhouse gas emissions to a central part of the solution to the climate change, energy consumption, and economic crises. Our goal is straightforward: to achieve a dramatic reduction in the climate-change-causing greenhouse gas (GHG) emissions of the Building Sector by changing the way buildings and developments are planned, designed and constructed.

- About Us
Architecture 2030.org

Architecture 2030 was formed by noted architect and environmental advocate Edward Mazria to promote architectural solutions to the climate crisis. The foundational tool developed to accomplish this transformation of the building industry is **the 2030 Challenge**, a pledge to design and operate buildings meeting energy efficiency targets that ratchet down incrementally to a carbon neutral standard by the year 2030. As a public awareness campaign, the 2030 Challenge has been extremely effective, gathering commitments from bodies as diverse as the United States Green Building Council and the United States conference of Mayors. The first professional organization to adopt the 2030 Challenge was the **American Institute of Architects** in 2006, and the **Society of Building Science Educators CND Project** is born out of a collaboration between the AIA and the SBSE aimed at generating educational resources for AIA members, students, and the architectural community as a whole.

While the question of carbon emissions implicates everything from the patterns with which we settle the land to the longevity of the buildings that we build, the primary use of fossil fuels associated with buildings is in their operation.

The 2030 Challenge is thus framed exclusively in terms of reducing operational fossil fuel energy use within the building- with the use of coal to make the electricity consumed in buildings being the most highly polluting fuel in terms of CO_2 emissions and hence our most dangerous dependency. The 2030 Challenge standard promotes reductions in energy use through 1.) better, less energy demanding design, 2.) better, more efficient engineering design and equipment, 3.) the generation of on-site renewable energy, and 4.) a limited allowance for the purchase of off-site renewable energy credits.

This guidebook provides a road map to apply the first three of these questions to the realm of Affordable Housing,

Coal Pile, We Energies Valley Power Plant, Milwaukee, WI. 2006 data shows the Valley Power Plant emitting close to 2M tons of CO_2 per year. It's age and location in the urban core also add to the harm associated with its emissions.

The 2030 Challenge - Residential Targets

Buildings are the major source of demand for energy and materials that produce by-product greenhouse gases (GHG). Slowing the growth rate of GHG emissions and then reversing it over the next ten years is the key to keeping global warming under one degree centigrade (°C) above today's level. It will require immediate action and a concerted global effort.

To accomplish this, Architecture 2030 has issued The 2030 °Challenge asking the global architecture and building community to adopt the following targets:

- *All new buildings, developments and major renovations shall be designed to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 50% of the regional (or country) average for that building type.*

- *At a minimum, an equal amount of existing building area shall be renovated annually to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 50% of the regional (or country) average for that building type.*

- *The fossil fuel reduction standard for all new buildings shall be increased to:*
60% in 2010
70% in 2015
80% in 2020
90% in 2025
Carbon-neutral in 2030 (using no fossil fuel GHG emitting energy to operate).

These targets may be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power and/or purchasing (20% maximum) renewable energy and/or certified renewable energy credits.

Source: ©2006-2010 2030 Inc. / Architecture 2030
Data Source: U.S. Environmental Protection Agency; U.S. Energy Information Administration

2030 CHALLENGE Targets: U.S. Residential Regional Averages

U.S. Regional Averages for Site Energy Use and 2030 Challenge Energy Reduction Targets by Residentail Space/Building Type (RECS 2001)[1]
From the Environmental Protection Agency (EPA): Use this chart to find the site fossil-fuel energy targets.

Residential Space/Building Type[2]	Average Source EUI[3,4] (kBtu/Sq.Ft./Yr)	Average Site EUI[3,5] (kBtu/Sq.Ft./Yr)	2030 Challenge Site EUI Targets (kBtu/Sq.Ft./Yr)				
			50% Target	60% Target	70% Target	80% Target	90% Target
Northeast							
Single-Family Detached	67.5	45.7	**22.9**	18.3	13.7	9.1	4.6
Single-Family Attached	68.6	50.3	**25.1**	20.1	15.1	10.1	5.0
Multi-Family, 2 to 4 units	78.8	57.8	**28.9**	23.1	17.3	11.6	5.8
Multi-Family, 5 or more units	98.2	60.7	**30.4**	24.3	18.2	12.1	6.1
Mobile Homes	145.5	89.3	**44.6**	35.7	26.8	17.9	8.9
Midwest							
Single-Family Detached	76.2	49.5	**24.7**	19.8	14.8	9.9	4.9
Single-Family Attached	66.6	44.8	**22.4**	17.9	13.4	9.0	4.5
Multi-Family, 2 to 4 units	104.8	74.0	**37.0**	29.6	22.2	14.8	7.4
Multi-Family, 5 or more units	93.3	50.9	**25.4**	20.4	15.3	10.2	5.1
Mobile Homes	168.9	103.3	**51.6**	41.3	31.0	20.7	10.3
South							
Single-Family Detached	86.0	41.5	**20.8**	16.6	12.5	8.3	4.2
Single-Family Attached	82.5	38.8	**19.4**	15.5	11.6	7.8	3.9
Multi-Family, 2 to 4 units	113.6	46.9	**23.5**	18.8	14.1	9.4	4.7
Multi-Family, 5 or more units	122.4	47.9	**24.0**	19.2	14.4	9.6	4.8
Mobile Homes	162.0	63.3	**31.6**	25.3	19.0	12.7	6.3
West							
Single-Family Detached	67.2	38.4	**19.2**	15.4	11.5	7.7	3.8
Single-Family Attached	63.2	38.8	**19.4**	15.5	11.6	7.8	3.9
Multi-Family, 2 to 4 units	87.3	47.6	**23.8**	19.1	14.3	9.5	4.8
Multi-Family, 5 or more units	81.7	40.0	**20.0**	16.0	12.0	8.0	4.0
Mobile Homes	128.2	65.8	**32.9**	26.3	19.7	13.2	6.6

Notes

1. This table presents values calculated from the Energy Information Administration in the Residential Energy Consumption Survey (RECS), conducted in 2001. The survey data is available on the EIA's website at http://www.eia.doe.gov/emeu/recs/recs2001/detailcetbls.html.
2. Space/Building Type use descriptions are taken from valid building activities as defined by the Energy Information Administration in the Residential Energy Consumption Survey (RECS), conducted in 2001.
3. The average Source EUI and Site EUI are calculated in kBtu/Sq.Ft./Yr as weighted averages across all buildings of a given space type in the RECS 2001 data set. Souce Energy is a measure that accounts for the energy consumed on site and the energy consumed during generation and transmission in supplying energy to the site.
   Converting Site to Source Energy:
   Source Energy values are calculated using a conversion for electricity of 1 kBtu Site Energy = 3.013 kBtu Source Energy; a conversion for natural gas of 1 kBtu Site Energy = 1.024 kBtu Source Energy; and a 1:1 conversion for fuel oil and district heat.
4. Energy Information Administration (EIA), U.S. Residential Energy Intensity Using Weather-Adjusted Primary Energy by Census Region and Type of Housing Unit, 1980-2001, Table 8c.
5. Energy Information Administration (EIA), U.S. Residential Energy Intensity Using Weather-Adjusted Site Energy by Census Region and Type of Housing Unit, 1980-2001, Table 6c.

EUI: Energy Use Intensity

The SBSE

Carbon Neutral Design Project

The Society of Building Science Educators' Carbon Neutral Design Project is the research and dissemination effort that underlies this guide to Affordable Housing.

As indicated on this web page introducing the project, the CND webiste contains a variety of resources on the question of carbon neutral design. Several of these topics are explicitly supporting this Affordable Housing Guide. Others are linked to it in hopes that the additional resources provided on the website will expand your conversations about the possibilities of design to reduce energy use and the tools to accomplish these goals.

Much of the material on the site is developed for commercial and institutional buildings, which tend to be the focus of architectural education. The lessons learned and the tools to apply them to Affordable Housing are often the same, if you consider the most basic challenge to be to design well rather than pay for expensive systems.

The general topics index includes:

- Project Introduction
- What is Carbon Neutral Design
- Carbon Neutral Design Process
- Carbon Neutral Design Strategies
- Carbon Calculation Protocols
- Carbon Calculation Tools
- Carbon Neutral Building Case Studies
- Carbon Neutral Teaching Topics
- Resources
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THE AMERICAN INSTITUTE OF ARCHITECTS

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- What is Carbon Neutral Design?
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CARBON NEUTRAL DESIGN CURRICULUM MATERIALS PROJECT CND

The Society of Building Science Educators www.sbse.org

The Carbon Neutral Design Project:

Introduction:

Unknowingly, the architecture and building community is responsible for almost half of all U.S. greenhouse gas emissions annually. Globally the percentage is even higher.
-- *Ed Mazria*

Never before have architectural educators and professionals faced the magnitude and urgency of today's ecological challenges resulting from global warming and climate change. To meet these challenges, the Society of Building Science Educators (SBSE) has initiated the Carbon Neutral Design (CND) Project to create and disseminate the resources and tools needed to integrate carbon neutral and zero-energy design into professional architecture programs and practice. This project is a direct response to the *2010 Imperative* (which is a call for architectural educators to address carbon neutral design and fossil fuel reduction in the design studio, to improve ecological literacy for design students, and to integrate related issues in the design and operations of university facilities and campuses) as well as the *Architecture 2030 Challenge* (the realization of carbon neutral architecture by the year 2030).

The Carbon Neutral Design (CND) Project is a joint effort by the AIA, members of AIA Committee on the Environment (COTE), and the Society of Building Science Educators (SBSE) to produce educational and resource materials for carbon neutral design. SBSE, a non-profit educational organization with members from the academy, governmental agencies and publishers, has for over twenty years served as an incubator for new approaches to teaching environmentally responsive architectural design. This partnership with the academy has capitalized on the expertise of building science educators and practitioners to produce this peer reviewed, web-ready content on carbon neutral design.

The CND Project acknowledges that there are identifiable starting positions and best practices that are required to succeed in reducing the energy demands of a building to allow it to reach a state of Carbon Neutrality.

This, the initial phase of the Carbon Neutral Design Project will focus on reducing the carbon emissions for the operating energy of the building. Operating energy has been selected over embodied energy as it represents the major contribution to the carbon emissions of a building, and is the focus of the 2030 Challenge. Practices, protocols and tools to reduce the carbon associated with embodied energy will form the focus of subsequent research associated with this project.

Funding for the project has been provided by the American Institute of Architects, the Brico Fund and a private donor.

The Carbon Neutral Design Case Study Project is an ongoing research project that has included detailed case studies of three affordable housing projects that will be featured throughout this guidebook.

Behind the Case Studies, the actual research effort has been to develop a new method for capturing and analyzing building performance data; the **CND Case Study Protocol**. This protocol and the logic behind it are also woven throughout this guidebook.

Our hope is that this guidebook, and the research behind it, will inspire affordable housing organizations, designers of affordable housing and students to use the protocol, and participate in the project.

The CND Case Study Project

The SBSE **Carbon Neutral Design Case Study Project for Affordable Housing** currently includes three detailed and ongoing case studies; ecoMOD3 the SEAM house in Charlottesville, VA.; the Wild Sage Cohousing community in Boulder, CO; and the LIHI Denny Park Apartments in Seattle WA.

These projects were chosen as the test cases for the development of the CND Case Study Protocol for Affordable Housing for a variety of reasons, including their disparate scales, their disparate climates, and the disparate populations that they serve. They are all on the path towards carbon neutrality, though it is important to acknowledge up front that none of them satisfy the 2030 Challenge criteria in full- they do not produce on balance as much renewable energy as they consume. Denny Park in fact does not currently incorporate any renewable energy production.

For this reason, another pivotal case study of the project, the Aldo Leopold Legacy Center, will be used throughout this guidebook where illustrations of a successfully carbon neutral building are helpful.

The Aldo Leopold Legacy Center

The Aldo Leopold Legacy Center in Baraboo, WI is a modern example of carbon neutral design. The building has Platinum LEED® Certification, receiving the most points towards a LEED certification to date in 2007. The building is designed to be net-zero energy and the Aldo Leopold Foundation is credited with operating the facility as carbon neutral. This has been accomplished through on-site solar energy generation via photovoltaic panels, carbon sequestration via the management of a Forest Stewardship Council Certified forest, and a number of energy efficient design strategies including passive solar, daylighting, and insulation. The center uses 70 percent less energy than a building built to code and is capable of producing 110% of its annual energy needs.

The CND Affordable Housing Case Studies

ecoMOD3: the SEAM house

Charlottesville, Virginia
University of Virginia - ecoMOD3 Design Team
Piedmont Housing Alliance (PHA)
Historic single family home with accessory dwelling unit
Renovation and New construction
1,400 sq. feet (427 sq. meters)
Completed 2007

The ecoMOD Project at UVA was asked to renovate an historic house believed to be built as a slave quarters. To ensure the house would remain affordable enough for someone that qualifies for financing assistance, PHA asked ecoMOD to create a small addition to the old house, and also place a detached accessory dwelling unit (ADU) in the backyard. The SEAM house system can be added to any existing home, or sited independent of a home. At 398 sq. ft., the LEED for Homes Platinum ADU design is the smallest LEED certified building in the world. The two units are metered separately, and the income from the rental of the ADU helps offset the mortgage costs for the owner of the historic house.

**Wild Sage Cohousing-
Habitat for Humanity Units**

Boulder, Colorado
Jim Logan, Architect
Wonderland Hill Development Company
Boulder Housing Partners, Master Site Developer
New construction
34 Unit Cohousing Community
Completed 2004

The Wild Sage Cohousing Community is a part of the Holiday Neighborhood, a green/ new urbanist redevelopment of a 27 acre parcel that once was the home to a drive-in movie theater; one of the last developable blocks of land in the City of Boulder.

The entire Holiday Neighborhood is held to a 40% permanently affordable unit standard. At Wild Sage, four of those affordable units were built by Habitat for Humanity working in partnership with the general contractor. Perhaps uniquely, the Cohousing community was initiated by the developer and included Habitat for Humanity participants throughout it's community based design process.

LIHI Denny Park Apartments

Seattle, Washington
Runberg Architecture Group
LIHI Denny Park Apartments, LLC
50 Unit Housing with Ground Floor Commercial and Underground Parking Garage
New construction
Completed 2006

Denny Park Apartments includes 50 units of affordable rental housing. The residential portion includes a community room, an office, common laundry facilities, and a common landscaped courtyard. The average residential unit size is 541 net square feet and includes 5 three bedroom, 8 two bedroom, 12 one bedroom and 25 studio units.

Of the housing units, 40% are reserved for households at or below 30% of the area median income (AMI), 50% are reserved for households at or below 50% AMI, and 10% are reserved for households at or below 60% AMI. The AMI for King County was, in 2004, $70,100 for a family of three.

Interviews with the Design Team: Quotes from these and other interviews appear throughout the Guidebook

Jim Logan

Jim Logan Architects,
on the design of
Wild Sage Cohousing

an interview *with N.J. Unaka and*
Jim Wasley,
UW-Milwaukee

NJ Unaka: Could you speak generally about how you came to participate in this project? Who was at the table when the project was hatched?

Jim Logan: The project was initiated by the Boulder Housing Partners. That is a nonprofit that owned the land, and they served as the primary site developer. They then brought in five other developers to work in different parts of the site. Jim Leach of Wonderland Hill Development Company approached me and asked me if I would like to design one block of co-housing. I said I would, and that was basically it - we concluded a deal in the parking lot. That was all it took....

Brian Bowen

Project designer and resident,
on the design of
Wild Sage Cohousing

an interview *with Jim Wasley,*
UW-Milwaukee

Jim Wasley: I've talked to Jim about the plan -the key seems to be that the units are all grouped with east/west axis; there is south light in every single unit and a highly developed strategy of layering space between the rows of units.

Brian Bowen: The spacing between the units is key- it works to give you solar access to the windowsill on the first floor of the unit to the north, and it also really works for the social programming. It's somewhat of a coincidence, but the spatial layering works really well.

Jim Wasley: So if it had been even wider it might not have been as nice socially?

Brian Bowen: Yeah. The compression of the space is actually part of what makes it vibrant. The whole site design goal from a social perspective is to create opportunities for casual social interaction that don't feel obligatory....

Cohousing in action

While Brian and I sat on the commons lawn talking, a little girl decided to climb to the top of the tree. Getting up was easy... getting down required a village.

I. PLAN WITH CARBON NEUTRALITY AS THE GOAL

Carbon neutrality is a critical societal goal because climate change is an existential threat. It is a critical goal for Affordable Housing because energy insecurity is an economic threat to those least able to afford it.

*The hypothesis that the **Carbon Neutral Design Project** has set out to test is that the achievement of this state of balance between the carbon impacts of energy consumed and energy generated is within reach, but only through the rethinking of the entire design process.*

Achieving AFFORDABLE carbon neutrality in particular is not a question of applying new technologies to conventional practice. It is a question of design intent.

Solarsiedlung Freiburg- a 59 unit housing estate designed to be carbon neutral in Freiburg

Germany. Note that the form and composition of the buildings all work together to harness the sun. South sloping roofs are shingled with photovoltaic panels, south facing living rooms and balconies heat the buildings passively in the winter and provide shade in the summer. South facing yards are welcoming year round.

I think you get a different set of results if you start from 'this is going to be carbon neutral...' I think you really need to state your goals from the get-go and start there with the design. - Jim Logan

1. Organize the Team with the Goal of Carbon Neutrality in Mind

For CND to be successful in affordable housing projects, it is essential to identify carbon neutrality as a goal from the outset. The team then helps to ensure that these goals are met at each step in the building process. At a minimum, this team would include the affordable housing provider, an architect, and a builder. The affordable housing provider best understands the budget and occupant needs and is instrumental in establishing the project's goals.

With clear direction, the architect will be tasked with designing a building from the ground up to meet a carbon neutral standard and employing the consultants necessary to achieve such a highly integrated end. The builder will oversee construction practices and follow through on important design intentions, materials and details, and equipment choices, all balanced against budget and scheduling requirements. As success depends on both integrated design work and its faithful execution, it is essential that all members of the team be selected early in the process and involved in joint problem solving throughout. Team members with experience working with passive design strategies will be valuable resources. Other possible members for a team could include:

Interested Parties

- o Future residents
- o Neighbors to the proposed project
- o Caseworkers and non-profits that work with existing affordable housing residents

Professionals

- o Engineers, including professionals in the structural, civil, electrical, mechanical, and environmental disciplines
- o Energy simulation consultants
- o Lighting designers
- o Landscape architects
- o Contractors
- o Cost Estimators

The National Institute of Building Sciences' Whole Building Design Guide program provides resources and case studies of successful integrated building design. Once a committed team is established, the participants work together to define the project's objectives and goals at the start and work together throughout to understand the various aspects of the project, including design, materials, systems, and assemblies. Because each participant has a different expertise, insights can be derived throughout the process to identify possible issues and opportunities that result in a better design. . This process continues throughout all phases of the project, in order to ensure that cost, quality-of-life, flexibility, efficiency, environmental impact, productivity, and creativity objectives are met.

Contracting for collaboration

Traditional building projects approach both design and contracts with the owner or leader retaining distinct and separate services from architects, contractors, and other professionals. A team-based approach is inherently different, given the level of collaboration throughout the project. A few contract models have been put forth to respond this.

Relational Contracts

These represent the smallest divergence from traditional contracts. Relational contracts contain specific information only related to payment and termination. Project scoping and considerations are pointed to another document that is used for both the architect and the contractor. This document outlines the nature of the collaborative process expected. This model retains bilateral confidentiality between owner-architect and owner-contractor, but may not create as strong an incentive between the architect and contractor to work collaboratively.

Single-purpose Entity

In this model, the owner, architect, and contractor form a single-purpose entity for this project and contract the services of each party through the entity. The entity typically takes the form a limited liability company (LLC) that is linked to the project and dissolved at its completion. Here, each party takes an equity stake in the project through the LLC. Compensation to each party is typically linked to the success of the project. A benefit of this approach is that each party becomes formally vested in the project's success. A limit of this approach is that project accounting becomes more complicated with the LLC.

Project Alliance Agreements
In this model, used often in Australia, a leadership team with representative from the owner, architect, and builder is created. All decisions about the project must be reached through consensus of this team and all liability is waived between parties. In terms of compensation structure, the owner commits to pay the direct costs incurred by the architect and the contractor, which are recorded in an open-book. Bonuses are then awarded and penalties assessed against each party for achievements against established performance targets on a shared-basis. By bringing the compensation of each party into the open and by sharing rewards and penalties, an environment of trust, openness, and collaboration is created. A limit of this model is overcoming the desire to keep contractual agreements confidential.

Performance-Based Contracts
Performance-based contracts are just that - contracts that tie compensation to documented performance achievements of the finished building against goals established at its inception. For a renovation, the performance is assessed relative to the existing building. For a new project, the performance is assessed relative to the expected performance of the building had it been built to code. It is important in this model to allow for a margin of error around the goals to allow for occupant-influence on observed performance. This model truly holds the architect and contractor accountable for the project's success, however, it may be difficult to determine which party is responsible for any failings of the design/construction in practice. It may also be difficult to find an architect and contractor willing to commit to these terms.

Habitat for Humanity Construction Crew, Wild Sage Cohousing

While Wild Sage Cohousing as a whole includes a mandated 40% of units designated as 'affordable,' the four units that are at the heart of the CND case study are the center two over and under duplex units in a seven unit structure built by Habitat for Humanity in collaboration with the general contractor for the entire project. This arrangement tested all of the parties involved, from the developer to the to the contractor to the co-housing community members themselves, including the four families sponsored by Habitat for Humanity. In the end this unique arrangement created both economic and social benefits for all involved.

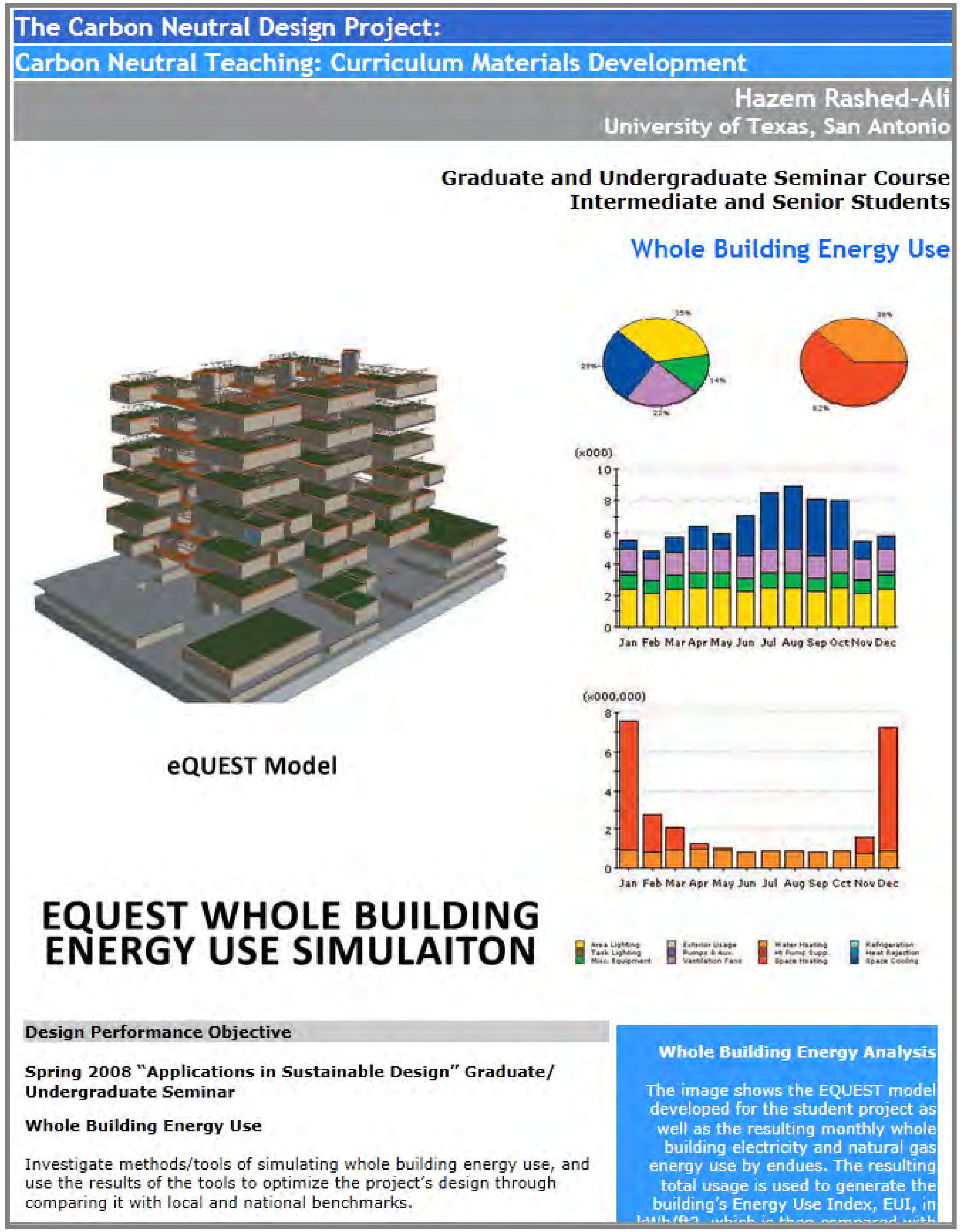
The way the GC handled it was, I think, really elegant. They made Habitat a subcontractor, which covered Habitat under their insurance for multi-family construction. This saved Habitat a fantastic amount of money and provided, I think, a real benefit to anyone who would have been hurt. -Brian Bowen

2. Invest in Energy Modeling at the Outset

Each year more tools are developed to assess the expected energy use of a building during the design phase. While no one tool is yet seamless, there are many tools that now can assist the design team at each step of the process and it is not an exaggeration to say that approaching the goal of carbon neutrality is impossible without a commitment to the iterative process demanded by well integrated performance modeling. It is a budget item and set of expertise that should absolutely be planned for. It should also be incorporated from the outset of the design process, in order to shape the most basic decisions.

Many of these new tools are simulation and energy modeling software packages that require the sophistication of an engineer to get useful results. If the design team is collaborating from the start, and the engineer is able to test multiple variations of building designs, solar orientations and building envelope choices, it is possible for the team to have important information about projected performance before too many design decisions are made.

As with all scientific activities, effective simulation involves developing a clearly defined set of questions and variables that can be tested. Is it also important for design teams to revisit simulations as the design evolves and decisions are made. If the team really does want to focus on operating costs and not just first costs, the simulations are one of the most important tools in a decision making process.



Click Here!
CND TEACHING TOPICS: ENERGY
see Energy Simulation

The most important thing is to shift the timeframe from looking at initial cost or cost over three years or ten years, and start looking at a longer timeframe... In the affordable housing market, the maintenance costs on the unit can be the largest expense of the agency. If we can reduce those expenses, then we've dramatically changed their economics. -Jim Logan

3. Define Affordability for the Long Haul

The typical approach to residential development is to minimize construction costs in order to stretch the project's budget as far as possible. While these decisions save money during construction, they also result in higher monthly costs than alternatives with comparable or slightly higher price tags.

By shifting cost accounting from the short-term first costs, measured in months, to the long-term operating costs, measured in years, it is easier to justify design and construction decisions that result in higher up-front costs.

Educating the project team and funders about this shift in accounting can help make the case for design and material choices that reduce carbon impacts and lower tenant occupancy costs on a monthly basis. Focusing on operation costs instead of first costs is an essential theme during the design process.

Reducing Operating Costs: Durable Efficiencies

If energy costs money, then one end goal of carbon neutral design is to lower utility costs to zero, which is in fact one way of defining a net-zero energy building standard.

Building to the extreme high-performance building standard necessary to approach a net-zero operating cost target means that aspects of the construction are going to be higher quality and thus more expensive than they might otherwise be. In what Amory Lovins famously calls 'tunneling through the cost barrier,' there are often mechanical systems choices in particular that these investments will allow to tend towards simpler, more robust choices.

The challenge and the promise of the quote by Jim Logan to the right is that if EVERYTHING is evaluated together over a longer time frame, then larger system efficiencies surface that can help pay for the up-front cost upgrades of individual systems or aspects of the building.

For example, adding additional insulation to the envelope of a building is often the most effective possible long-term investment if the goal is to zero out operating costs, but it often is not justifiable when judged in isolation. If this can be paired with a smaller mechanical system, then it has justified itself on slightly wider terms. If everything is on the table in terms of long-term operating expenses, then there is much greater leverage possible- a maintenance free cladding material that saves repainting costs perhaps contributes to the financial viability of the added insulation.

In our interview with him, Wild Sage Architect Jim Logan went on to describe how he has moved away from higher efficiency instantaneous water heaters towards simpler and less efficient electric resistance water heaters. In the long term analysis, the more sophisticated systems tend to break down without maintenance, while the less efficient systems have no carbon penalty if the savings that they accrue pay for greater efficiencies elsewhere in the project.

Low-maintenance metal cladding, Denny Park

Roofing, exterior cladding, and flooring choices all deserve consideration from a longer term perspective than they typically receive. These durability choices compliment building energy efficiency choices such as the quality and design of mechanical systems.

Wild Sage is 40 percent affordable housing, and we chose to have four of those homes done by Habitat for Humanity. That gave us a different layer of affordability. -Brian Bowen

4. Express the Goal of Carbon Neutrality in the Program

For carbon neutrality to be a strong goal of a project doesn't mean that it must be the only goal, but it does mean that every decision should be evaluated on how it will impact the carbon emissions of the occupants. This likely means that it's impact will be felt in every document that describes the project.

Keep it Small -- Build Less

By the evidence of the CND Case Studies presented here, the single most important factor in reducing energy use per family or per unit is to build smaller units.

Building less will reduce the scope and size of a building. More intentional design can meet occupant needs in a smaller space. Strategies for building less include:

- Working closely as a collaborative team, assess the space needed for all activities.
- Creating shared spaces where they can serve to build community while eliminating duplication
- Eliminate to the extent possible space dedicated to circulation. For example, placing the entry door near the center of a housing unit can reduce corridors.
- Create multi-use spaces that serve multiple programming needs, which may require the team to only add walls and doors when absolutely necessary.
- Reduce the size of the 'conditioned' zone. Some spaces can serve their purpose without being fully heated and cooled. This might include making circulation corridors and storage areas either exterior spaces or minimally conditioned buffer spaces between the interior and the exterior.
- Create outdoor spaces that extend interior spaces functionally as well as aesthetically.

The benefits of building less include using fewer materials, reducing the energy needs of associated systems, and maximizing site potential, resulting in space for additional units or community green space.

The fundamental architectural challenge is then to build small spaces that seem accommodating.

Sleeping Loft, ecoMOD3 (right)

This adaptive reuse project restructures the roof framing of an existing house to allow for both spatial drama and extra quarters.

Communal Balconies, Denny Park (above)

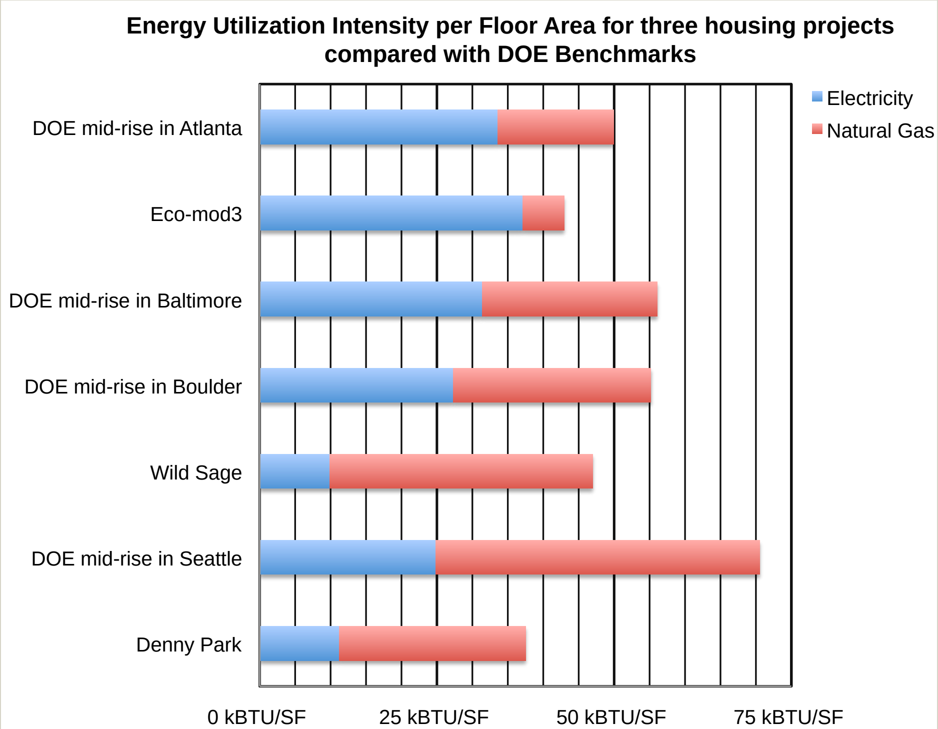
Denny Park provides relief from it's small individual units in the shared community spaces that it provides, and it gives these amenities pride of place. These sunny balconies on the southwest corner of the building are accessed through the communal laundry rooms on each floor.

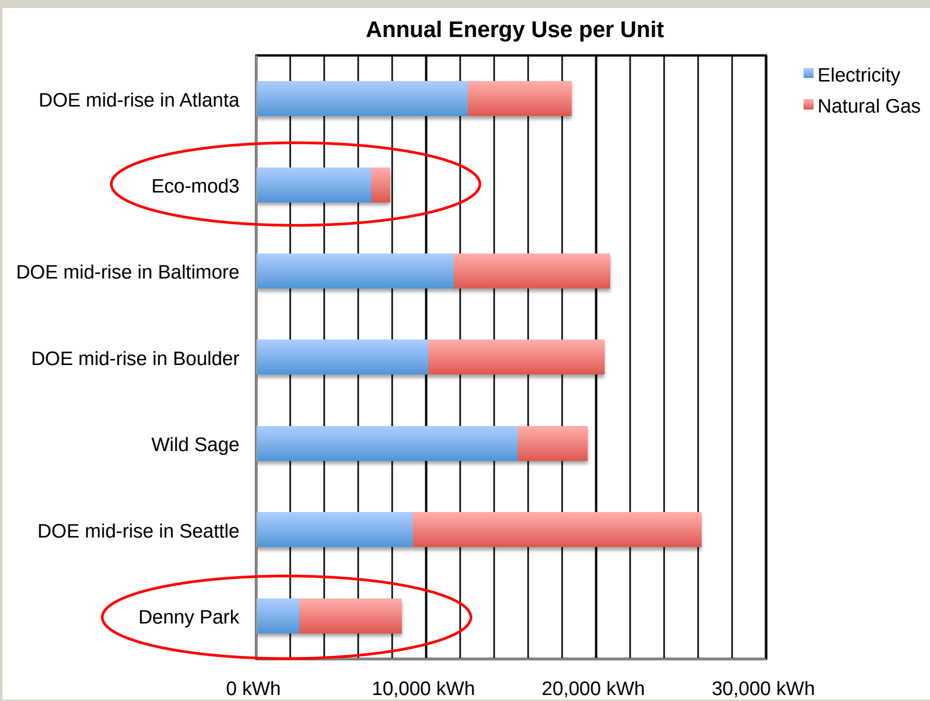
Sleeping Nook, Denny Park (left)

A space tucked behind the kitchen and barely large enough for a matress provides shelter and a view out the living room window.

The sleeping nooks were very popular because they gave a sense of privacy and space, even thought the actual square footage was the same. -Michelle Wang, Project Architect, Denny Park

Click Here!
CND TEACHING TOPICS: FRAMEWORKS see Programming/ Carbon Goal Setting





Size Matters- CND Case Studies

These two charts show the CND project's analysis of the energy use of the three Affordable Housing Case Studies. These are also placed in the context of base models created by the Department of Energy for mid-rise housing in each of our three climates (DOE does not provide a base for Charlottesville, so ecoMOD3 is set between the DOE predictions for Atlanta and Baltimore.)

The top chart graphs the Energy Utilization Intensity (EUI) which is the common unit of analysis relating energy use in per s.f. terms. Here, all three of the case studies are shown to be more efficient than the reference buildings for their climates, though only in the case of Denny Park is that reduction significant. All three of the case study buildings are also relatively similar to one another in their EUIs.

The bottom chart graphs energy use per unit rather than per sq.ft.. Suddenly the simple fact that ecoMOD3 and Denny Park's units are roughly half the size of Wild Sage's makes a significant difference. Where Wild Sage is roughly the same unit size as the base model and is seen to be more efficient per sq.ft. but roughly equal per unit, ecoMOD3 and Denny Park's efficiencies per sq.ft. are amplified by the smaller units, so that both are significantly less per unit than their comparable DOE base models. Where efficiency needs to translate into affordability, SIZE MATTERS.

5. Express the Goal of Carbon Neutrality in the Selection of the Site

The carbon impacts of the building project begin with the site -- no two sites will have the same impact. The building in the context of its site highlights the site's influence on carbon impacts during construction and occupation.

Locate Near Public Transit

Select a location with good access to public transit to minimize the economic and ecological impacts of the resident's work lives. Selecting a site on virgin land outside of town means residents will likely rely on personal vehicles for transportation to work, shopping, and recreation. Not only does this generate more carbon dioxide emissions, but it also imposes the cost burden of owning and maintaining a personal vehicle on occupants. Selecting a site that redevelops property in an urban setting means residents will have more options for transportation, including public transportation, bicycles, walking, or carpooling. This helps eliminate the need for a personal vehicle and results in better access to community services, employment, and stores, including groceries.

Reuse a Site or a Building

Select a site that has been previously developed to minimize the economic and ecological costs of preparing the site and providing infrastructure. Selecting a site that has previously been developed increases the likelihood that sewer, water and electrical connections will be convenient, and can result in less site excavation than a comparably sized virgin site.

Reusing a building has many benefits, and potential pitfalls. For every building material that remains in place, something new doesn't have to be installed,which reduces carbon emissions from manufacturing, transporting and constructing the building. The ecoMOD3 project involved a deep energy retrofit of a 19th century historic structure that was not structurally sound. The costs of stabilizing and renovating the structure exceeded a normal affordable housing budget. However many homes in better shape can be retrofitted to achieve carbon neutrality.

Infill vs. Greenfield Development

Greenfield sites are those that have never been developed. While these offer a great degree of flexibility for site design, greenfield development may necessitate a greater degree of site disturbance and ecosystem disruption. Public infrastructure will likely need to be extended in order to service the site, adding costs to the project via proffers or impact fees.

Infill sites are those that are within the existing development footprint of a city -- they may have previously been developed for industrial or commercial uses or be vacant parcels that have been previously passed over for development. Infill development is seen as an advantage in many cities, as those sites are typically well-served by existing public infrastructure, like roads and sewer. Infill sites may also be served by public transportation and located closer to amenities like jobs, schools, and shopping centers than greenfield sites.

At Home in the Community

All three CND Case Studies are located on previously developed land, though the scales of their communities are very different.

Click Here!
CND TEACHING TOPICS: FRAMEWORKS
see Affordability Goals- small lots...

6. Plan the Site and Not Just the Building to Reduce Carbon Impacts

Pedestrian Muse, Wild Sage Cohousing

The space between the buildings is one of the most intensely designed spaces in the project- careful layering provides both privacy and connection while insuring solar access for every unit.

Minimize Site Disturbance

A design strategy should be established to minimize site disturbance and to retain existing plantings where possible. Minimizing site disturbance can reduce construction costs for site preparation and proffers, as well as save time in construction. In addition, keeping site disturbance to a minimum can also reduce environmental and energy impacts more broadly, by disturbing the sequestered carbon in existing vegetation. Maintaining stormwater drainage patterns when they already effectively recharge the water table on site, can reduce reliance on municipal facilities.

Evaluate Solar Access across the Site

The site itself must be evaluated holistically in order to plan for not only the building's footprint, but also placing renewable energy systems. In evaluating the site, it is important to note contextual information. This includes not only the site's solar orientation, but also topography and existing adjacent buildings, which impact the building's ability to harness solar energy.

Create Outdoor Living Spaces

The landscape plan of a building can be designed to increase the functionality and comfort of the building while creating outdoor living space that are appealing to residents. Some examples include:

- trees sized and located to provide shade for the building in summer, reducing demand for conditioning inside while providing additional privacy for residents enjoying outdoor space
- hedges and other vegetation planted to mitigate temperature swings, dust, and noise associated with heavy winds
- vegetated walls can be engineered for vertical surfaces to naturally regulate building temperature and create additional surface area for plants to absorb carbon.

Low Maintenance = Low Energy

Landscape maintenance can be resource-intensive. Using indigenous plants will reduce the need for pesticides, synthetic fertilizers, and watering. To reduce solid wastes and nurture topsoil, consider composting food wastes on site to enhance the nutrient content of the soil. When selecting new vegetation, consideration should be given to:

- enhancing biodiversity of the site to cultivate a robust ecosystem
- planting indigenous species
- avoiding annual species
- including larger tree species, which sequester greater quantities of carbon than smaller ones

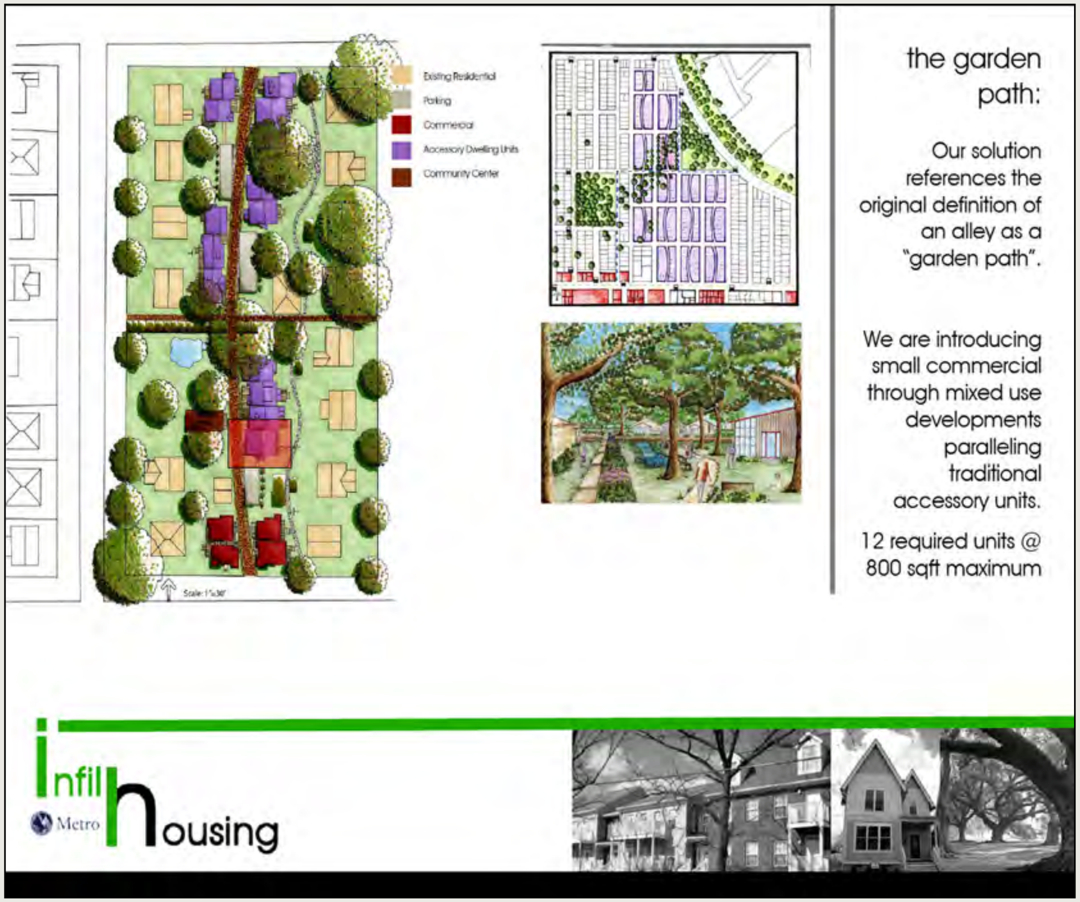
Click Here!
CND TEACHING TOPICS: SITE
see Site Analysis

Click Here!
CND TEACHING TOPICS: SITE
see Site Design/ Neighborhood Design

Affordable Housing: Small Lots/Small Enclosures

Bruce Haglund, University of Idaho

F2007 Integrating Habitats Studio



High Density/Small Lot Masterplanning
Clayton Harrison

The masterplan shows how in-fill housing can densify a typical mid-twentieth century single family occupancy residential block; and by extension, how it can transform the neighborhood.

Design/Performance Objective
Design small enclosures that reduce both first and operational costs. Design for increased density and small lot sizes.

Investigative Strategy
Develop a master plan that doubles the density of an existing neighborhood while holding individual floor plans to 800 sq.ft. or less. Clayton Harrison's master plan shows fifteen new units, four with small commercial or workplaces on the ground floor, arranged as in-fill units along the redesigned alley of an existing urban single-family occupancy neighborhood.

Evaluation Process
Evaluation Process. Design typical units to prove livability and rate the plan with the SBSE Checklist for Regenerative Design and Construction.

Evaluative Criteria
Compare before and after densities and check building size. Evaluate livability and sustainability with the SBSE checklist.

Cautions- Possible Confusions
Forming a local improvement zone can be a way of avoiding the restrictions caused by simply subdividing existing lots.

Duration of Exercise
This work was presented at the culmination of an eight-week comprehensive design phase.

Degree of Difficulty
This is work assigned to a graduate student in his penultimate studio taken after all of the basic technical courses on structures and environmental systems.

References
SBSE Checklist for Regenerative Design and Construction on the SBSE web <http://www.sbse.org/resources/>

Integrating Habitats web <http://www.integratinghabitats.org/>

CND Teaching Resources: One aspect of the CND website are the teaching resources that are referenced throughout these pages with blue link boxes. TEACHING TOPICS are short descriptions of architectural design studio assignments dealing with issues relating to carbon neutral design. Here, Professor Bruce Haglund at the University of Idaho offers his design investigation of neighborhood density patterns for affordable housing.

Click Here!
CND TEACHING TOPICS: SITE
see Site Design/ Neighborhood Design

II. DESIGN FOR AN ARCHITECTURE WITHOUT POWER

To design for an architecture without power means to design the building so that mechanical equipment providing heating, cooling, ventilation and lighting is not just more efficient than typical- it means that it is ***OFF*** *for as much of the day and the year as possible.*

Reducing as many loads to ***ZERO*** *as possible is the only way to approach carbon neutrality overall.*

An additional benefit of this approach is that the building will be more likely to survive without power should power fail; an additional level of economic security for a vulnerable population.

Load Reduction Through Design: The First 50% Percent of the Goal

The team should concentrate on reducing energy loads and demands from the beginning of the process, not after a basic strategy for the building has been determined. It is often helpful to imagine the occupants having to survive and be comfortable if there were no power in the building for an extended period of time. While this may sound extreme, it does tend to focus the design team on value of design that reduces energy use. These considerations fall mostly into the realm of the architect, and affordable housing provider or client. They include site selection, passive design (including daylighting, shading, solar orientation, ventilation and control of heat gains), appropriate building envelope design, and energy modeling.

7. Design to Harness the Rhythms of the Climate

Passive design begins with a solid understanding of the regional climate and the microclimate at the building site. It assumes that the advantages of any given climate should be utilized in the design, and the disadvantages should be minimized. Site considerations are an essential aspect of carbon neutral design. Working with the site characteristics and local climate conditions will allow the project to capitalize on passive design features, which help regulate building temperature and provide natural light. These elements use no energy once installed and save the occupant money by reducing utility bills. Passive design also contributes to the well-being of the occupant, by providing access to sunlight and nature. Passive design strategies should be selected carefully based on an analysis of the most efficient and inexpensive ways to respond to the climate. Financially, passive design adds little or no additional cost to a construction budget, but the ideas have to be well understood and integrated early into the design process. Working with a design team with experience in passive design is essential.

Building Energy Codes RESOURCE CENTER

Energy Code Climate Zones

1. EcoMOD3, Charlottesville, VA
2. Wild Sage Cohousing, Boulder CO
3. Denny Park Apartments, Seattle WA

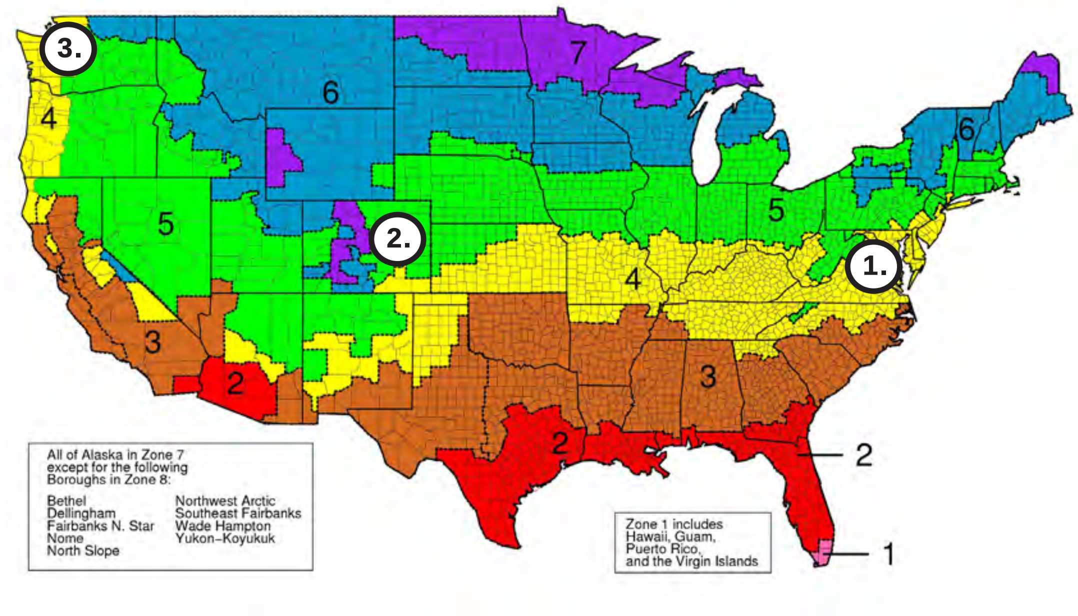
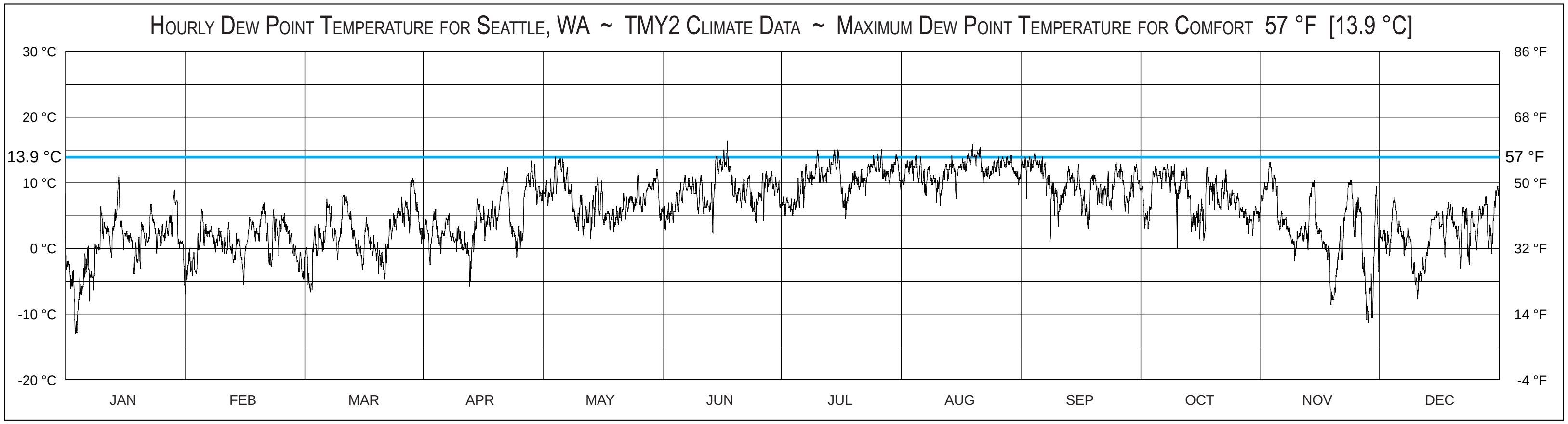
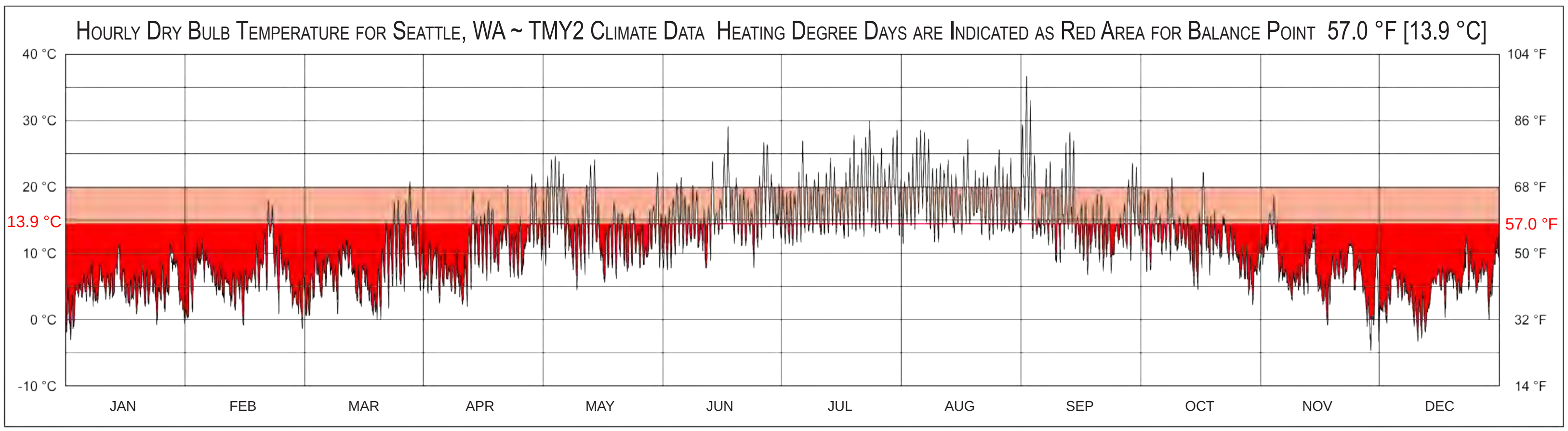


Table 2B – Climate Zone Definitions for New Classification (Part B)

B. Thermal Zone Definitions

Zone No.	Climate Zone Name and Type	Thermal Criteria[1,8]	Representative U.S. City*	Köppen Class.	Köppen Classification Description
1A	Very Hot – Humid	5000 < CDD10ºC	Miami, FL	Aw	Tropical Wet-and-Dry
1B[7]	Very Hot – Dry	5000 < CDD10ºC	---	BWh	Tropical Desert
2A	Hot – Humid	3500 < CDD10ºC ≤ 5000	Houston, TX	Caf	Humid Subtropical (Warm Summer)
2B	Hot – Dry	3500 < CDD10ºC ≤ 5000	Phoenix, AZ	BWh	Arid Subtropical
3A	Warm – Humid	2500 < CDD10ºC ≤ 3500	Memphis, TN	Caf	Humid Subtropical (Warm Summer)
3B	Warm – Dry	2500 < CDD10ºC ≤ 3500	El Paso, TX	BSk/BWh/H	Semiarid Middle Latitude/Arid Subtropical/Highlands
3C	Warm – Marine	HDD18ºC ≤ 2000	San Francisco, CA	Cs	Dry Summer Subtropical (Mediterranean)
4A	Mixed – Humid	CDD10ºC ≤ 2500 AND HDD18ºC ≤ 3000	Baltimore, MD	Caf/Daf	Humid Subtropical/Humid Continental (Warm Summer)
4B	Mixed – Dry	CDD10ºC ≤ 2500 AND HDD18ºC ≤ 3000	Albuquerque, NM	BSk/BWh/H	Semiarid Middle Latitude/Arid Subtropical/Highlands
4C	Mixed – Marine	2000 < HDD18ºC ≤ 3000	Salem, OR	Cb	Marine (Cool Summer)
5A	Cool – Humid	3000 < HDD18ºC ≤ 4000	Chicago, IL	Daf	Humid Continental (Warm Summer)
5B	Cool – Dry	3000 < HDD18ºC ≤ 4000	Boise, ID	BSk/H	Semiarid Middle Latitude/Highlands
5C[7]	Cool – Marine	3000 < HDD18ºC ≤ 4000	---	Cfb	Marine (Cool Summer)
6A	Cold – Humid	4000 < HDD18ºC ≤ 5000	Burlington, VT	Daf/Dbf	Humid Continental (Warm Summer/Cool Summer)
6B	Cold – Dry	4000 < HDD18ºC ≤ 5000	Helena, MT	BSk/H	Semiarid Middle Latitude/Highlands
7	Very Cold	5000 < HDD18ºC ≤ 7000	Duluth, MN	Dbf	Humid Continental (Cool Summer)
8	Subarctic	7000 < HDD18ºC	Fairbanks, AK	Dcf	Subarctic





CND Case Study Graphical Climate Analysis- Denny Park Apartments, Seattle WA

Simple yearly climate data overlaid with known attributes of the building here set the stage in terms of the climate challenges that Denny Park is designed to solve.

The lower yearly temperature graph is color coded to indicate heating degree days in red and if there were any, the cooling degree days in blue. A heating degree day is defined as the temperature difference between a daily low temperature and a baseline temperature.

The baseline temperature is the outdoor air temperature at which the building will require heating in order to maintain comfort, or it's 'balance point.' Here there are two baseline temperatures- the standard baseline of 65^{o} represents the outdoor air temperature at which a poorly insulated conventional house would require heating. The 57^{o} line represents the much lower balance point of the Denny Park Apartments, indicating that they are well insulated and have relatively little surface area for their volume. Think of the light red band as energy saved due to Denny Park's lower heat loss rate and you can visualize clearly how big a reduction in heating demand the better built building creates for itself.

The Dew Point Temperature graph at the top of the page makes a different point. The lower dew point, the more moisture in the air. Looking in particular at July and August, the relatively high dew point means relatively dry air. With 57^{o}F identified as the max. allowable dew point temperature for comfort, it is clear that the summer conditions are dry enough that this threshold is rarely crossed and it is rarely too humid to be cooled by moving fresh air across your body. This tells the design team that air conditioning should not be necessary as long as one can open a window and provide cooling through ventilation.

Click Here!
CND TEACHING TOPICS: SITE
see Climate Analysis

8. Design the Massing to Connect the Building to the Climate

Passive design involves a complex set of interrelated variables. From the designers perspective, the massing is the first and most important of these: you can always compensate for less than optimal massing decisions, but getting the massing fundamentals right makes everything easier.

Looking back to the yearly temperature analysis, the concept of the balance point describes what we might call the metabolism of the building in its environment. As a concept, it keeps track of all of the interrelated variables of passive design- the energy flows of solar radiation and air temperature outside, the heat generated inside through people, lights and electrical consumption, and the nature of the boundary that the building creates between them.

The balancing act is to keep the inside comfortable as exterior conditions change. The balance is determined by how well the building can either connect or disconnect the inside to the various energy flows outside when desirable.

By determining the surface area of the building and it's orientation, the building's massing sets the basic parameters of that exchange. Small buildings have lots of surface area in relation to their volumes with which to gather light and solar energy, and also through which to loose or gain heat through their envelopes. Larger buildings with less surface area relative to their volume are inherently less connected to the climate outside. This can work as an advantage when the climate is cold, but it presents limitations when the concern shifts to providing adequate daylight to allow lights to be turned off during the day or cooling without mechanical means through natural ventilation.

Here a critical distinction between the conventional logic of energy efficiency and a more radical goal of carbon neutrality may play a formative role in the architecture. Pursuing carbon neutrality means designing the building to operate with lights and mechanical systems turned OFF as much of the time as possible- to be an 'architecture without power.' This means biasing decisions towards ensuring adequate potential connection to the exterior to fully daylight and naturally ventilate every inhabitable space.

In the three case studies, ecoMOD3 has the most articulated massing and hence the greatest potential to connect to its climate. Wild Sage balances the surface to volume efficiency of row house construction with shallow plans that allow light to permeate the units and openings on both north and south to provide cross ventilation. Denny Park has the most efficient volume, which offers efficiencies both in terms of heat loss and the economics of construction. The double loaded corridor and multi-floor construction means that each unit is also inherently limited in its ability to gather light and to be naturally ventilated.

ecoMOD3

Wild Sage

Denny Park

Click Here!
CND TEACHING TOPICS: BUILDING FORM
See Massing, Form and Organization

All three buildings orient their massing with the long exposures facing north and south, providing an inherent advantage in capturing sunlight for heating and providing shade to prevent overheating.

The massing of Wild Sage is designed so that the bar of row houses on the south does not shade the south facing windows on the bar to the north. To accomplish this, the massing of the southern units is held to two stories, while the massing of the units to the north are allowed to go to three stories on the northern side of the building.

In this multi-building neighborhood scheme there is a further subtlety of massing. This pair of building forms is mirrored on the southern side of the site. The third floor windows on what is now the southern building now face south, and the asymmetrical roof form means that even with the taller units to the south they do not block the sun from reaching the lowest windows on the building to the north.

Comparative Massing

Here the impact of size and density is catalogued by the CND Protocol. ecoMOD3 has 4.37 square feet of enclosure area (walls and roof surface) for each square foot of floor space. Wild Sage is more compact at 1.2 s.f./sf. and the five residential floors of Denny Park is even more so at 0.78 s.f/s.f.

There is no ideal ratio separate from the other interdependent variables- especially the climate. What makes sense in one climate in terms of massing may be a much less optimal starting point in another climate. Compact masses are typical in colder climates, though better envelopes can easily compensate for greater surface exposure if the need for greater connection to the climate for other reasons is evident.

ENCLOSURE AREA / GROSS MEASURED AREA

Main House	**4.14 SF/SF**
Accessory Dwelling Unit	**4.99 SF/SF**
Total Building	4.37 SF/SF

ecoMOD3

ENCLOSURE AREA / UNIT FLOOR AREA

Total Building	1.20 SF/SF

Wild Sage

ENCLOSURE AREA / GROSS MEASURED AREA

Residential Area	**0.78 SF/SF**
Commercial Area	**1.56 SF/SF**
Total Building	0.97 SF/SF

Denny Park

We're buying a better envelope and we're buying less mechanical equipment, and sometimes less expensive mechanical equipment, than we would otherwise.
-Jim Logan

9. Design the Envelope to Isolate the Building from the Climate

The very basis of architecture is the need to protect humans from the elements. This protection is provided by the building envelope -- the critical first line of defense in building an energy efficient structure. The envelope includes walls, windows and doors, roof, foundation, insulation, and shading. A carefully designed building envelope can reduce a building's energy demands by between 20 and 60% in most climates, compared to a conventional building designed to meet most building codes.

The four most important aspects of building envelope design are:

Keep Water Out
Water can seriously damage the building's structural elements, leading to mold, pests and high humidity. Keeping water out requires careful attention to material choices and design of details at the connections between materials. Designers must also consider strategies to ensure water doesn't get trapped in the building or building envelope. Long-term maintenance of the building to ensure that moisture is controlled and leaks have not developed will improve the building's energy performance over time.

Resist the Flow of Heat
The ability to resist heat flow is measured in R-value and all layers of a building envelope contribute to assessing the design of a building envelope. In most U.S. climates, heat might flow in either direction through a building envelope depending on the season or time of day. The careful selection of insulation, which provides an additional layer between the building and the environment, increases resistance. Materials that touch both an interior and exterior surface, such as a wood stud, are thermal bridges - places that heat can flow easily and substantially reduce energy efficiency. Care should be taken to reduce or eliminate all thermal bridges. In addition, surfaces next to non-conditioned spaces, like garages and some attics, should be treated like an exterior wall or roof.

Minimize Air Infiltration
The degree of air tightness of the building envelope establishes the building's infiltration of air through gaps, cracks, and other openings. Infiltration leads to thermal energy loss and can result in a greater need for heating and cooling. Air tightness can be enhanced with careful construction techniques and use of insulation. Caulking, sealant and sealing tapes are effective ways of creating airtight building envelopes. Installed correctly, these can eliminate as much as an aggregate total of one square foot of gaps and holes in a typical American house. However, infiltration can also improve indoor air quality (IAQ) by diluting indoor contaminants with fresh air. Therefore as air tightness increases, so does the need for ventilation systems, including technologies that minimize the loss of heat in cold weather such as heat recovery ventilators (HRVs) or energy recovery ventilators (ERVs).

Icynene spray foam insulation installation, ecoMOD3

Ensure Breathability
Gaps and leaks that allow water infiltration, along with humid air that breaches the building envelope can result in mold and fungus in warm weather and climates. In cold climates, leaks and humid air can result in ice on the building envelope. Both can negatively impact building materials, indoor air quality and human comfort. The design team must take extra care in building envelope design when moisture is a factor. When water and moisture get in, the envelope needs to be able to breath.

The range of climate zones in the U.S. points to the need for a climate specific strategies for building envelope design. Strategies to resist heat flow and air infiltration or

Click Here!
CND TEACHING TOPICS: ENVELOPE
see Envelope Design

The City of Seattle allows for five floors of wood framing. At the same time, we are in an earthquake area, so the lower levels have a heck of a lot of wood in them to adhere to the structural requirements. You may have an R-21 wall in theory, but you're way above the typical 20% framing to insulation ratio typical for wood frame construction. Code compliance requirements never calculate that. -Sandra Mallory, Program Manager, City of Seattle Green Building Team

to increase breathability are not the same in Maine, Mississippi, and Montana. The "Builder's Guide" series of technical books by Joseph Lstiburek and others are excellent resources for climate-specific advice on building envelope design.

Some advice is common to all climates, especially when it comes to building materials and construction details. For example:

- "Simple" building envelopes with basic geometries tend to perform better.
- Pay special attention to corners, any penetration through the building envelope, and any place that walls, roofs or floors come together. This is where unwanted heat transfer and air infiltration tends to happen.
- Window selection is a complex process, and the entire design team should have a voice in the process, especially when it comes to performance specifications and maintenance concerns. Glazing and glazing coating selection in windows in most climates should be determined by orientation of the window and climate.

Take Special Care with Roof Design

The roof is the most important part of the building envelope because it keeps precipitation out of the building. The most basic form of shelter involves a roof if nothing else. Challenges that designers and builders face with the walls are only intensified at the roof.

Roofs are also the main culprit of unwanted heat flow in a building. Heat rises, so in cool climates, the roof is the most important location for resisting heat losses. In hot climates, the roof becomes a source of unwanted heat gains. In mixed climates, both concerns should be addressed. While roof design varies by climate, increasingly designers in many U.S. climate zones are recognizing that insulating the underside of the roof can save substantial energy. This involves treating attics as conditioned space, which serve as a buffer in both hot and cold weather. This has the added benefit of placing an attic mechanical equipment in a conditioned space, which reduces the energy necessary to run them.

In most U.S. climates, it makes sense to consider a reflective or light colored roof to reduce unwanted heat gain in the summer. The US Department of Energy found that a black roof on a sunny day in direct sunlight can be over 50ºF warmer than a white roof. Other basic principles of good roof design include keeping the shape simple, so as to avoid valleys and ridges, and to reduce the number of gutters and downspouts. Low slope roofs or flat roofs, if designed and installed property, can be excellent ways to reduce cost by eliminating unnecessary material and structure, but careful attention to water drainage is essential for maintaining high performance.

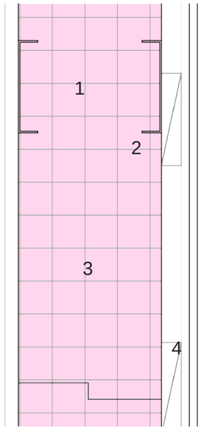
Green roofs refer to any vegetated roofing alternatives to traditional, non-porous roofing materials, like asphalt or bitumen. Green roofs provide benefits such as absorbing carbon dioxide, reducing the heat island effect, reducing stormwater runoff, providing acoustic insulation, providing some thermal insulation when dry, and enhancing habitat for flora and fauna.

There are two types of green roofs, extensive and intensive. Extensive green roofs are comprised of shallow soil (2-3 inches) and drought-tolerant species of grasses, mosses, and sedums. They require little to no irrigation, fertilization, or maintenance once established. Extensive green roofs do not add a lot of weight over a traditional roof system and can often be retrofitted to existing buildings without requiring additional structural support.

Intensive green roofs require deeper soil (6-8 inches typical) and can have larger plants, including trees. They typically require maintenance on par with a traditional garden and often include design elements like walkways and benches to encourage human interaction with nature. The engineering requirements of an intensive green roof are much higher than an extensive one.

Green roofs may be appropriate for buildings where a low slope or flat roof is designed. A life cycle assessment conducted comparing roof types showed that green roofs have a lower life cycle impact over conventional roofs. A conventional roof can lead to more than twice the carbon emissions than a green roof over the life cycle of the roof.

ecoMOD3
TYPICAL WALL SECTION- ADU



ThermaSteel Wall Connection Detail

1. THERMASTEEL WALL PANEL
2. STEEL CHANNEL
3. INTERLOCKING PANEL JOINT
4. EXTERIOR SIDING, FURRING STRIPS + BUILDING PAPER

ENCLOSURE HEAT TRANSFER RATE PER MEASURED FLOOR AREA

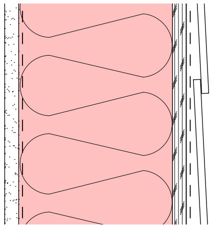
Main House	**0.27** Btu/ HR-SF-°F
	1.51 Watt/ M²-°C
Accessory Dwelling Unit (ADU)	**0.37** Btu/ HR-SF-°F
	2.12 Watt/ M²-°C
Total Building	0.30 Btu/ HR-SF-°F
	1.68 Watt/ M²-°C

Comparative Envelope Metrics

Two metrics define the CND Protocol's analysis of the building envelope; neither of which are simply the conductivity or resistance of the envelope assembly. Rather they place the assembly in the context of the floor area being contained.

The first is the ENCLOSURE AREA PER GROSS MEASURED AREA illustrated in the Massing discussion above. The second is the ENCLOSURE HEAT TRANSFER RATE PER MEASURED FLOOR AREA.

WILD SAGE
TYPICAL WALL SECTION



1. 1/2" GYPSUM WALLBOARD
2. 4 MIL. VAPOR BARRIER
3. 2 X 6 WOOD STUDS FILLED WITH WET BLOWN INSULATION
4. 1/2" OSB SHEATHING
5. BUILDING PAPER
6. HARDY PLANK LAPPED SIDING

ENCLOSURE THERMAL TRANSFER RATE PER FLOOR AREA

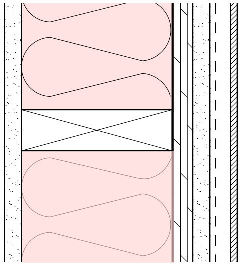
Residential	**0.28** Btu/ HR-SF-°F
	1.57 Watt/ M²-°C
Mechanical	**0.28** Btu/ HR-SF-°F
	1.57 Watt/ M²-°C
Total Building	0.28 Btu/ HR-SF-°F
	1.58 Watt/ M²-°C

Considered as a pair, the following observations can be made:

ecoMOD 3 and Wild Sage have nearly identical heat transfer rates while ecoMOD 3 has over three times the surface area per sq.ft. Clearly ecoMOD 3 has the more insulating thermal envelope assembly.

Denny Park has a heat transfer rate per sq.ft. of floor area that is only one quarter of that for either ecoMOD or Wild Sage, and by observation it has the least well built thermal envelope.

DENNY PARK
TYPICAL WALL SECTION



1. 5/8" TYPE 'X' GYPSUM WALLBOARD AND VAPOR BARRIER
2. R-21 FIBERGLASS THERMAL BATT INSULATION
3. 2 X 6 WOOD STUDS
4. PLYWOOD WHERE NEEDED FOR SHEAR
5. 5/8" TYPE 'X' FIBERGLASS-REINFORCED EXTERIOR GYPSUM SHEATHING
6. BUILDING PAPER
7. METAL OR FIBER CEMENT SIDING

ENCLOSURE HEAT TRANSFER RATE PER GROSS MEASURED FLOOR AREA

Residential Area	**0.07** Btu/ HR-SF-°F
	0.37 Watt/ M²-°C
Commercial Area	**0.40** Btu/ HR-SF-°F
	2.29 Watt/ M²-°C
Parking Garage	**4.47** Btu/ HR-SF-°F
	25.4 Watt/ M²-°C
Total Building	0.13 Btu/ HR-SF-°F
	0.72 Watt/ M²-°C

Clearly, Denny Park's very low surface to floor area ratio works in its favor in terms of isolating the residential units from the outside climate. Whether that inherent isolation ever works against the goal of reducing energy expenditures to zero is the question.

If we had one more dollar to spend, it'd be on insulation. That would be the thing we should have done.

-Brian Bowen

Project Architect, Wild Sage

10. Heat the Building with the Sun

Passive solar design is a form of passive design that utilizes solar energy to regulate temperature and provide light to interior spaces without the use of mechanical systems. Passive solar design relies on building orientation and five design elements -- aperture, absorber, thermal mass, distribution, and control -- to create livable spaces. Done well, passive solar design significantly reduces the need for mechanical conditioning by regulating temperature year-round.

Aperture
The aperture is usually a large window on the south-facing side of a house that collects sunlight. Apertures work best when there is little shading between 9am and 3pm in winter and faces within 30 degrees of true south

Absorber
The absorber acts as a storage element and receives light through the aperture. It is typically a hard, dark surface, such as a wall or floor. It can also be a water container

Thermal Mass
Thermal mass retains the heat captured by the absorber. It typically works in concert with the absorber, as the mass behind or underneath the surface. Examples of thermal mass include building materials such as stone and concrete, as well as water containers.

Distribution
The distribution system circulates heat from the thermal mass throughout the dwelling. A truly passive system accomplishes distribution through natural convection, conduction, and radiation, although blowers or fans may also be used.

Control
During summer months, roof overhangs, blinds, and awnings can be used to shade the aperture to prevent overheating.

These elements should be considered a system -- all are necessary to have a successful passive solar design.

Wild Sage as a Solar Village

Here we see the southern range of buildings mirroring the case study building to the north. One distinctive feature of Wild Sage is that every one of the 34 units is designed to have south facing windows for passive solar heating.

Click Here!
CND TEACHING TOPICS: PASSIVE STRATEGIES
see Passive Heating

11. Reject the Sun when it's Hot

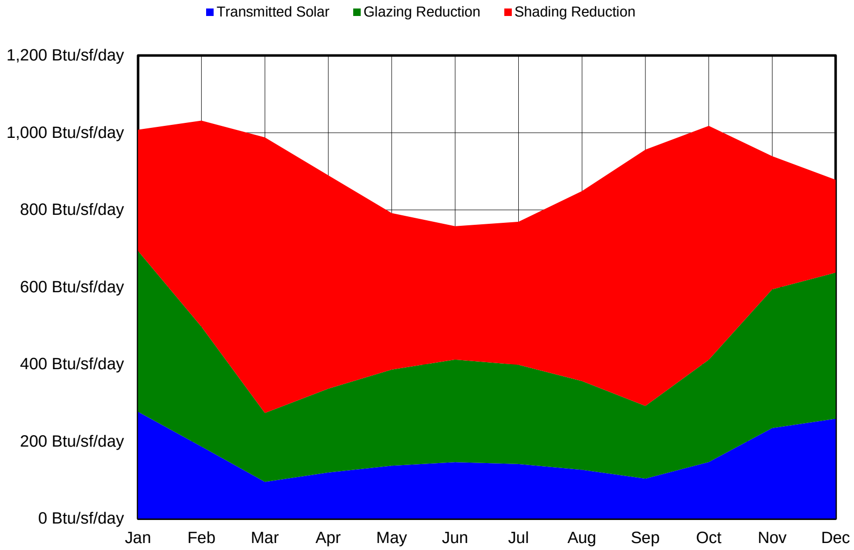
Stated bluntly, sun should never be allowed to strike glass if the result is going to be the need to cool the space mechanically.

The U.S. housing industry seems to have lost interest in the most common way to avoid overheating before the invention of air conditioning: shade devices such as operable shutters, shade devices and overhangs. Cooling loads are significantly reduced if the sun is prevented from ever entering the building during certain times of day. Internal shading strategies are far less effective than external ones because the heat has already entered the building.

In many climates, it may be helpful to consider the historic vernacular architecture of the area, which evolved prior to the widespread adoption of mechanical heating and cooling systems. This includes design strategies created to minimize the adverse impact of the local climate on the comfort of the occupants. Examples include tall ceiling heights to keep warm air above residents, operable shutters to control heat gain, covered porches to help temper adjacent indoor spaces, and locating windows to maximize cross breezes. However, it is important to recognize that vernacular buildings are not inherently better, and designers should carefully assess which vernacular strategies make sense in any given situation. A thoughtfully designed contemporary building can substantially outperform an historic structure when it comes to comfort and energy performance.

ecoMOD3 Southern Exposure Shading

Summer and winter photographs illustrate the layered shading strategy for south facing glass doors of the ecoMOD3 accessory dwelling unit. A trellis structure supports an extension of the roof plane as a horizontal shading device over the windows. The trellis also provides an armature for deciduous vines to grow and shade the path and glass at the front door. Both of these strategies are dwarfed by the effects of the trees to the south of the building. Both the trees and vines provide for seasonally adapted shading, loosing their leaves when the weather suggests that warmth would be welcome.



ecoMOD3 Shading Analysis- Horizontal Overhang only

This CND Protocol Level 3 analysis of the solar transmisison rate of the south facing floor to ceiling window above illustrates the effects of several strategies to reduce solar heat gain. The upper boundary of the red indicates the amount of solar radiation falling on the glass over the course of the year. The area of red is the amount of solar radiation blocked by the shade structure visible above the window. The green area is the amount of the remaining radiation that is filtered out by the high-performance glazing, and the blue is the radiation that is actually transmitted. The goal should be to not let the sun strike the glass whenever cooling is the concern, though any light that passes through the glass will introduce heat, so the blue area will never go away.

Click Here!
CND TEACHING TOPICS: ENVELOPE
see Solar Control/ Shading

12. Cool The Building Passively

Passive cooling like passive heating is the art of selectively connecting to and isolating from energy flows within the environment. Note that in both cases, focusing on people's comfort broadly rather than more static measures expands the range of options.

Where passive heating involves capturing sunlight or the metabolic heat of the occupants and the energy consuming activities within a space, passive cooling involves dumping heat to the environment. This can be through the movement of air, or through connection to the ground, or through radiation to the night sky. In dry climates where daily temperature swings are large, there are potentially many ways to harness and store these flows. The more humid the summer climate, the less the day to night temperature swing and the fewer ways there are available to dump heat to the environment.

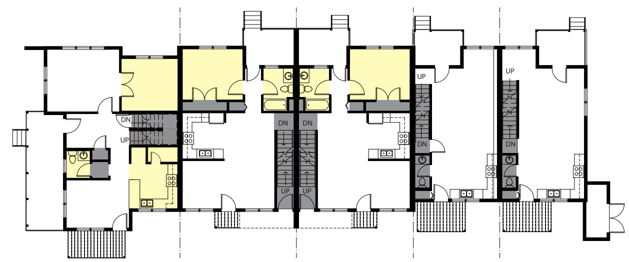
In many climates, it may be helpful to consider the historic vernacular architecture of the area, which evolved prior to the widespread adoption of mechanical heating and cooling systems. This includes design strategies created to minimize the adverse impact of the local climate on the comfort of the occupants. Examples include tall ceiling heights to keep warm air above residents, operable shutters to control heat gain, covered porches to help temper adjacent indoor spaces, and locating windows to maximize cross breezes. However, it is important to recognize that vernacular buildings are not inherently better, and designers should carefully assess which vernacular strategies make sense in any given situation. A thoughtfully designed contemporary building can substantially outperform an historic structure when it comes to comfort and energy performance.

ecoMOD3 Passive Cooling Strategies (Left and Above)

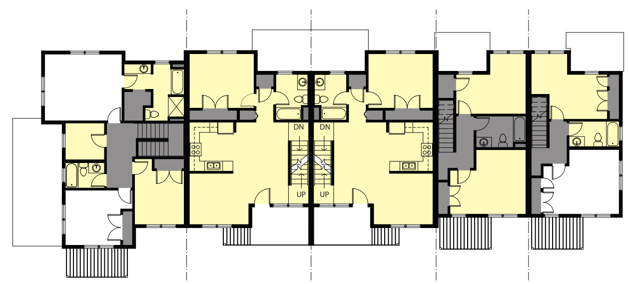
ecoMOD 3 blends vernacular and modern sensibilities in ways that promote passive comfort. To the right, a clear path of ventilation air movement is evident between the low hopper windows to the south and the high window to the north. Above, the ceiling space expanding to the rafters provides a place for warm air to stratify above the occupants.

Wild Sage Ventilation Study

This CND Protocol diagram provides a simple inventory of the potential for natural ventilation, which requires a clear entry and exit path for air to flow through each space.



First Floor Natural Ventilation Diagram



Second Floor Natural Ventilation Diagram

- Primary Natural Ventilation
  Space two or more inlet/outlets and clear cross or stack ventilation paths.
- Secondary Natural Ventilation
  Space with inlets/ outlets on a single face and no clear cross or stack ventilation path when internal doors are closed.
- Not Naturally Ventilated

Click Here!
CND TEACHING TOPICS: PASSIVE STRATEGIES
see Passive Cooling / Natural Ventilation

13. Light the Space with the Lights OFF

Buildings can easily be designed to effectively provide daylighting without the need for artificial lighting on most days in most climates. To do so requires careful consideration of window sizes and locations, as well as attention to the proportion of rooms and the reflectivity of surfaces.

If windows are thought of as if they were light fixtures, it is clear that several soft light sources will provide better illumination than one bright source, and that the surfaces that are illuminated are as important to the design as the source. In this way, windows can be placed to maximize the opportunity for light to wash surfaces, bounce deeper into a room and to balance other light sources so as to avoid glare that results from a strong source of light from one direction.

Thoughtful daylighting design is not about simply adding as many windows as possible, especially since windows are the weak link in the building envelope with respect to resisting heat flow.

Light must be controlled and directed to where it is needed. Generally, thin rooms with windows on two or three sides are easier to daylight than thick or large square-shaped ones with windows on one wall. Taller rooms allow for more high glazing, which tends to be one of the best ways to distribute light deep into a room. Skylights are useful when they distribute reflected light into a room, but are also a source of unwanted solar gains and winter heat loss, and should be avoided if not essential for daylight.

ecoMOD3 Accessory Dwelling Unit Daylighting

Several aspects of good daylighting design are visible in this image- There are two windows providing light from two different directions and a well-shaded south window wall is on a third wall. The interior surfaces are light colored, which bounces the available light around and also reduces contrast between the bright window and the surrounding wall.

More subtly, the high window on the left is close to the ceiling and the adjacent wall, so that these surfaces are washed with light. The deep window box to the right creates its own reflective side wall surface to bounce light into the room.

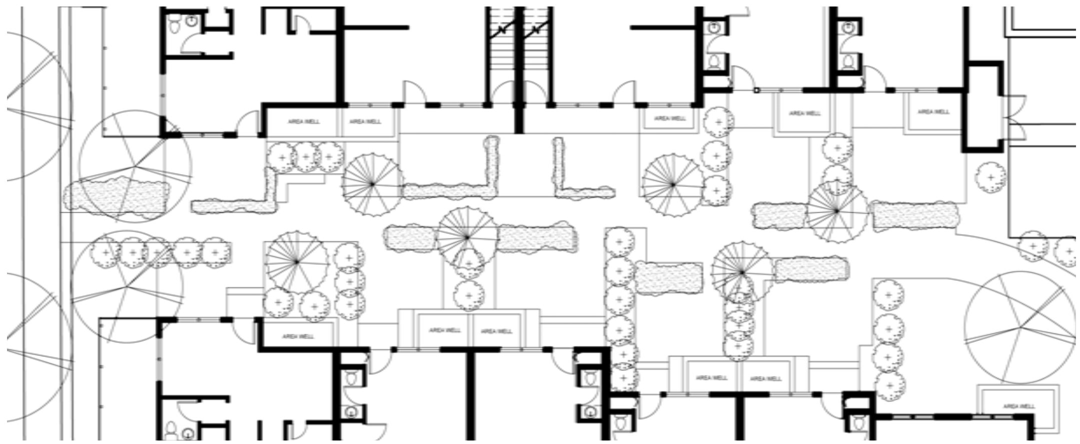
Click Here!
CND TEACHING TOPICS: PASSIVE STRATEGIES
see Daylighting

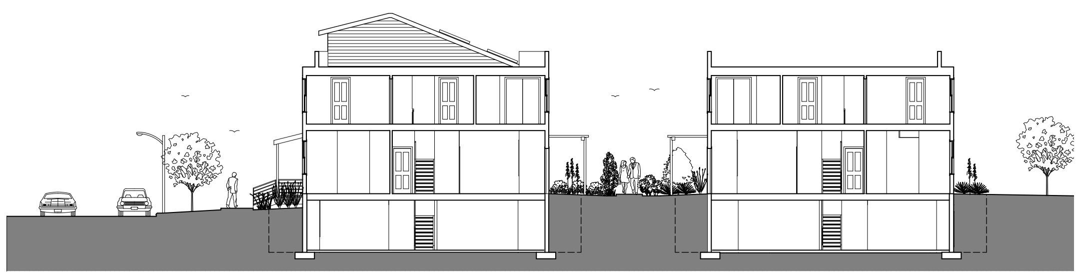
Design = Integration

The space between buildings at Wild Sage discussed in several of the above CND Imperatives is a good example of integrated site planning, massing and passive design. As described, the space is dimensioned to allow the winter sun to reach the southern facade of the northern building. Every unit in the building and at Wild Sage in general has a southern exposure for passive solar heating. As is evident in the South Elevation (right) even the basement windows are large, which brings sunlight , daylight, natural ventilation and a sense of spatial expansiveness to the basements.
Solar shading protecting the south facing glazing is one feature of the building that was eliminated due to budget limitations during design. At the same time, the densely vegetated space between the buildings will increasingly offer leafy shade during the summer months as the trees mature.


Basement Window Wells


South Elevation including Basement


Enlarged Site Plan

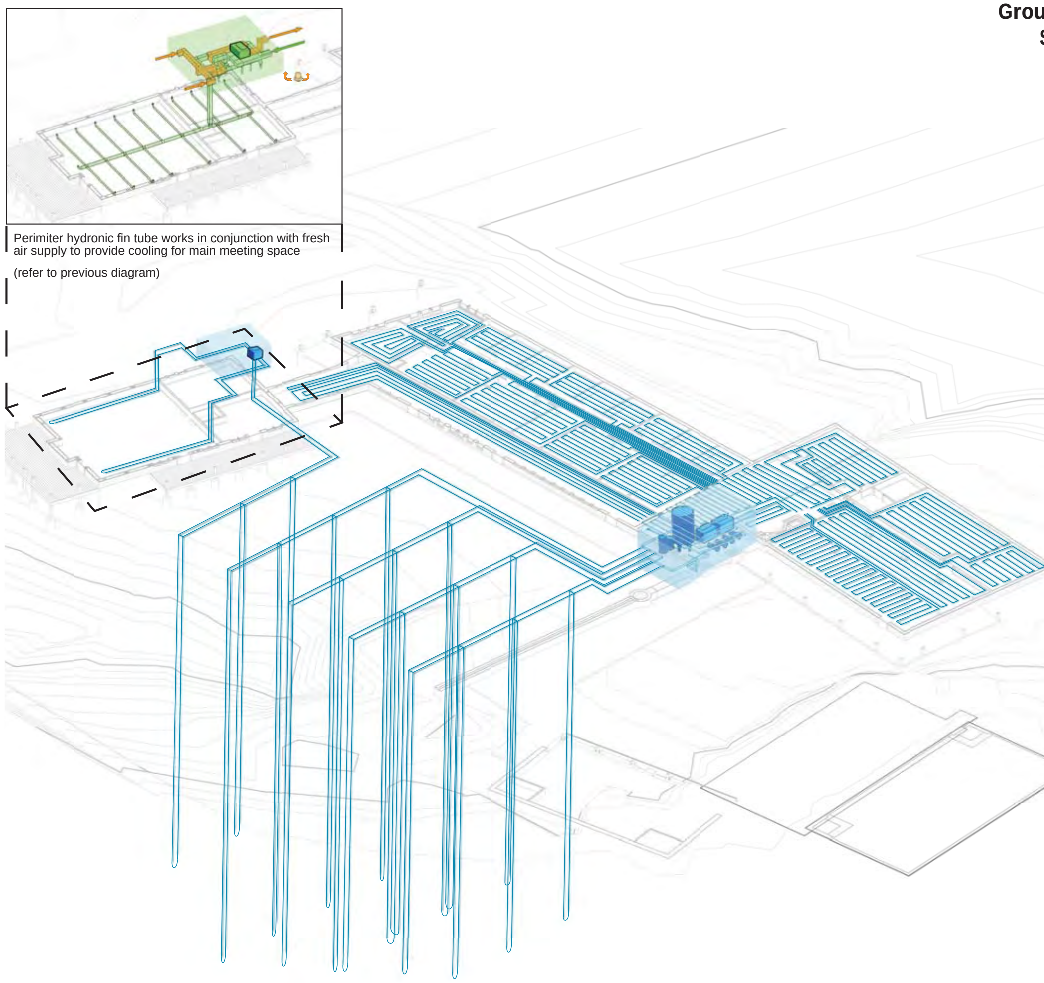

Site Section

III. ENGINEER THE SYSTEMS TO BE INHERENTLY EFFICIENT

Affordable Housing is rarely a good venue for deploying mechanical systems that achieve their efficiency through complex operational strategies or constant servicing. Rather, once the loads have been reduced to an absolute minimum through the architectural design, the best systems are often the most robust rather than the most capable of high performance.

The engineering of these systems matters. The ground source heat pump of the carbon neutral Aldo Leopold Legacy Center, for example, had the pump power installed for the system reduced by 75% from the initial 'best practices' solution simply by the use of larger pipe diameters and more elegant piping layouts.

Ground Source Heat Pump and Hydronic Cooling System (Radiant Floor Heating and Cooling), Aldo Leopold Legacy Center



MEET ENERGY LOADS EFFICIENTLY THROUGH GOOD ENGINEERING - THE NEXT 25%

This category is the responsibility by all project team members, including architect, contractor and engineers or subcontractors involved in selecting mechanical, electrical and plumbing technologies and equipment. The focus is on energy efficient lighting, high-efficiency equipment, monitoring systems, control systems among other choices.

Systems and fixtures actively consume energy. Selecting highly efficient products and strategies will reduce that need. All of these systems have specifications that may need to be considered in the design phase and many should be selected early in the project to be accommodated. The Energy Star label is helpful in identifying products that achieve energy efficiency above typical products in the same class and are comparably priced or offer a reasonable payback period over less efficient products.

As the Aldo Leopold Legacy Center demonstrates, however, these systems all involve design. The most efficient systems possible will still perform wastefully if the design does not focus on making the most of their capabilities and reducing to a minimum their energy demand.

Some things that now are thought to be green, like instantaneous hot water heaters, if you look at maintenance the whole thing falls apart. It falls apart because you are supposed to take the heat exchanger out and flush it with vinegar once a year, which nobody does, and if you did it would be three hundred bucks a year... -Jim Logan

14. Select Systems for Robustness and Transparency

Perhaps more so than for market rate construction, the first CND requirement of mechanical equipment and systems in the affordable housing arena is that they be both highly efficient and easily operated and maintained at their peak efficiency.

For this reason, ecoMOD3 utilizes a mini-split air to water heat pump system, the fan coil unit of which is visible in both the old house and accessory dwelling unit- this is considered high efficiency equipment in the U.S., and is commonly used in many countries, due to its performance and reliability.

Also visible in these three photos of ecoMOD 3 are three high efficiency ceiling fans- a simple way to maintain comfort that eliminates the need for mechanically cooled air some of the time and improves the distribution of the mechanically cooled air at other times.

The City of Milwaukee's award winning Hopes VI Highlands Gardens multi-family housing employs a simple technical adaptation to improve the serviceability of its mechanical systems. Each apartment is served by a small heating and cooling fan coil unit located in a closet within the apartment but opening to the corridor. The mechanical box is on wheels and is connected to the room's ductwork and the building's hydronic loops with compression fittings that allow for easy removal. Any time one requires maintenance, it is simply removed and another box is installed in its place.

15. Minimize Fan Power

Air is a lousy heat transfer medium. Forcing air through ductwork using fan power turns out to be a very inefficient way to change the temperature of a space. To move beyond the use of forced air, it is important to tease out the various functions of air movement and deal with them individually.

Ventilation is required in buildings for two distinctly different reasons- to provide for the health of both the occupants and the building materials, and to cool (and potentially to supply mechanical heating and cooling) to both the occupants and the space.

The lesson of the CND case studies of commercial and institutional buildings like the Aldo Leopold Legacy Center also applies to residential construction, though in smaller ways. The need for fresh air and exhaust should be separated conceptually from the need for heating and cooling, which should use water rather than air as it's transport fluid.

Eliminating the use of forced air for heating and cooling means that the required fan power and ductwork for fresh air ventilation can be greatly reduced in size. These fans and duct runs should in turn be designed to be as efficient as possible, which suggests highly efficient fans, very short duct runs, larger diameter ductwork and fewer bends. These small efficiencies can make a significant difference in overall energy demand. At the Leopold Legacy Center, the toilet exhaust alone uses more electricity than all of the pumps that drive the radiant floor system.

Fresh Air Ventilation Systems, Denny Park

This typical floor of the Denny Park Apartments illustrates the presence of two fresh air ventilation systems. The primary heating of the building is done with a hydronic perimeter loop and a centralized boilder. Mechanical cooling is not provided given the mild summer climate of Seattle.

At the far left, a fan coil unit mounted in the ceiling of the corridor on each floor brings in fresh air, tempers it hydronically, and pressurized the corridor. This pressurization provides the fresh air supply to the units and is required to counteract odor migration from one unit to the next. Stale air is exhausted through the individual kitchen and bathroom fans in each unit. At the opposite end of the hall, corridor exhaust ductwork is collected and exhaused at the roof level, allowing balancing of the system.

This system illustrates the separation of ventilaion and heating, but it is not necessarily radically efficient.

16. Empower the Inhabitants through Design

Occupants can do a lot to reduce energy demands by making small adjustments to their daily lives, and decisions made in the design phase can influence occupant energy use.

Energy conservation systems and controls will help tenants reduce their energy use.

Individually meter each unit

Install sub-meters for each unit - this brings tenant attention to energy usage. If each tenant is responsible for paying for their individual energy use, the incentive to reduce energy use is greater than if all tenants pay a percentage of the total bill (or if a flat monthly fee is attached to rent). Sub-meters work by measuring the amount of a utility (electricity, water, gas) consumed by each unit. This information is sent to a third party that then bills tenants for the utilities they consumed. When tenants have to pay for the utilities they consume, the amount used falls compared to buildings using flat utility fees. By some estimates, the difference is as high as 20-40%.

Install programmable thermostats

Good programmable thermostats have timers that allow occupants to automatically turn the system off when everyone leaves the house for the day and on shortly before they return, in order to return the temperature to a comfortable level. This saves energy by not having to condition space while no one is home.

Install shades for windows

Shades help regulate interior temperature during summer months, which can help reduce the need for mechanical conditioning. Providing these to tenants increases the likelihood that they will be used.

Install motion sensors

Install motion sensors in common areas, like circulation corridors. This will activate lights when people are present and ensure they are off when the space is empty.

Install switched outlets

Install outlets that are switch controlled to reduce phantom loads. "Phantom loads" refers to the small amount of electricity some electronic devices draw when turned off but still plugged in. This may be due to standby mode or power indicator lights. By unplugging devises or turning off power strips, these loads are eliminated.

It is estimated that phantom loads account for 10% of household energy use in the U.S.. Installing outlets controlled by switches makes it easy for tenants to eliminate power to appliances and fixtures when not in use, saving them money while they sleep or are away at work.

Programmable Thermostat, Wild Sage

The fourth generation of the ecoMOD project (ecoMOD4) devised a strategy to address the issue of phantom loads by color-coding outlets. Outlets that are operated by switches are an easy way to cut power to electronics without having to unplug them individually.

In ecoMOD4, gray-colored outlets are controlled by these switches and white outlets are "always on" traditional outlets (for appliances, like the refrigerator).-Paxton Marshall, ecoMOD Engineeing Director

17. Consider Systems Selection Holistically

What wisdom would I offer your guidebook? I'd say that it's worth doing the energy modelling regardless and looking at the mechanical systems that make the most sense. -Sandra Mallory, Program Manager, City of Seattle Green Building Program

There are no universal solutions for the choices presented by the question of mechanical systems selection, other than everything we have stressed so far: Reduce the heating, cooling and electrical loads through design to the point where the efficiency of the system is less critical than it's reliability, and then solve for achieving efficiency, reliability and occupant ease of engagement holistically.

Denny Park offers a case in point for examining trade-offs. Denny Park's primary gesture towards energy efficient mechanical systems is it's use of a central boiler and hydronic perimeter loop for heating. The more conventional alternative in Seattle would be the use of electric resistance heat, which is very carbon intensive. (This is true even in the Pacific Northwest, where electricity has a history of being provided inexpensively by low-carbon hydropower. The key to the carbon intensity of Seattle's or any other electrical grid is the fuel used for adding capacity to meet a continually rising demand. This would typically be coal for base load plants or natural gas for peaking plants, as large scale hydropower has other serious environmental impacts.)

The conundrum is that hydronic heat is currently expensive to meter at the level of the individual apartment, which means that the residents receive no direct feedback linking their behavior to their utility bill. Anecdotally, Denny Park has a high concentration of residents from East Africa, who drive up heating demand in Seattle's dreary winters without realizing the cost in terms of energy use. Electrical resistance heating would provide a direct feedback in the form of a utility bill. The open question is which system would prove to be more efficient over time?

Wild Sage similarly has natural gas fired boilers serving each building as a whole. The overall efficiency and the ability to link this system to a solar hot water system drove the choice, though the fact that the utility bills are pooled for each building in this Cohousing community causes occasional friction amongst the community members. Here at least the community size is small and highly sensitive to environmental issues. Again, the same question has no simple answer.

It's really hard to find equipment that's small enough. Very little equipment is made to meet these very small loads. Things that don't intuitively make sense, like using little-resistance electric heaters, actually can make sense in these really low-energy buildings. -Jim Logan

High Efficiency Boiler, Wild Sage

IV. PRODUCE YOUR OWN RENEWABLE ENERGY ON SITE

Once the demands for carbon fueled power has been reduced to a quarter or less of what they would typically be through design and engineering, the potential exists for on-site renewable energy generation to meet that demand.

This doesn't mean that the building needs be completely self sufficient but that it's carbon footprint is balanced by its generation of zero or low carbon electricity displacing carbon fueled electricity elsewhere in the grid.

Grid tied buildings are part of a community. Their ultimate efficiencies are generated at the scale of the local power plant and their impacts are measured at the scale of the global atmosphere.

***Eagle Place**, an approximately 100 unit apartment complex in Layefeyette, Colorado, is the first HUD funded affordable housing project in the U.S. to approach a zero (fossil fuel) energy standard. George Watt, Architect.*

Note the domestic solar hot water systems on the orange portion of the building and the integrated photovoltaic sunshades over the south facing windows.

PRODUCE YOUR OWN RENEWABLE ENERGY ON SITE - THE LAST 25%

The next step is to determine the gap that remains to achieve carbon neutrality. Even if all of the above energy reduction and efficiency strategies are implemented, the building will use some energy in its operation. Using renewable energy to meet the electrical demands of a building will significantly reduce its carbon footprint and because of the energy-saving strategies already mentioned, the amount of renewable energy needed will be smaller than in typical construction. Renewable energy can be utilized in a number of different ways to meet the project's needs.

On site energy generation integrates renewable energy production directly into the project. The property owner assumes the costs for the equipment, installation, and maintenance the systems, but receives the full benefit of the energy generated. The resources section provides links to information for siting these technologies.

Due to the variability of solar exposure and wind on site both during the day and throughout the year, it is recommended that multiple strategies be implemented in order to ensure an adequate supply of renewable energy on site. Local building codes regarding on site renewable energy facilities vary widely and may require additional permitting. No matter which technologies are selected, it is important to identify them early in the design stage, as siting the facilities with the building greatly impacts the amount of energy that can be generated.

A warranty and a maintenance contract are strongly recommended. There is no reason to spend money on expensive technologies if they are not kept in working order.

Off-site Renewable Energy

The non-profit Architecture 2030 seeks to reduce fossil fuel consumption in buildings by 60% of conventional design. Once passive and active design elements and on-site renewable energy generation have been exhausted, up to 20% of reductions may be achieved through the purchase of carbon offsets. This recognizes the radical transformation of the design and construction industries to achieve truly passive designs and the realities of site constraints on renewable energy generation. Understanding that this transformation will take time to fully realize, carbon offsets may be used to help achieve the goal.
Affordable housing projects may find it difficult to justify the additional costs associated with contracting for renewable energy off-site. For this reason, it is recommended that these approaches be used as a stopgap measure while a long-term strategy for more direct energy generation is formulated. The goal would be to seek out specific local opportunities that create contractual price stability for the residents and/or invest in local economic and ecological redevelopment.

Contract with a Green Energy Provider

There may be green energy providers in the building's service area that can be contracted with to provide energy to the site that is generated from renewable energy sources. Some states require all energy providers to include some renewable energy sources in their portfolios. Some energy providers give consumers an opportunity to "opt in" to sourcing renewable energy, although this typically costs more per kilowatt. The resources section provides links to websites to find providers in your area.

Use Purchased Offsets as a Last Resort

If there remains a gap to achieving carbon neutrality, it is unlikely that an affordable housing budget will stretch this far, although grants may be available to facilitate this final step. Offsets help to compensate for the carbon that cannot otherwise be eliminated through design or on site renewable energy generation by helping to pay for carbon sequestration projects elsewhere. Offset purchasers buy certificates for tons of carbon reduced through methane capture, renewable energy generation, and landfill gas utilization. Certified brokers of carbon offsets verify that the projects truly provide reduced impact that would not have occurred without the offset program and that offsets are not sold more than once. It is important to note that the planet's ability to offset carbon is limited, which is why carbon avoidance achieved through design elements are preferred. A list of carbon offset providers is available in the Resource section.

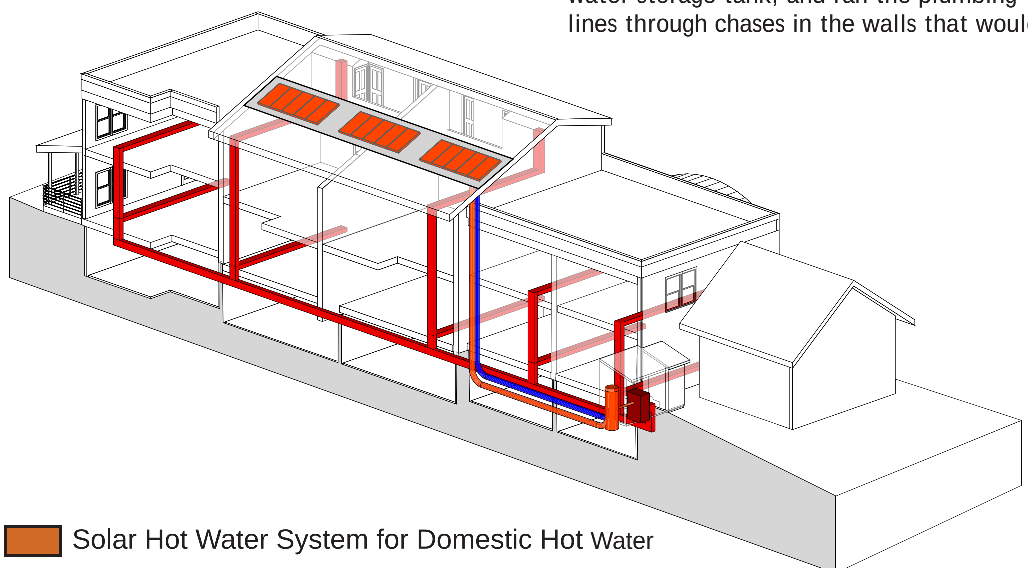
18. Integrate Domestic Solar Hot Water Now or Provide for it Later

The principle behind solar thermal energy is using solar energy to directly heat air or water in the home. Unlike with photovoltaic systems, solar energy is not converted to electricity before it is used. This results in a more efficient transfer of energy. Solar thermal for domestic hot water is a proven technology.

Solar thermal systems use a solar collector to store solar energy. The collector is typically an insulated frame or box comprised of glass, metal, and/or plastic that contains an absorber, which is usually steel or aluminum that has been painted black. Solar thermal water systems may use pumps, which require electricity and wiring to function. Solar thermal air systems use a fan to draw cool air into the system and pump warm air back into the room. These fans often are designed to connect to a small photovoltaic panel co-located with the solar thermal collector for power. These materials are comparable to those found in solar panels and would have similar carbon impacts.

Wild Sage illustrates an important commitment that we would argue is critical for the Carbon Neutral Design of Affordable Housing in particular. At the time of its design, the Cohousing community could not afford to add a solar thermal system to each of the buildings, even though in sunny Boulder, Colorado the economic payback is extremely short.

Instead, the architects designed roof slopes appropriate for a solar hot water system. They also designed the space for the necessary hot water storage tank, and ran the plumbing lines through chases in the walls that would be difficult to retrofit later. This allowed for the happy event that the residents located a solar hot water system that was being de-commissioned, and had it installed during the construction.



Solar Hot Water System for Domestic Hot Water

Boiler and Hydronic Heating System

Reclamation of a Previously Owned Solar Hot Water System, Wild Sage

Solar Hot Water Storage Tank, Wild Sage Mechanical Closet Basement

Click Here!
CND TEACHING TOPICS: ENERGY
see Renewable Energy

19. Integrate Photovoltaics Now or Provide for them Later

Photovoltaic systems can include stand-alone panels or building-integrated panels. Stand-alone panels can be sited on the ground or mounted to the building's roof or walls. Building-integrated panels are integrated into the actual building materials, replacing conventional materials.

Photovoltaic panels are positive technology in that they allow buildings to harness solar energy to generate electricity. However, the panels themselves are not without carbon impacts. Rigid photovoltaic panels consist of silicon, glass, steel and/or aluminum, and concrete. Electricity is generated and harnessed by connecting the panel to an inverter, wiring, and controller. The life-cycle of photovoltaic panels includes the mining of raw materials, refining, and manufacturing of component materials, including silicon, glass, steel, aluminum, concrete, and plastics, as well as the manufacture of the modules themselves and eventual decommissioning. Mining operations disrupt the natural landscape and rely on fossil-fuel dependent equipment. With the exception of concrete and glass, the materials comprising the modules have relatively energy-intensive production processes.

Electronic components of a photovoltaic system are comprised of energy-intensive materials, including plastics and metals. These materials also require raw material extraction using fossil-fuel burning equipment. Electronic components contain hazardous chemicals that require special handling at end-of-life. Some systems include batteries for electricity storage that contain additional hazardous chemicals.

Large-scale photovoltaic systems have a large footprint and are typically incompatible with other on site land uses. In areas where land is scarce or expensive, the feasibility of large-scale photovoltaic systems diminishes.

Again, we consider it an important commitment to Carbon Neutral Design that projects that cannot afford photovoltaic power systems be designed to accommodate them later.

At Wild Sage, this has not been well integrated into the architecture, but the predominantly flat roofs allow for many varieties of rack systems to be installed independently by each condominium owner. ecoMOD3 does not incorporate PV, but ecoMOD2 below illustrates a low-profile roof mounting system. Finally, Eagle Place illustrates a fully building-integrated installation in which the PV panels serve a dual role as sun shades for the south facing windows.

Roof mounted PV, ecoMOD2

Owner installed PV rack , Wild Sage

Building Integrated PV sunshade, Eagle Place

Click Here!
CND TEACHING TOPICS: ENERGY
see Renewable Energy

20. Consider Providing Low-Carbon Heat and Power at a Neighborhood Scale

Community energy generation looks both beyond the individual building's needs and the site itself towards community-wide renewable energy generation.

A study by the National Renewable Energy Lab (NREL) considered the question of achieving net-zero energy use for multi-story buildings. Assuming that photovoltaics are limited to the roofs of buildings (as would be the case in a city), then the size of the roof will limit the total amount of energy able to be generated. NREL determined that four stories is the limit on achieving net-zero energy use in ideal conditions. With five stories or more, the amount of energy expected, even in energy-efficient designs, would exceed what could reasonably be generated on the roof. Another consideration is that in cities, unless buildings have a uniform height, shading from other buildings will result in decreased output. Working in cooperation and not in competition with neighboring buildings can result in the optimal outcome for all buildings.

Community-scale energy generation has a number of advantages. A study done by Pacific Northwest National Laboratory on mixed-use communities of about 16,000 people compared the per kWh cost of five renewable energy strategies -- photovoltaics on each building, photovoltaics clustered on adjacent land, solar thermal, a wind farm on leased land, and a wind farm on purchased land. The study used Chicago and Phoenix as test cities. For both, the cheapest output per kWh came from a wind farm on leased land and individual photovoltaics came in fourth -- even in sunny Phoenix. The economies of scale that can be achieved through community-scale energy generation cannot be ignored. Nor are they without precedent, as universities often generate energy on site for distribution around campus. Siting on the community-scale can also help overcome site constraints, like solar orientation and shading.

Community-scale energy generation is not without challenges, however. In communities with multiple owners, ownership of the energy generation system can be difficult to establish. Multiple owners complicates financing strategies as well. These can be overcome by establishing a legal entity to retain control and operation of the system, as discussed above. From the user perspective, more users in the system can disincentivize personal energy consumption reduction, as it will be more difficult to understand the personal impact on the system.

Wind Turbines are an Option in Some Locations

Wind turbines should be considered in areas of the country where they are likely to pay for themselves within a reasonable amount of time. They come in two main varieties, horizontal axis and vertical axis. Horizontal axis turbines have two or three long blades. These turbines are able to convert a higher percentage of wind energy to electricity, but require steady winds to do so. Vertical axis turbines take an eggbeater form. These turbines are able to produce energy from wind coming from every angle, although with less energy output. Vertical axis turbines are recommended when pole heights are restricted or an area free from building obstructions is not available.

Commercial wind turbines are typically comprised of steel, aluminum, and fiberglass. The electronic generator and controls include steel, copper, and plastics. These materials are comparable to those found in solar panels and would have similar carbon impacts.

Wind turbines have a smaller footprint than photovoltaic modules and they can often be sited in conjunction with other land uses, including residential developments. However, wind turbines present challenges because of noise and shadows created by the blades, bird deaths, and visual impacts.

V. Go Beyond...

Carbon Neutrality as defined by the 2030 Challenge concerns operational energy consumption. This makes sense given the huge impacts that heating, cooling and electrical consumption within buildings have over time.

At the same time, the more that these cumulative operational impacts are reduced towards net-zero, the greater the importance of other aspects of energy use and carbon emissions in the life of these buildings becomes.

This is the next frontier of architecture for a low-carbon future… the recognition that all aspects of a building's life-cycle have carbon impacts that can be managed. Currently these choices are difficult to evaluate and positive results are not reflected in the economic balance sheet in the way that energy savings are.

This doesn't mean that simple choices can't be articulated and decisions made that will help reduce the impacts of your construction project on the planet. Go ahead and anticipate the future….

21. Minimize the Carbon Embodied in the Building

After energy performance, the construction phase is the second most important phase to consider for a building. The construction phase represents 2-10% of the energy used in the building sector, depending on the structure size. The architect and contractor can have the most impact within this category. Opportunities include building reuse, construction material reuse, off-site construction, design for disassembly, and material and equipment selection metrics that emphasize the importance of embodied carbon.

Reuse a Building

It is often argued that the “greenest” buildings are actually renovations of existing structures. Building reuse helps minimize carbon emissions associated with the building sector by using fewer materials, reducing materials in landfills and minimizing site disturbance. Some building reuse can also lead to reductions in energy needed for demolition, transportation of materials and transportation of employees. Energy use that is avoided from reusing a building is ‘embodied’ energy that is a major consideration when choosing between renovation and new construction. One study found that a renovated building used 28% of the embodied and operating energy that would be used to construct a new building of a similar size over a 40 year operation timeline. This represents significant carbon savings.

Building reuse has some drawbacks, however. Older building tend to have less insulation than “green” buildings do today, so installation of insulation is usually needed. Original windows, if still in place, are typically of higher craftsmanship than today’s windows, but are often single-glazed. Depending on whether the building is being preserved or adapted, it may be necessary to either apply low-e coatings to the old windows, install storm windows over existing windows, or replace the units entirely for double or triple glazed updates. Plumbing in older buildings is typically oversized from today’s standards and less efficient. Replacing old pipes and fixtures may be necessary to achieve an efficient system. All of these renovations can be complicated to design and construct, however, they typically still result in overall reduced environmental impacts.

When reusing a building, it is important to carefully evaluate the condition of the building, its current efficiencies and deficiencies, and understand the needs that future residents will have. Commissioning agents, energy service companies (ESCO), and energy consultants are professionals that can provide valuable insight into what aspects of a building are appropriate for the new use and identify aspects for improvement. This could include systems, fixtures, and lighting improvements. ,

When renovating a building to CND, it is important to thoroughly evaluate what elements of the building that need updating in order to achieve carbon neutrality goals. Some major considerations will be the building envelope, insulation, and systems.

Select Low Carbon and Other Low Impact Materials

Building materials can enhance the energy performance of the building, as discussed above. However, they also can increase the carbon footprint of the project due to their embodied carbon. Embodied carbon is a similar concept to embodied energy, which seeks to quantify the carbon emissions of the material over its life cycle. Embodied carbon is reported in kilograms of carbon dioxide per kilogram of material (kgCO2/kg). Embodied energy analyses derive data from Life Cycle Assessment. The following table shows the embodied energy and embodied carbon estimates for a concrete, steel, and wood. These values have been converted from kgCO2/kg of material to kgCO2/square foot, for more easy comparison.

Embodied Carbon (kgCO2/sf)

Concrete	43.88
Steel	29.78
Wood	25.93

Concrete has high embodied carbon per square foot of material. This is primarily due to the use of Portland cement. Converting limestone to Portland cement is an energy-intensive process. Reducing the percentage of Portland cement used in concrete will help

Click Here!
CND TEACHING TOPICS: ENERGY
see Embodied Energy

Go Beyond...

reduce this impact. Wood has the lowest overall embodied carbon per square foot. If structurally feasible, wood-framing should be used over steel-framing. Of course, areas prone to termites should careful design the wood construction, or select steel over wood as the shortened longevity of wood in that setting would offset the short-term carbon savings.

Tools are available to help work through the trade-offs of using certain materials over others. Build Carbon Neutral (www.buildcarbonneutral.org) is a free tool and the Pharos Project (www.pharosproject.net) and the Athena Institute (www.athenasmi.ca) are subscription-based tools for assessing these impacts.

A material's embodied energy is only one piece of information needed to compare building materials. Other considerations include:

Durability and longevity
Embodied carbon does not consider a material's useful life. A material that has low embodied energy but needs replacing every year may not be a good choice. Compared to a material that has a high-embodied energy but will last 50 years. Moisture management achieved with effective ventilation and a tight building envelope will increase the longevity of materials.

Installation
Embodied carbon does not consider a material's installation requirements. A material that can be quickly installed manually may be preferable to one with similar embodied energy that requires construction equipment to install.

Maintenance
Embodied carbon does not consider maintenance of a material. A material that only requires annual rinsing may be preferable to one that requires weekly polishing.

Functional unit
Because embodied carbon is defined by mass, it is important to compare the mass of a material based on square footage coverage. One square foot of wallpaper coverage has more mass than one square foot of paint coverage.

Waste
Embodied carbon does not consider waste generated during installation. For instance, concrete poured on-site will generate less waste than pre-formed concrete, as the builder will only pour what is necessary.

Carbon sequestration
Embodied carbon does not consider if a material sequesters carbon. A construction material that sequesters carbon, like wood, may be preferable to one that has a high embodied carbon content, like concrete block.

Local sourcing
Hardwood sourced locally is more carbon efficient than bamboo sourced from Asia due to transportation emissions.

By including contextual information, a different material may have a lower carbon impact than the raw data suggests. For example, projects sited in areas prone to termite infestations may be better off selecting steel framing over wood when longevity is considered.

Material selection can have a net positive carbon impact by serving as a carbon sink. Wood obtained in the following ways may be considered net carbon sinks:

- Certified from renewable sources, like Forest Stewardship Council's Forest Management certification
- Harvested on site
- Salvaged locally

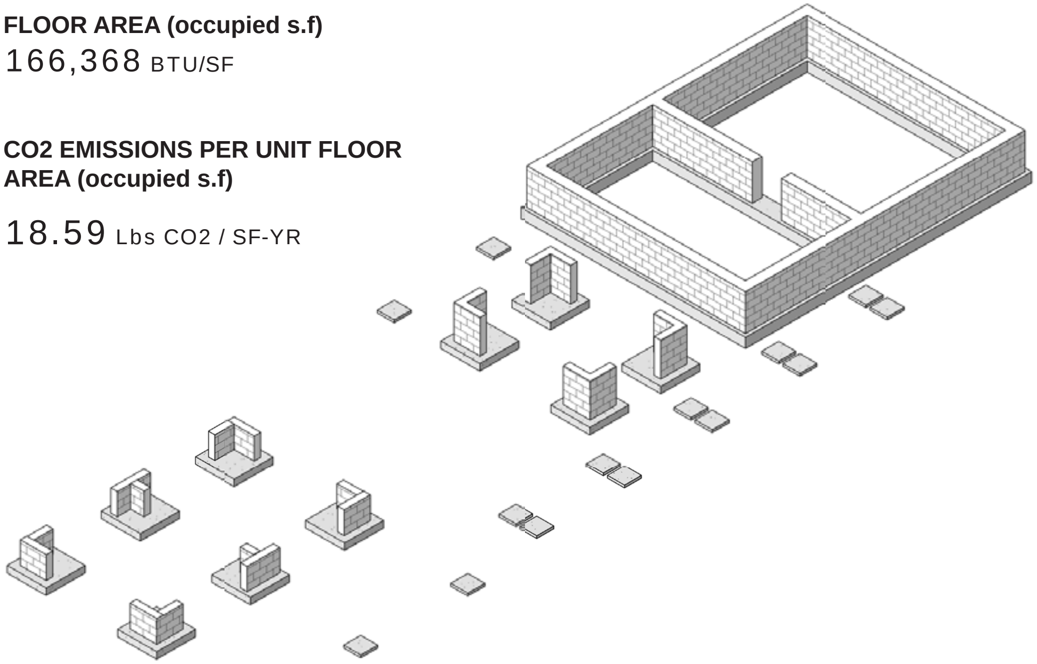
Material selection can influence a building's energy needs. The color of materials exposed to the sun can make a big difference in terms of surface temperatures of that material – and internal temperatures of living space inside the building.

EMBODIED ENERGY PER UNIT

FLOOR AREA (occupied s.f)
166,368 BTU/SF

CO2 EMISSIONS PER UNIT FLOOR AREA (occupied s.f)

18.59 Lbs CO2 / SF-YR

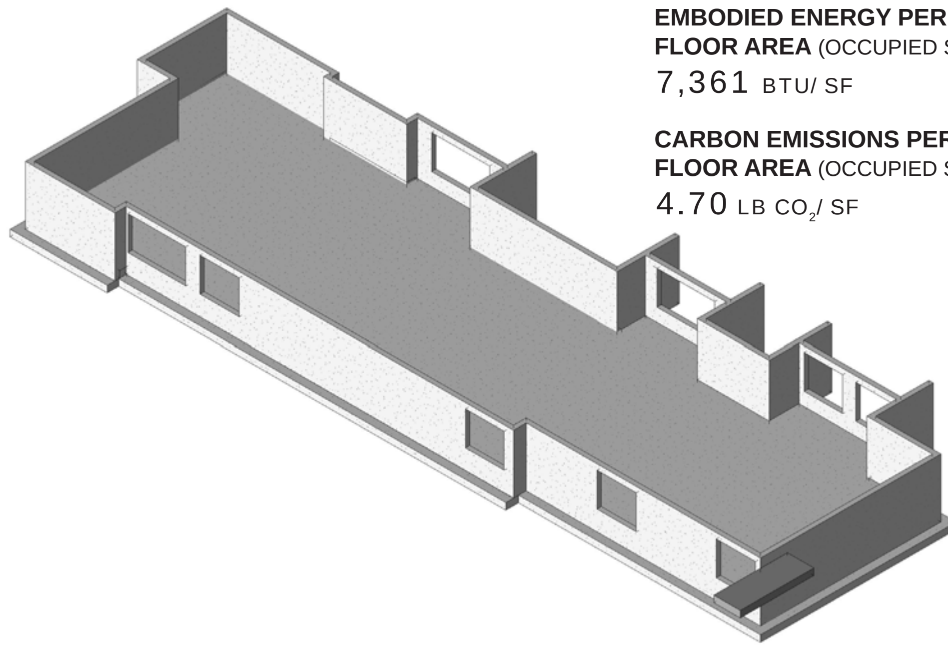


Alternately, the use of high-fly ash content concrete is becoming common as a carbon reduction strategy, as fly-ash displaces the energy intensive ingredient of Portland Cement with an industrial by-product. Interestingly, fly ash can actually improve overall structural performance significantly, though slowing the construction process with longer curing times and more difficult finishing requirements.

Here, as with the other comparative analysis of building massing, ecoMOD3 is shown to have a significantly higher embodied energy content per square foot of unit floor area (18.6 lbs. CO2/s.f.-year) than does Wild Sage (4.7 lbs. CO2/s.f.-year), even though it has a very limited combination of perimeter foundation and footings. The simple difference is that the concrete basement at Wild Sage supports two to three stories of housing above.

EMBODIED ENERGY PER UNIT FLOOR AREA (OCCUPIED S.F.)
7,361 BTU/ SF

CARBON EMISSIONS PER UNIT FLOOR AREA (OCCUPIED S.F.)
4.70 LB CO_2/ SF



The CND Case Study Protocol Embodied Energy Metric

Current embodied energy studies of building materials hold concrete to be the single largest contributor to carbon emissions, due to it's energy intensive manufacturing, typically extensive use in construction, and high mass requiring fuel intensive transport.

For this reason, the CND Case Study Protocol documents the volume of concrete in a building as a proxy for its total embodied energy.

This type of analysis leads to the conclusion that Carbon Neutral buildings should be designed to minimize the use of concrete.

22. Design for Disassembly

Even the most well-designed building projects will not stand forever. Designing a building for the end of its useful life is another intentional design technique that can reduce carbon impacts. A Design for Disassembly (DfD) project will have design features that facilitate renovation and dismantling through a variety of strategies, including:

- Use of mechanical fasteners (screws and nails) instead of chemical bonders (adhesives)
- Keep materials with a high reuse/recovery value pure. For example, using spray-foam insulation on wood framing will make it difficult to recover that wood.
- Separating mechanical, electrical, and plumbing systems to facilitate upgrades and removal
- Draw detailed plans for both "as-built" and disassembly/demolition . Such a plan should contain both floor plans and photographs documenting the location of service infrastructure.
- Create a building material inventory. When it comes time to decide whether to demolish or deconstruct a building, it can be difficult to determine what materials are in the building. By providing an inventory of materials available, the owner can more easily determine the market for the materials present -- making the argument for deconstruction over demolition much stronger.

Companies specializing in deconstruction are becoming more prevalent. The National Demolition Association (www.demolitionassociation.com) has resources for finding local companies. The "Design for Disassembly in the Built Environment: A Guide to Closed Loop in Design and Building," by Brad Guy and Nicholas Ciarimboli is a terrific resource.

The EPA and the Construction Materials Recycling Association , and the Whole Building Design Guide all provide links to recycling resources for common construction materials by state.

As suggested below, modular construction, which will be discussed in terms of reducing the energy embodied by the construction process, also suggests a larger scale of design for disassembly. What arrives at the site as a coherent unit can also be relocated as a coherent unit with appropriate construction detailing.

Module Placement, ecoMOD3

Design for Deconstruction by Layer

Green Roof System:
Planting trays can be dug out and re-used in other green roof systems.

Plywood Sheathing:
Screwed into Thermasteel panels. Easily disassembled.

Thermasteel Roof:
Steel and foam panels assembled with screws. Simple connections leads to easy disassembly.

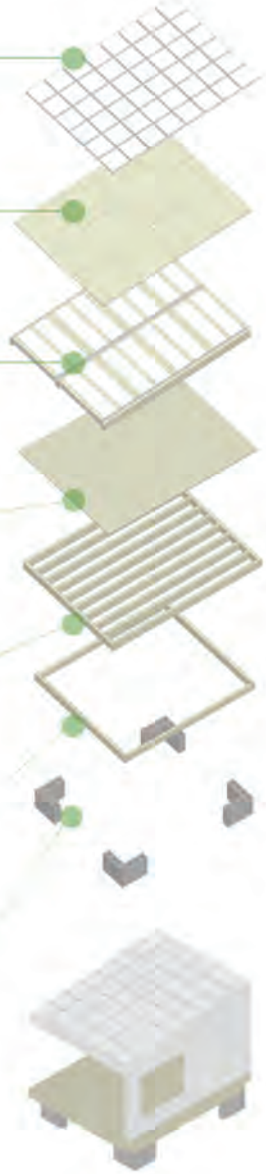
Wood Flooring:
Reclaimed from existing house on site to be renovated. Closes the loop on construction waste.

Floor Framing:
Lumber assembled with screws and can be easily disassembled and reused.

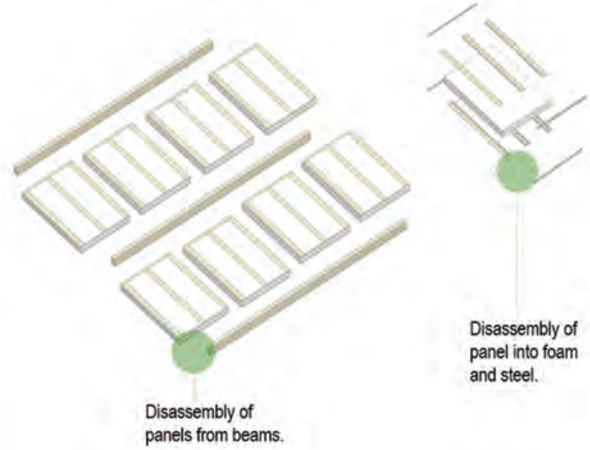
Site Framing:
Lumber assembled with screws and can be easily disassembled and reused..

Concrete Block Piers:
Reclaimed from the foundation of the existing house on site. Closes the loop of construction waste.

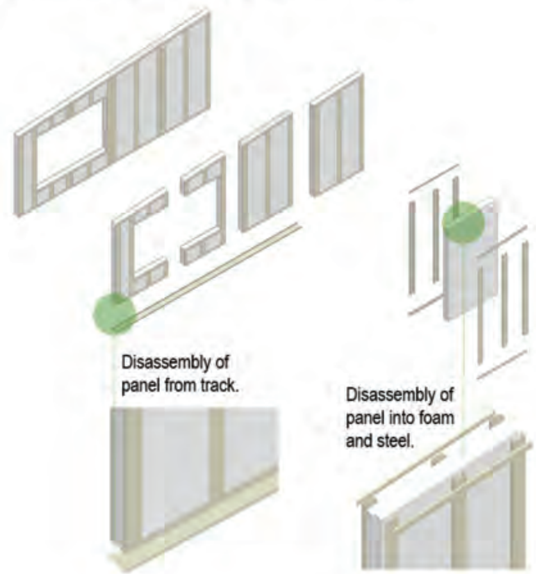
Module layers



Thermasteel Roof Design for Deconstruction:



Thermasteel Wall Design for Deconstruction:



23. Reduce the Carbon Impacts of the Construction Process

Typical Modular Housing Factory

After the energy performance, the construction phase is the second most important phase to consider for a building. The architect and contractor can have most impact within this category. Opportunities include building reuse, construction material reuse, off-site construction, design for disassembly, and material and equipment selection metrics that emphasize the importance of embodied carbon.

The construction phase represents 2-10% of the energy used in the building sector, depending on the structure size. The carbon impact of construction can be reduced in a variety of ways:

- Implement modular construction techniques
- Power electric tools with renewable energy
- Use biodiesel to run heavy equipment

Use Modular Construction

The majority of construction in the US occurs on the project site. Modular construction, in which the majority of the building is fabricated in a manufacturing facility and then transported as large volumes of space to the project site, can substantially reduce carbon equivalents. A recent study compared on-site and modular versions of a typical 2,000 square foot single family home, as well as a multi-unit affordable housing complex. The use of modular construction reduced greenhouse gas emissions by 40% for the wood frame single-family homes. The difference was less striking for the steel frame / concrete floor slab multi-unit structure, but the modular building still had a lower overall impact. Despite the modular housing industry promoting itself as being sustainable due to reduced material waste, the impact of that factor is offset by the impact of the additional materials required needed to frame modular buildings compared that are not needed in on-site buildings. The surprising result was that the primary difference between on-site and modular construction is the shortened construction schedule, and reduced commuting by employees. Designing and constructing modular buildings can bring a project closer to CND.

Recycle Construction Waste

Across the country, greater efforts are being made to divert demolition material from landfills as much as possible. Landfills have finite capacity and siting of new landfills has become increasingly difficult as the “not in my backyard” attitude takes hold. As a result, more communities have to transport solid wastes further – generating more carbon emissions. Organic materials in landfills have further greenhouse gas impacts. It is estimated that one ton of organic material in a landfill generates about 0.25 tons of carbon dioxide equivalents. In the US, 164,000 million tons of building-related waste is generated annually. Of that, 9% is from new construction, 38% is from renovation, and 53% is from demolition. Recycling of construction waste can therefore help extend the life of landfills and reduce carbon emissions.

Establishing a clear and consistent waste management strategy is an essential component of a CND building.

24. Maximize the Carbon Sequestered in the Building

Carbon sequestration within building materials is an emerging topic in Carbon Neutral Design, and one that the CND Case Study Protocol does not attempt to quantify.

Considering construction materials in terms of their carbon footprints suggests compelling reasons why materials such as wood, which rely on solar energy for their primary production and sequester carbon in their make-up, are preferable over materials such as concrete, which are energy intensive in all aspects of their production and consequently have a high embodied carbon content.

While the embodied energy of resource production and distribution points to fossil fuel inputs that are clearly part of the problem that Carbon Neutral Design is intending to address, the case is less clear when considering the inverse flow of carbon being sequestered in a material. Wood entombed in a building intended to last several hundred years truly represents sequestered carbon. Wood entombed in a building material that ends up in a landfill in twenty years has not in any meaningful way been removed from the terrestrial carbon cycle.

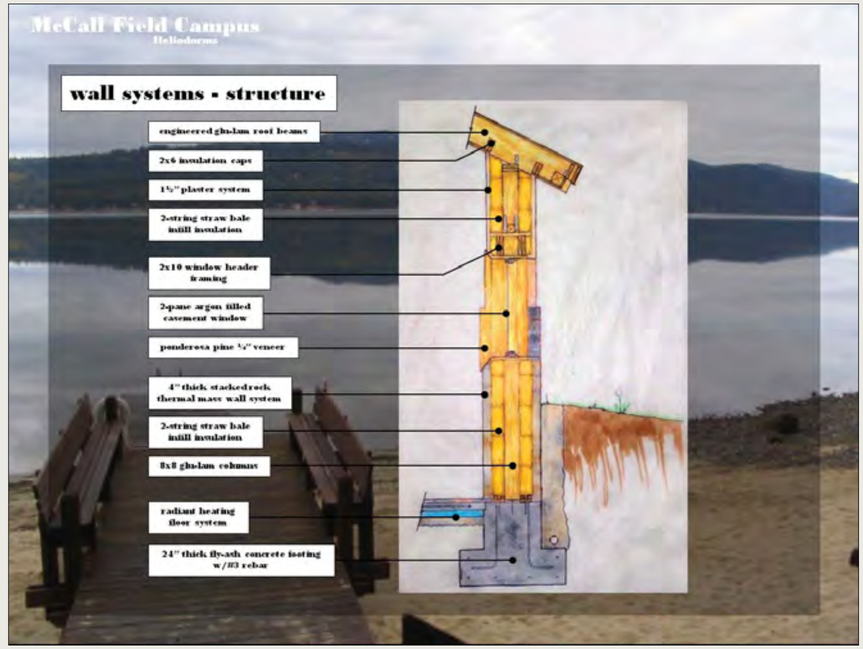
The lesson is to focus on the long term. Bio-based materials are preferential to non organic materials in constructing low-embodied energy structures. Bio-based building material assemblies that are built to last or have their materials reused with little degradation can claim to sequester carbon.

Click Here!
CND TEACHING TOPICS: MATERIALS
see Local Materials

Affordable Housing: Use Local Underutilized Materials

Bruce Haglund
University of Idaho

F2006 McCall Field Campus Studio



Wall Systems - Structure
Mark Weagel

The wall section illustrates the use of locally produced straw bales and lumber as well as flyash and windows produced regionally.

Design/Performance Objective

Use local and underutilized materials to reduce cost and carbon emissions.

Investigative Strategy

Research availability of local underutilized materials. Mark Weagel's wall section shows the use of straw bales from nearby farming operations, glu-lam beams from a regional manufacturer in Boise (ID), windows from a factory in Bend (OR), flyash from Montans coal-fired power plants (ugh!) and ponderosa pine from the local mill. The wall is a super-insulated composition that will minimize energy used for heating, especially since the building features sufficient thermal mass and a wide southern aperture.

Evaluation Process

Opaque software from UCLA was used to model the thermal properties of the wall, while *HEED* was used to model the thermal performance of the building.

Evaluative Criteria

A successful project uses far more local materials than exotic ones and exploits at least one under-used material. The materials are combined to create a high-performance wall as demonstrated by the *HEED* and *Opaque* analyses.

Cautions- Possible Confusions

Research is necessary to determine the availabilty and suitability of local and regional products, recycled components, and under-used materials.

Duration of Exercise

This work was presented at the culmination of an eight-week comprehensive design phase.

Degree of Difficulty

This is work assigned to a graduate student in his penultimate studio taken after all of the basic technical courses on structures and environmental systems.

Refrences

HEED and *Opaque* web <http://www2.aud.ucla.edu/energy-design-tools/>

VI. BUILD IN FEEDBACK LOOPS

Carbon Neutrality does not exist as an achievement in the abstract- it is not guaranteed by design unless the supply of energy is truly limited to that which is produced by renewable sources on site.

Rather, achieving efficiencies in the range of carbon neutrality is a lived discipline. It requires educated and committed operation of the building by both maintenance staff and residents.

Another way of saying this is that it requires learning.

25. Evaluate What You've Accomplished and Share Results

A critical part of any project is the feedback and evaluation that occurs once the project is complete, although these steps are often overlooked.

In order to understand how design concepts translate into the built environment and how occupants interact with the space, it is important to analyze the finished project. This process would take into consideration things like the energy performance of systems, occupant energy use, and human comfort/ livability of the space.

Data should be analyzed not just on day or year one performance, but continuously in order to see how the systems perform over time. This is particularly important in an apartment setting, as tenant turnover will be higher than a single-family home and it will be necessary to evaluate how successful the knowledge transfer is maintained over time. By evaluating this data, the design process can adapt for continual improvement towards carbon neutrality.

In the evaluation process, it is important to measure both objective metrics, like actual energy use, and subjective metrics, like thermal and acoustic comfort. The process not only will help management and the project team to make tweaks to the building to improve performance, but the data gained will also inform future projects.

CBE Occupant Indoor Environmental Quality Survey

The Center for the Built Environment (CBE) has a web-based survey for building performance that includes these types of questions, which can be tailored by building use. Partners of CBE can administer the survey for free and non-partners pay a fee.

Whatever the make-up of the project team and the contract model chosen, it is important for everyone to participate in a post-project evaluation. Collaborative projects typically result in innovative solutions to the design problem, but also require stakeholders to work outside of their comfort zone and with a great degree of flexibility. Reflecting on this process will help everyone understand how to effectively communicate and work together in a positive way. The post-project evaluation can also identify areas for improvement that can be integrated into the team's next project. The evaluation should identify project and process strengths, weaknesses, successes, and challenges in order to result in a comprehensive understanding of the process. Carbon Neutral Design is a complex process, and sharing your results with others will help all concerned.

The Carbon Neutral Design Case Study Protocol

(link to PDF featured in next section)

Finally, this guidebook is meant as an invitation to join us in building a knowledge base around the physical design parameters of Affordable Housing projects seeking to meet the 2030 Challenge and ideally to operate at a carbon neutral standard. To date, the CND Case Study Project has documented the three affordable housing projects that illustrate this guide, and in the process we have developed the protocol itself. Its goal as a research project is to identify design based metrics that can be used by the design team to establish goals and judge the design in process... for this to happen we now need to build the data base with richly varied cases.

The following section of this guide provides an introduction to the CND Case Study Protocol for Affordable Housing as it currently exists.

For access to this research and to start a conversation about how the CND Project, the Society of Building Science Educators and your affordable housing team might collaborate to develop your own portfolio of CND case studies, please contact the tool's author:

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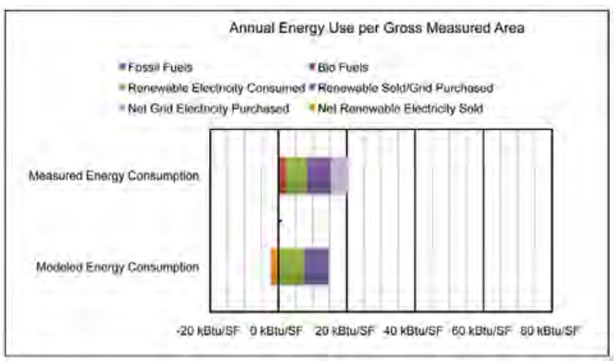
THE CND CASE STUDY PROTOCOL

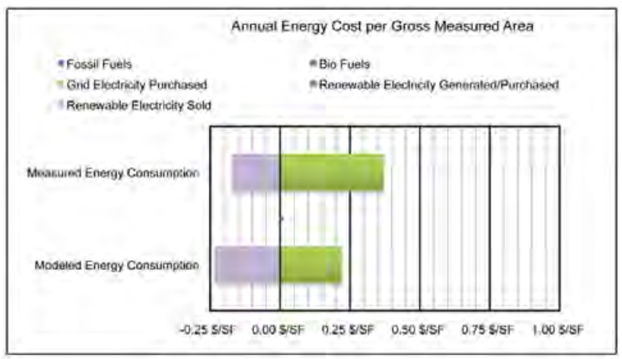
Carbon Neutral Design

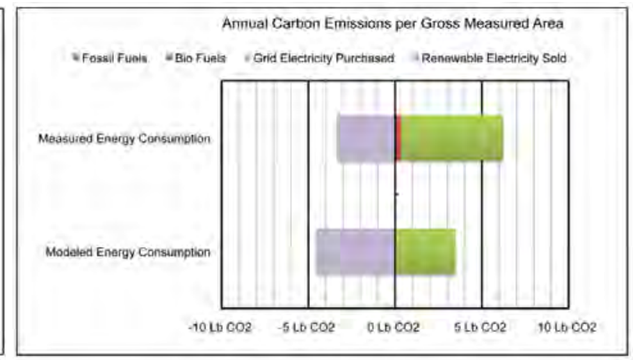
Building Case Study Spreadsheet PDF

Michael Utzinger

December 1, 2010







Purpose of the Carbon Neutral Design Building Case Study Spreadsheet

The AIA 2030 Challenge requires new buildings to consume 50% less energy than a similar building designed to codes in 2010 and be carbon neutral (no net carbon emissions) by 2030. To achieve these goals, architects and their consultants need to be able to measure the performance of the buildings they design. The Carbon Neutral Design (CND) Building Case Study Spreadsheet is designed to allow architects and consulting engineers to input building design information and energy and water consumption measurements. The spreadsheet calculates resource consumption and emission metrics and normalized building design and system variables. The spreadsheet is divided into two Levels.

Level 1 takes building project information (areas, cost, and occupancy data) and resource consumption data (fossil fuels, biofuels, grid electricity, renewable electricity and water) and produces a set of building resource consumption and carbon emissions metrics. The graphs illustrated on the title page are taken from the Level 1 Design Goals tab. There are a number of emissions calculators and spreadsheets currently available that produce resource consumption and emissions metrics. This spreadsheet has attempted to be broadly applicable by allowing the user to choose the appropriate building area for normalization, include or exclude parking garage area, normalize resource consumption and emissions to the occupant and output metrics in both imperial and standard international units.

The significant difference between this building case study spreadsheet and other emissions calculators is the inclusion of building and system design variables in Level 2. The building enclosure, lighting system, HVAC system, elevator/escalator system plug load demands and process load demands are inputs in Level 2. The CND Building Case Study Spreadsheet normalizes building shell and system variables to the building area definition chosen in Level 1. Most architects and engineers can suggest an appropriate normalized lighting power density (W/SF or W/m^2). Very few could suggest an appropriate normalized fan power density. Performance of buildings cannot be understood without measurement. By measuring resource consumption and carbon dioxide emissions and comparing them with normalized building and system design variables, architects and engineers should be able to understand their designs and produce better buildings in the future. Hopefully, the 2030 challenge can be met.

This document describes the inputs and outputs of the CND Building Case Study Spreadsheet.

Acknowledgements

Work on the building case study spreadsheet began in 2008 as part of the Carbon Neutral Design Curriculum Materials Project sponsored by the Society of Building Science Educators and the American Institute of Architects. After initial presentations to educators and professionals at a Carbon Neutral Design Conference in Milwaukee, Wisconsin in October, 2008 and a Carbon Neutral Design Workshop in Portland, Oregon in February 2010, additional funding support was provided to revise and complete the spreadsheet by the University of Wisconsin-Milwaukee, the University of Oregon, and BetterBricks.

A number of people provided helpful feedback which hopefully improved the usability of the final spreadsheet. James Wasley, Greg Thomson, Leyla Sanati, Steve Wollner and Mark Mommerts at the University of Wisconsin-Milwaukee; Alison Kwok, Karen Buse, Audrey Snyder and Cierra Mantz at the University of Oregon; Terri Boake at the University of Waterloo and John Quale at the University of Virginia all provided helpful feedback during the development. Architects and engineers participating in BetterBricks sponsored workshops in Portland, Oregon in February and September, 2010 and in Seattle, Washington in October, 2010 provided very helpful criticism of the spreadsheet tool. I thank all of you for your input into the final for of the spreadsheet.

Michael Utzinger
University of Wisconsin-Milwaukee
December 2010

The Carbon Neutral Design Building Case Study Spreadsheet

A completed case study of the Aldo Leopold Legacy Center will be used to introduce and explain inputs for and outputs of the Carbon Neutral Design Case Study Spreadsheet. The Aldo Leopold Legacy Center, designed by the Kubala Washatko Architects, is located outside Baraboo, Wisconsin near a pine forest planted in the 1930s by Aldo Leopold and his family. A campus of three small buildings, the Legacy Center was designed to be carbon neutral and net zero in its operation. As you will see later in this manual, the projected design performance can be compared to the actual resource use of your buildings. The three graphs on the cover of this manual are a comparison of the design and actual energy use, energy cost and carbon emissions of the Legacy Center.

The Legacy Center includes three buildings. The largest is conditioned and contains offices, exhibit space and a conference room. One of the smaller buildings is a seasonally occupied classroom. The other is a workshop and garage. The completed spreadsheet for the Aldo Leopold Legacy Center is used to introduce the spreadsheet tool on the following pages.

The photos at left, graciously provided by Mark Heffron, provide a view of the Legacy Center looking west with the 39.4 kW PV array and 100 SF solar thermal collectors located on the main office building roof and a view looking out to the northwest from inside the seasonal classroom. The following page illustrates the CND Case Study Spreadsheet Project tab with values entered for the Aldo Leopold Legacy Center.

Level 1 Case Study - Project Information

Aldo Leopold Legacy Center		**Design & Construction Cost**	
the Kubala Washatko Architects	*2007*	Design Costs	$ 375,685
Baraboo	*Wisconsin*	Construction Costs	$ 4,042,140
Building Type	*Office Building*	LEED Costs	$ 112,500
No Housing	*0 Units*	Furnishing & Relocation	$ 134,500
Ownership Type	*Non-profit*	Total Costs	$ 4,664,825

Building Floor Areas		**Distinct Building Areas**		
		Main Area	**SubArea 1**	**SubArea 2**
Area Name	Total Building	*Office*	*Classroom*	*Workshop/Garage*
			Unconnected, Unconditioned	*Unconnected, Unconditioned*
Gross Floor Area	13,452 SF	*10,398 SF*	*1,351 SF*	*1,703 SF*
Gross Measured Area	12,322 SF	*9,562 SF*	*1,209 SF*	*1,551 SF*
Major Vertical Penetrations	105 SF	*105 SF*	*0 SF*	*0 SF*
Building Common Area	2,269 SF	*2,269 SF*	*0 SF*	*0 SF*
Floor Common Area	1,293 SF	*1,293 SF*	*0 SF*	*0 SF*
Usable (Assignable) Area	8,655 SF	5,895 SF	1,209 SF	1,551 SF
Total Occupied Area	12,217 SF	9,457 SF	1,209 SF	1,551 SF
Mechanically Heated Area	9,316 SF	*9,316 SF*	*0 SF*	*0 SF*
Mechanically Cooled Area	9,316 SF	*9,316 SF*	*0 SF*	*0 SF*
Mechanically Ventilated Area	9,316 SF	*9,316 SF*	*0 SF*	*0 SF*
Parking Garage	0 SF	0 SF	0 SF	0 SF
Daylit Area	10,760 SF	*8,000 SF*	*1,209 SF*	*1,551 SF*
Metric Analysis Area	12,322 SF	9,562 SF	1,209 SF	1,551 SF
These Cells Calculated for Housing Only				

OCCUPANCY			
Staff	**Number of People**	**Time in Building**	**F.T.E**
Full Time Staff	*12*	*60%*	7.2 FTE
Part Time Staff	*3*	*10%*	0.3 FTE
Total Staff			7.5 FTE
Others	**Visits per Week**	**hours/visit**	**F.T.E**
Visitors	*140*	*2*	7.0 FTE
Student or Client	*0*	*0*	0.0 FTE
Total Others			7.0 FTE
Total Occupants			14.5 FTE

Building Area Used in Metrics Calculations	**Gross Measured Area**
Is Parking Garage included in Calculations?	**No**

CND Case Study   Project Data   12/2/10 Page 1

Figure 1: CND Level 1 Project tab for Aldo Leopold Legacy Center

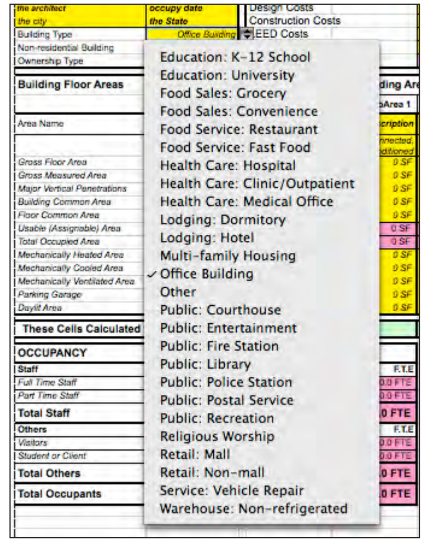


Figure 2: Building type drop-down menu

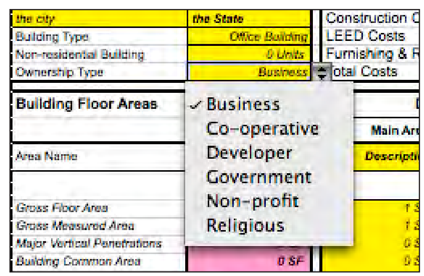


Figure 3: Ownership drop-down menu

the building	
the architect	*occupy date*
the city	*the State*
Building Type	*Multi-family Housing*
Number of Housing Units	*100 Units*
Ownership Type	*Business*

Figure 4: Building type Multi-family Housing

LEVEL 1 Case Study

A Level 1 Building Case Study provides energy and water consumption as well as carbon dioxide emissions per unit building area and per occupant (if the building type is residential, consumption per residential unit or room is also computed). Information for the building project is input on the *Level 1 - Project* tab. Resource consumption for the building project is input on the *Level 1 - Resources* tab. Modeled (estimated) energy consumption is input on the *Level 1 - Design Goal* tab. Graphic comparison of estimated and actual energy use, energy cost and emissions data are found on the *Level 1 - Design Goal* tab. The *Level 1 - Metrics* tab provides energy consumption, carbon dioxide emissions, and water consumption use per unit area of the building, per full time equivalent occupant of the building and, if the building type is residential, per housing unit or per room. The user can chose whether to use gross building area, gross measured area or occupied area as the area for the energy us metrics calculations. If the building includes a parking garage, the user can also chose whether to include or exclude the parking garage area in the metric calculations.

For all tabs in the workbook, the yellow cells are the only cells for inputs. All other cells are protected. The worksheet/workbook protection does not include a password and can be unprotected (allowing modification of any of the equations and cell values) at any time by the user. The protection was placed to require the user to clearly decide to open up the case study spreadsheets for modification. Inputs and a description of each excel tab for a Level 1 Case Study follow.

Level 1 - Project

Project information includes general building data, construction cost, area and sub area data, and occupancy data. Figure 1 illustrates the completed Level 1 - Project tab for the Aldo Leopold Legacy Center. Discussion of each Project data input is provided below.

General Building Data

In the appropriate cells enter the building name, architect, year of occupancy, and location (city and state). The building type is chosen from a drop-down list (see Figure 2). Input the number of units only if building type is *Multi-family Housing, Lodging: Dormitory* or *Lodging: Hotel.*

Ownership Type is also chosen from a drop-down list (see Figure 3).

If the building type is residential, some of the cell values change to permit input of the number of housing units if the type is *Multi-family Housing* (Figure 4). If the building type is *Lodging: Dormitory* or *Lodging: Hotel,* the number of dorm or hotel rooms are entered. For these three residential building types, other cells in the workbook will change to permit building metrics per unit of housing or lodging room as will be described in the following pages.

Building Cost Data

Building Cost Data input is illustrated in Figure 1 for the Aldo Leopold Legacy Center. Only the total costs are used in the metrics calculations. The total costs will be the sum of all costs entered under each area. If different cost categories are desired, for example, site purchase costs, the user can unprotect the spread sheet and edit one of the cost categories.

Building Floor Areas		Distinct Building Areas		
		Main Area	SubArea 1	SubArea 2
Area Name	Total Building	*Office*	*Classroom*	*Workshop/Garage*
			Unconnected, Unconditioned	*Unconnected, Unconditioned*
Gross Floor Area	13,452 SF	*10,398 SF*	*1,351 SF*	*1,703 SF*
Gross Measured Area	12,322 SF	*9,562 SF*	*1,209 SF*	*1,551 SF*
Major Vertical Penetrations	105 SF	*105 SF*	*0 SF*	*0 SF*
Building Common Area	2,269 SF	*2,269 SF*	*0 SF*	*0 SF*
Floor Common Area	1,293 SF	*1,293 SF*	*0 SF*	*0 SF*
Usable (Assignable) Area	8,655 SF	5,895 SF	1,209 SF	1,551 SF
Total Occupied Area	12,217 SF	9,457 SF	1,209 SF	1,551 SF
Mechanically Heated Area	9,316 SF	*9,316 SF*	*0 SF*	*0 SF*
Mechanically Cooled Area	9,316 SF	*9,316 SF*	*0 SF*	*0 SF*
Mechanically Ventilated Area	9,316 SF	*9,316 SF*	*0 SF*	*0 SF*
Parking Garage	0 SF	0 SF	0 SF	0 SF
Daylit Area	10,760 SF	*8,000 SF*	*1,209 SF*	*1,551 SF*
Metric Analysis Area	12,322 SF	9,562 SF	1,209 SF	1,551 SF
These Cells Calculated for Housing Only				

Figure 5: CND Level 1 Project tab Building Area Section

Main Area	SubArea 1	SubArea 2
Office	Classroom	Workshop/Garage
	Unconnected, Unconditioned	Unconnected, Unconditioned
10,398 SF		
9,562 SF		
105 SF		
2,269 SF		
1,293 SF		
5,895 SF		
9,457 SF	1,209 SF	1,551 SF

Connected, Conditioned
Connected, Unconditioned
Not Used
Unconnected, Conditioned
✓ Unconnected, Unconditioned

Figure 6: CND Level 1 Project tab SubArea drop-down menu.

Building Floor Areas

Many projects include differing functions with differing HVAC systems. The CND Case Study spreadsheet allows subdivision of the building into three distinct areas: a Main Area and two SubAreas. If the building case study is not broken down into sub areas, all area values are input in the Main Area column. Figure 5 illustrates the building area inputs for the Aldo Leopold Legacy Center. The building includes a main building, which is thermally conditioned, a seasonally occupied classroom building and a workshop and garage. The thermal conditions and relationship of the sub area to the main building area are set using a drop-down menu illustrated in Figure 6. The sub area can be connected to the main area or not and can be conditioned or not. If sub areas are not used, select not used. The Classroom and Workshop/Garage of the Aldo Leopold Legacy Center are both unconnected and unconditioned.

There are a number of differing area definitions for buildings. The CND Case Study spreadsheet uses the BOMA (Building Owners and Managers Association) definitions of building areas. Building Resource Metrics and Building Unit Design Variables are computed as functions of specific building floor areas. The most common floor area measure used in metrics is the Gross Floor Area. The Total Occupied Area is also useful in computing resource metrics. This building performance analysis method uses the BOMA (Building Owners and Managers Association) area definitions along with additional floor area definitions. Each area is defined as follows:

- Gross Floor Area (GSF): The total constructed area of the building measured to the outside surface of the walls. This definition is from BOMA.
- Gross Measured Area (GMA): The total area of the building enclosed by the inside wall surface. This definition is from BOMA. NREL (National Renewable Energy Laboratory) calls this area the Gross Interior Floor Area and suggests that this is the appropriate building area for energy metrics calculations. (*Standard Definitions of Building Geometry for Energy Evaluation*, NREL/TP-550-38600, October 2005.)
- Major Vertical Penetrations (MVP): The stairs, elevator shafts, flues, pipe shafts, vertical ducts and the like, and their enclosing walls, which serve more than one floor of a building. Space considered either unsafe or not functional is classified as unusable and is included in the MVP calculations. This definition is from BOMA.
- Building Common Area (BCA): The area of the building that provides services to all building tenants. This area includes main and auxiliary lobbies, fire control rooms, mechanical rooms, etc. This definition is from BOMA.
- Floor Common Area (FCA): The areas on a floor, such as washrooms, janitorial closets, electrical rooms, elevator lobbies, public and shared corridors which are available primarily for the use of tenants on that floor. This definition is from BOMA.
- Usable Area (UA): The actual area of a floor that a building tenant is assigned. (Note: Space considered unsafe or not functional is classified as unusable and is included in the MVP calculations.) When a building has a single tenant, the sum of the Usable Area, Floor Common Area, Building Common Area and Major Vertial Penetrations should equal the Gross Measured Area.

$$UA_{all\ tenants} + FCA_{all\ floors} + BCA + MVP = GMA$$

This definition is from BOMA.

- Total Occupied Area (TOA): The sum of the Building Common Area, all Floor Common Areas and all Usable Areas. This definition is unique to the building case study method presented in this document, although based on BOMA area definitions. Using BOMA definitions, the TOA is defined as follows:

$$TOA = GMA - MVP$$

- Mechanically Heated Area (MHA): That portion of the Building Common Area, all Floor Common Areas all Usable Areas and Measured Vertical Penetrations served by a mechanical heating system. This definition is unique to the building case study method presented in this document.
- Mechanically Cooled Area (MCA): That portion of the Building Common Area, all Floor Common Areas all Usable Areas and Measured Vertical Penetrations served by an air-conditioning system. This definition is unique to the building case study method presented in this document.
- Mechanically Ventilated Area (MVA): That portion of the Building Common Area, all Floor Common Areas all Usable Areas and Measured Vertical Penetrations served by a mechanical ventilation system. This definition is unique to the building case study method presented in this document.
- Daylit Area (DA): That portion of the Building Common Area, all Floor Common Areas and all Usable Areas which is substantially illuminated by daylighting. The method of computing daylit areas is from LEED NB 3.0. This definition is unique to the building case study method presented in this document.

There are two unique building area types: Residential and Parking Garage. If the Building Type is either *Multi-family Housing, Lodging: Dormitory* or *Lodging: Hotel,* then energy matrics per residential unit or room can be computed. This is done by inserting the number of units or rooms in cell B5 and naming the *Main Area, SubArea 1* or *SubArea2* "Residential". The average assignable area per residential unit or room will be automatically calculated. In urban areas, parking garages are often included in building projects. Parking garages are often not conditioned and may or may not be mechanically ventilated. If a parking garage is a part of the building project, it should be input as a sub area of the building. NREL recommends that parking garages not be included in building energy evaluations. For the CND Case Study spreadsheet, inclusion or exclusion of parking garages in energy evaluations is a choice as described later. Figure 7 below provides an example of area inputs and calculations for a multifamily residential building with a parking garage, the parking garage area is chosen to be not included.

Note that the only Area Names for the Distinct Building Areas resulting in additional calculations are "Residential" and Parking Garage".

Building Floor Areas		Distinct Building Areas		
		Main Area	SubArea 1	SubArea 2
Area Name	Total Building	*Residential*	*Commercial*	*Parking Garage*
			Unconnected, Conditioned	*Unconnected, Unconditioned*
Gross Floor Area	55,290 SF	*35,088 SF*	*4,317 SF*	*15,885 SF*
Gross Measured Area	52,961 SF	*33,543 SF*	*4,078 SF*	*15,340 SF*
Major Vertical Penetrations	2,834 SF	*1,975 SF*	*301 SF*	*558 SF*
Building Common Area	2,525 SF	*1,589 SF*	*198 SF*	*738 SF*
Floor Common Area	2,914 SF	*2,914 SF*	*0 SF*	*0 SF*
Usable (Assignable) Area	44,688 SF	27,065 SF	3,579 SF	14,044 SF
Total Occupied Area	50,127 SF	31,568 SF	3,777 SF	14,782 SF
Mechanically Heated Area	30,644 SF	*27,065 SF*	*3,579 SF*	*0 SF*
Mechanically Cooled Area	0 SF	*0 SF*	*0 SF*	*0 SF*
Mechanically Ventilated Area	45,426 SF	*27,065 SF*	*3,579 SF*	*14,782 SF*
Parking Garage	14,044 SF	0 SF	0 SF	14,044 SF
Daylit Area	15,660 SF	*12,740 SF*	*2,920 SF*	*0 SF*
Metric Analysis Area	38,917 SF	33,543 SF	4,078 SF	1,296 SF
Area per Housing Unit		541 SF		

Figure 7: CND Level 1 Project tab Sampe area inputs and calculations for a multifamily residential building with parking garage.

Occupancy

The CND Case Study spreadsheet estimates resource metrics per building occupant. One full time occupant (FTE) occupies the building 40 hours per week, 50 weeks per year. The occupants for the Aldo Leopold Legacy Center are illustrated in Figure 8. Full Time and Part Time Staff are estimated by the number of staff and their average percentage of weekly time in the building. Visitors, Students and/or Clients are estimated as the product of the number per week and the hours per visit. If the building type is either *Multi-family Housing*, *Lodging: Dormitory* or *Lodging: Hotel*, then the Visitors, Students or Clients are replaced with the number of Residents. One Resident equals one FTE. A sample Occupancy input for a multifamily housing project is illustrated in Figure 9.

OCCUPANCY			
Staff	**Number of People**	**Time in Building**	**F.T.E**
Full Time Staff	12	60%	7.2 FTE
Part Time Staff	3	10%	0.3 FTE
Total Staff			**7.5 FTE**
Others	**Visits per Week**	**hours/visit**	**F.T.E**
Visitors	140	2	7.0 FTE
Student or Client	0	0	0.0 FTE
Total Others			**7.0 FTE**
Total Occupants			**14.5 FTE**

Figure 8: CND Level 1 Project tab Occupancy data for Aldo Leopold Legacy Center.

OCCUPANCY			
Staff	**Number of People**	**Time in Building**	**F.T.E**
Full Time Staff	1	100%	1.0 FTE
Part Time Staff	2	25%	0.5 FTE
Total Staff			**1.5 FTE**
Residents	**Number**		**F.T.E**
Residents	120	24	120.0 FTE
	0	0	0.0 FTE
			120.0 FTE
Total Occupants	**Residents**	**120 People**	**121.5 FTE**

Figure 9: CND Level 1 Project tab Occupancy data for Multifamily Housing Project.

Areas Used in Metrics Calculations

Different building areas have been proposed for resource use metrics calculations. The CND Building Case Study spreadsheet allows the choice for four possible building areas for metrics calculations: the *Gross Floor Area*, *Gross Measured Area*, *Total Occupied Area*, and *Usable (Net Assignable) Area*. A drop-down menu allows the user to choose the building area to be used in all metrics calculations (Figure 10). NREL recommends the Gross Measured Area (defined as Gross Interior Floor Area in their publications) as the appropriate building area for resource metrics calculations. If the building includes a parking garage, it can be included or excluded from the metrics calculations by choosing yes (to include) or no (to exclude) from metrics calculations. NREL recommends excluding parking garage areas from the building area used in energy evaluations (*Standard Definitions of Building Geometry for Energy Evaluation*, NREL/TP-550-38600, October 2005).

Building Area Used in Metrics Calculations	**Gross Measured Area**	**12,322 SF**
Is Parking Garage included in Calculations?	**No**	

Figure 10: CND Level 1 Project tab Area Selection for Building Resource Metrics Calculations.

Level 1 Case Study - Measured Resource Consumption

Aldo Leopold Legacy Center	**Solar PV Capacity**	*39.40 kW DC peak*
the Kubala Washatko Architects	**Solar Thermal Area**	*100 SF*
Baraboo **Wisconsin**	**Wind System Capacity**	*0.00 kW DC peak*

Scope 1 Energy & Emissions: Site Combustion

Fossil Fuels	**Natural Gas**			
Comments	Date	Days	Fuel Purchased	Cost of Fuel
Natural Gas Consumption	*1-Jan-09*			
	1-Feb-09	31	*0 Therm*	$ -
	1-Mar-09	28	*0 Therm*	$ -
	1-Apr-09	31	*0 Therm*	$ -
	1-May-09	30	*0 Therm*	$ -
	1-Jun-09	31	*0 Therm*	$ -
	1-Jul-09	30	*0 Therm*	$ -
	1-Aug-09	31	*0 Therm*	$ -
	1-Sep-09	31	*0 Therm*	$ -
	1-Oct-09	30	*0 Therm*	$ -
	1-Nov-09	31	*0 Therm*	$ -
	1-Dec-09	30	*0 Therm*	$ -
	1-Jan-10	31	*0 Therm*	$ -
Annual Total		**365**	**0 Therm**	**$ -**
Natural Gas in kBtu & CO2 Emissions			**0 kBtu**	**0.00 Ton CO2**
Fossil Fuels	**LPG (Propane)**			
Comments	Date	Days	Fuel Purchased	Cost of Fuel
Propane Consumption	*1-Jan-09*			
	1-Feb-09	31	*0 gal*	$ -
	1-Mar-09	28	*0 gal*	$ -
	1-Apr-09	31	*0 gal*	$ -
	1-May-09	30	*0 gal*	$ -
	1-Jun-09	31	*0 gal*	$ -
	1-Jul-09	30	*0 gal*	$ -
	1-Aug-09	31	*0 gal*	$ -
	1-Sep-09	31	*0 gal*	$ -
	1-Oct-09	30	*0 gal*	$ -
	1-Nov-09	31	*0 gal*	$ -
	1-Dec-09	30	*0 gal*	$ -
	1-Jan-10	31	*0 gal*	$ -
Annual Total		**365**	**0 gal**	**$ -**
Propane in kBtu & CO2 Emissions			**0 kBtu**	**0.00 Ton CO2**

CND Case Study Resource Data 12/2/10 Page 1

Figure 11: CND Level 1 Resources tab Page 1 ~ Natural Gas & LPG.

Level 1 Case Study - Measured Resource Consumption

Fossil Fuels	**Heating Oil**			
Comments	Date	Days	Fuel Purchased	Cost of Fuel
Heating Oil Consumption	*1-Jan-09*			
	1-Feb-09	31	*0 gal*	$ -
	1-Mar-09	28	*0 gal*	$ -
	1-Apr-09	31	*0 gal*	$ -
	1-May-09	30	*0 gal*	$ -
	1-Jun-09	31	*0 gal*	$ -
	1-Jul-09	30	*0 gal*	$ -
	1-Aug-09	31	*0 gal*	$ -
	1-Sep-09	31	*0 gal*	$ -
	1-Oct-09	30	*0 gal*	$ -
	1-Nov-09	31	*0 gal*	$ -
	1-Dec-09	30	*0 gal*	$ -
	1-Jan-10	31	*0 gal*	$ -
Annual Total		**365**	**0 gal**	**$ -**
Heating Oil in kBtu & CO2 Emissions			**0 kBtu**	**0.00 Ton CO2**
Fossil Fuel Summary	**Energy**		**CO2**	**Cost of Fuel**
	0 kBtu		**0.00 Ton CO2**	$ -
Biofuels	**Wood**		Wood Species	***Oak - White***
Comments	Fuel	Quantity	Energy Equivelent	Cost of Biofuel
		0.85 Cords	24,735 kBtu	$ -
			0 kBtu	$ -
			0 kBtu	$ -
			0 kBtu	$ -
Annual Total			**24,735 kBtu**	**$ -**
			Biofuels CO2 Emissions	**2.15 Ton CO2**

CND Case Study Resource Data 12/2/10 Page 2

Figure 12: CND Level 1 Resources tab Page 2 ~ Heating Oil & Biofuels.

Level 1 - Resources

Actual building resource consumption (energy and water) is entered on the *Level 1 - Resources* tab. In addition, renewable energy resource systems are identified at the top of the tab (see Figure 11). Site solar photovoltaic systems are identified by their peak DC capacity in kW. Site solar thermal systems are identified by their collector area. Site wind electric systems are identified by their peak DC capacity in kW.

Scope 1 Energy Resources ~ Fossil Fuel & Biofuel Combustion

The World Resources Institute structure for carbon dioxide emissions accounting is used to organize energy consumption into Scope 1: On Site Combustion and Scope 2: Electricity Consumption and Generation. For Scope 1, on site combustion use is divided into fossil fuel use (natural gas, propane and fuel oil) and biofuel use. Fossil fuel use can be input from utility or fuel bills. Input dates for the beginning and end of each billing cycle, the energy consumed in that billing cycle, and the cost of supplying the energy during the billing cycle. The spreadsheet automatically computes the number of days in the billing cycle. For each fuel type, the annual energy consumption is prorated to 365 days (actual annual billing cycle may be slightly more or less than 365 days). The prorating calculation provides estimates of annual fuel consumption when partial year consumption is available. Click on Cell D21 to examine the prorating equation for natural gas consumption. Biofuels are limited at this time to wood energy measured in cords. The species of wood combusted is chosen from a drop-down menu located in cell E60 (see Figure 12, the cell containing *Oak - White*).

Carbon Dioxide emissions due to energy consumption are automatically estimated using conversion constants given in *Source Energy and Emission Factors for Energy Use in Buildings* (M. Deru & P. Torcellini, NREL/TP-550-3867). Separate calculations of fossil fuel and biofuel carbon dioxide emissions are calculated (see Figure 12).

Scope 2 Energy Resources ~ Electricity

Electricity purchased from the power grid and electricity produced from wind or solar energy on site are entered as Scope 2 Energy and Emissions quantities. Billing cycle start and end dates, energy quantities and energy costs are entered in the same manner as fossil fuel consumption (see Figure 13). Note that the electricity produced from solar PV panels is entered as a single annual value (see Figure 13). While actual measurements of energy consumption and production are desired, there were problems with the site measurements and an estimate based on the energy simulation, 48,000 kWh, was used. The solar generated electricity sold to the electric utility was metered by the utility and it is entered in the area for solar electricity sold to the grid (see Figure 14). Wind electricity generated on site and wind electricity sold to the grid are treated similar to solar electric (Figures 14 and 15). The Aldo Leopold Legacy Center did not include wind electric systems.

Carbon Dioxide emissions due to electric generation are estimated using conversion constants given in *Source Energy and Emission Factors for Energy Use in Buildings* (M. Deru & P. Torcellini, NREL/TP-550-3867). The user must select the appropriate electric generation region from a drop-down menu in cell C165 (Figure 15). The *Eastern* electric region is chosen for the Legacy Center. If sub-metering is provided in the building project, the spreadsheet permits input of submetered electric consumption based either on sub areas of the building or on sub-metered uses. For the Aldo Leopold Legacy Center, each building was sub-metered as were the lights and the plug loads (see Figure 15).

Finally, water consumption can be entered (Figure 16). None is entered for the Legacy Center as water from the site well was not metered.

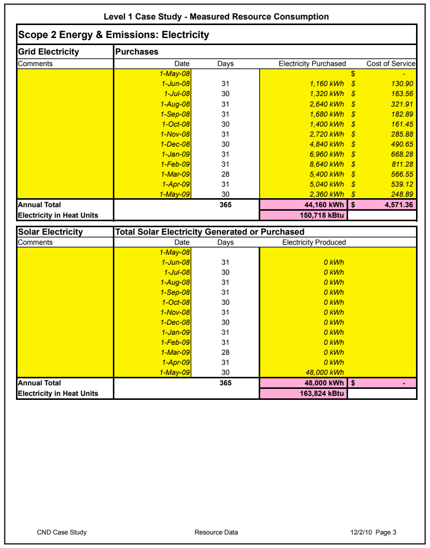


Figure 13: CND Level 1 Resources tab Page 3 ~ Grid & Solar Electricity.

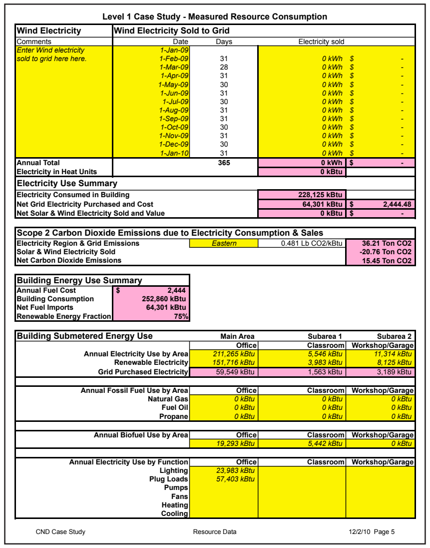


Figure 15: CND Level 1 Resources tab Page 5 ~ Electricity Summary.

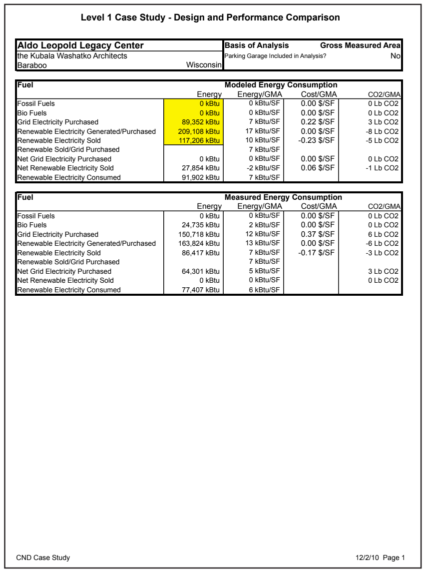


Figure 17: CND Level 1 Design Goals tab Page 1 ~ Modeled Energy Use.

Level 1 - Design Goals

With the input of estimated energy consumption of the building deign, actual resource use can be compared to design projections. Estimated energy consumption of the building is input on the *Level 1 - Design Goals* tab (one could also input actual energy consumption fo a building before rennovation). Energy estimates typically are provided in a LEED submission. Values for fossil fuel, biofuel, electricity purchases from the grid, site based renewable electricity sold to the grid, and the renewable energy generated or purchased for direct use in the building are entered on page one of the *Level 1 - Design Goals* tab (see Figure 17). Three graphs are produced to compare actual and estimated (modeled) energy use and emissions.

Comparison of actual and modeled building energy use (EUI) is given in the top graph of Figure 18. The building EUI in kBtu/SF per year is the total length of the bar, mad up of different energy consumption components. There are no fossil fuels consumed in the Legacy Center. Actual biofuel consumption (wood burning stoves) is included, but it was not modeled during design. The dark purple indicates an equal portion of renewable electricity sold to the grid and electricity purchased from the grid. The simulation model indicated more renewable energy sold to the grid (the negative portion of the modeled energy consumption). The actual building consumed more electricty from the grid than was sold (light purple area in the Measured energy consumption bar). The lower graph indicates electricity purchases (green) and renewable electricity sales (purple) in dollars per SF per year.

The carbon emissions graph is illustrated in Figure 19. Renewable energy is indicated as negative, or avoided, carbon dioxide emissions.

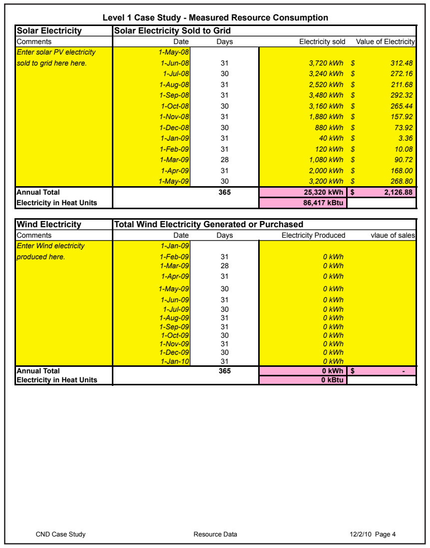


Figure 14: CND Level 1 Resources tab Page 4 ~ Solar & Wind Electricity.

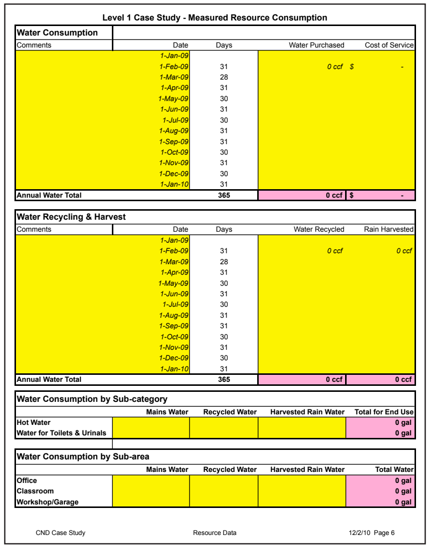


Figure 16: CND Level 1 Resources tab Page 6 ~ Water.

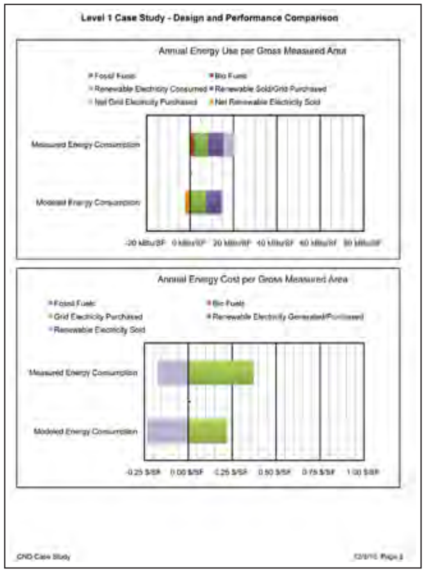


Figure 18: CND Level 1 Design Goals tab Page 2 ~ Energy & Cost Graphs.

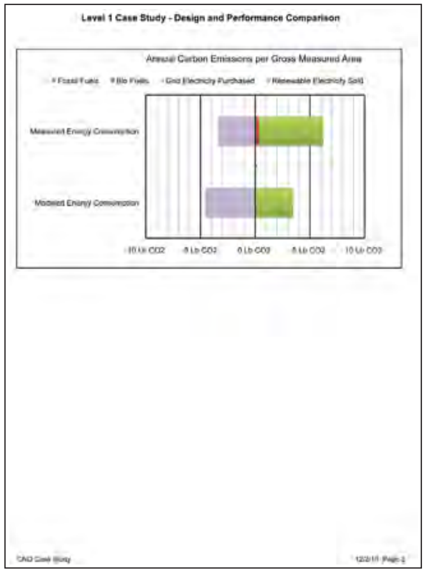


Figure 19: CND Level 1 Design Goals tab Page 3 ~ CO_2 Emissions.

Level 1 Case Study - Building Resource Use Metrics

Aldo Leopold Legacy Center	
the Kubala Washatko Architects	
Baraboo	**Wisconsin**

Building Type and Ownership		
Building Type	Office Building	Year Completed
Ownership Type	Non-profit	2007

Costs per Gross Measured Area	IP Units	Metric Units
Unit Construction Cost	378.58 $/sf	4074.97 $/m^2
Unit Energy Cost per year	0.20 $/sf-yr	2.14 $/m^2-yr
Unit Water Costs per year	0.00 $/sf-yr	0.00 $/m^2-yr

Energy Use per Gross Measured Area	IP Heat Units	IP Electrical Units	Metric Electrical Unit
Energy Utilization Intensity	20.5 kBtu/SF-yr	6.0 kWh/SF-yr	64.7 kWh/m^2-yr
Site Renewable Energy Generation Intensity	15.3 kBtu/SF-yr	4.5 kWh/SF-yr	48.3 kWh/m^2-yr
Net Imported Energy Intensity	5.2 kBtu/SF-yr	1.5 kWh/SF-yr	16.5 kWh/m^2-yr

Carbon Dioxide Emissions	IP Units	Metric Units
Scope 1 - Fossil Fuels	0.00 Ton CO2	0.00 metric T CO2
Scope 1 - Biofuels	2.15 Ton CO2	1.95 metric T CO2
Scope 2 - Grid Electricity	36.21 Ton CO2	32.88 metric T CO2
Scope 2 - Solar PV Electricity	-20.76 Ton CO2	-18.85 metric T CO2
Total Emissions	**17.60 Ton CO2**	**15.98 metric T CO2**
Net Fossil Fuel Emissions	**15.45 Ton CO2**	**14.03 metric T CO2**
CO2 Emissions per Gross Measured Area	**2.51 Lb CO2/SF-yr**	**12.3 kg CO2/m^2-yr**

Water Usage	IP Units	Metric Units
Water Usage per Gross Measured Area	0.0 gal/sf-yr	0.0 l/m^2-yr
Site Recycled Water	0%	
Site Rainfall Harvested	0%	

Resource Use per Occupant	IP Units	Metric Units
Occupant Utilization Intensity	850 sf/FTE	79 m^2/FTE
Occupant Energy Intensity	17,439 kBtu/FTE-yr	5,109 kWh/FTE-yr
Occupant Imported Energy Intensity	4,435 kBtu/FTE-yr	1,299 kWh/FTE-yr
Occupant Net CO2 Emissions Intensity	1.07 T CO2/FTE-yr	0.97 mT CO2/FTE-yr
Occupant Water Intensity	0 ccf/FTE-yr	0 l/FTE-yr

Daylighting	per Gross Measured Area
Percent Daylit Spaces	87.3%

Floor Area Efficiencies	per Gross Area
Measured Area/Gross Area Ratio	91.6%
Usable (Assignable) Area/Gross Area Ratio	64.3%
Occupied Area/Gross Area Ratio	90.8%
Mechanically Heated to Occupied Area Ratio	76.3%
Mechanically Cooled to Occupied Area Ratio	76.3%
Mechanically Ventilated to Occupied Area Rat	76.3%

CND Case Study   Level 1 - Metrics   12/2/10 Page 1

Figure 20: CND Level 1 Design Goals tab Page 1 ~ Modeled Energy Use.

Level 1 Case Study - Building Resource Use Metrics

BUILDING RESOURCE USE METRICS BASED ON SUB-AREAS

Energy Use per Gross Measured Area	Office	Classroom	Workshop/Garage
Energy Utilization Intensity	**24.1 kBtu/SF-yr**	**9.1 kBtu/SF-yr**	**7.3 kBtu/SF-yr**
	7.1 kWh/SF-yr	**2.7 kWh/SF-yr**	**2.1 kWh/SF-yr**
	76.0 kWh/m^2-yr	**28.7 kWh/m^2-yr**	**23.0 kWh/m^2-yr**
Site Renewable Energy Generation	**17.9 kBtu/SF-yr**	**7.8 kBtu/SF-yr**	**5.2 kBtu/SF-yr**
	5.2 kWh/SF-yr	**2.3 kWh/SF-yr**	**1.5 kWh/SF-yr**
	56.4 kWh/m^2-yr	**24.6 kWh/m^2-yr**	**16.5 kWh/m^2-yr**
Net Imported Energy Intensity	**6.2 kBtu/SF-yr**	**1.3 kBtu/SF-yr**	**2.1 kBtu/SF-yr**
	1.5 kWh/SF-yr	**0.7 kWh/SF-yr**	**0.4 kWh/SF-yr**
	16.5 kWh/m^2-yr	**7.2 kWh/m^2-yr**	**4.8 kWh/m^2-yr**

Carbon Dioxide Emissions per Sub Area	Office	Classroom	Workshop/Garage
Scope 1 - Fossil Fuels	0.00 Ton CO2	0.00 Ton CO2	0.00 Ton CO2
	0.00 metric T CO2	0.00 metric T CO2	0.00 metric T CO2
Scope 1 - Biofuels	1.68 Ton CO2	0.47 Ton CO2	0.00 Ton CO2
	1.52 metric T CO2	0.43 metric T CO2	0.00 metric T CO2
Scope 2 - Grid Electricity	14.31 Ton CO2	0.38 Ton CO2	0.77 Ton CO2
	12.99 metric T CO2	0.34 metric T CO2	0.70 metric T CO2
Scope 2 - Solar PV Electricity	0.00 Ton CO2	0.00 Ton CO2	0.00 Ton CO2
	0.00 metric T CO2	0.00 metric T CO2	0.00 metric T CO2
Total Emissions	15.98 Ton CO2	0.85 Ton CO2	0.77 Ton CO2
	14.51 metric T CO2	0.77 metric T CO2	0.70 metric T CO2
Net Fossil Fuel Emissions	14.31 Ton CO2	0.38 Ton CO2	0.77 Ton CO2
	12.99 metric T CO2	0.34 metric T CO2	0.70 metric T CO2
Fossil CO2 Emissions Intensity	**2.99 Lb CO2/SF-yr**	**0.62 Lb CO2/SF-yr**	**0.99 Lb CO2/SF-yr**
per Gross Measured Area	**14.6 kg CO2/m^2-yr**	**3.0 kg CO2/m^2-yr**	**4.8 kg CO2/m^2-yr**

CND Case Study   Level 1 - Metrics   12/2/10 Page 2

Figure 21: CND Level 1 Design Goals tab Page 2 ~ Energy & Cost Graphs.

Level 1 - Metrics

Once project and resumption data is entered, the Carbon Neutral Design Building Case Study Spreadsheet produces two pages of resource consumption and emissions metrics (Figures 20 and 21 at left). Metrics are computed based on the metric area chosen on the Project tab. In the case of the Aldo Leopold Legacy Center, Gross Measured Area (which NREL calls the Gross Interior Floor Area) is the metric area. The chosen metric area is automatically indicated in the spreadsheet for each consumption metric. Normalized consumption is given in both imperial (IP) and standard international (Metric) units.

The first set of metrics relate to costs. Construction, annual energy, and annual water costs are provided per SF and m^2.

Energy Use is given in heat and electrical energy units for total building energy consumption, renewable energy generation and net imported enery consumption.

Carbon dioxide emissions are given by Scope for the total building and as net emissions per chosen floor area measure.

Water usage is given as total consumption, fraction recycled, and fraction harvested from rain. Water usage was not measured at the Aldo Leopold Legacy Center.

Energy and water use as well as emissions are given per occupant FTE in both heat (kBtu) and electrical energy (kWh) units.

Daylit area of the building is provided as a percentage of the chosen floor area. Often this percentage is calculated for the LEED submission.

Floor area efficiencies are given as percentages of the gross floor area.

The second page of the tab (Figure 21) provides resource metrics based on sub areas.

Energy use and carbon emissions are given as a functions of the sub area of the chosen floor area metric, in the case of the Legacy Center illustrated, the metrics are based on the gross measured area of each sub area. The blank cells would be visible of the building type were multifamily housing or lodging with measrements given per housing unit or lodging room.

LEVEL 2 Case Study

A Level 2 Building Case Study allows input of building shell and systems data. The measures output are building enclosure and system design variables normalized to the chosen building metric area. Think of how installed lighting power density is understood as a system variable. Is 2 Watt per square foot energy efficient for a general office? Of course not. Under 1 Watt per square foot would be considered approaching an efficient design. We know this because light power density has been a measure of building lighting design for over a decade. Now, what installed fan power density for HVAC system fans would be appropriate? We don't know what an appropriate installed HVAC fan system power density (W/SF or W/m2) is because we haven't, as a profession, been consistently measuring this value. The Level 2 analysis has been structured to provide a number of building shell and building system variables normalized to the chosen building floor area metric to provide architects and engineers with data to compare energy metrics as a function of design over the portfolio of there energy efficient buildings. There are four input tabs in the spreadsheet for building and system information: *Enclosure, Lights, HVAC,* and *Plug_Process*. Two output tabs are included: *Level 2 - Metrics* and *Graphs*. Each input and output tab is described on the following pages.

NOTE: The input tabs may not provide enough rows for variable inputs, for example, your building may have more unique building enclosure surfaces or system supply air fans. The process of expanding input tables is the same for any of the input tabs.

- Unprotect the sheet.
- Select a row in the middle of the table.
- Insert as many additional rows as you need.
- In the row just above the newly inserted rows, select all of the cells contained in the table in that row.
- Copy those table cells into the blank cells of your inserted rows (this copies all appropriate equations of the table into your new rows).
- Select the yellow input cells in the inserted rows.
- From the excel menu command **Format:Cells:Protection** uncheck the **Locked** box.
- Protect the sheet.

This procedure will allow the expansion of any building enclosure or system variable table to the number of inputs needed for the building case study.

Level 2 - Enclosure

Enclosure information for the main building area and two sub areas is input on this tab. Heat loss rate to the ground, heat loss rate through enclosure surfaces (opaque, windows and doors), and heat loss rate through infiltration are calculated for the main area and each sub area. In addition, if a sub area is connected to the main area (walls and/or floors separating the main area and sub area), the description of the surfaces separating the two areas are input in the sub area section. The tab provides project information and calculated heat transfer rates for the main area and each sub area the top of the sheet (Figure 22, upper right). The total enclosure heat transfer rate, UA, for the main building area is given as:

$$UA_{mainarea} = UA_{perimeter} + UA_{walls} + UA_{windows} + UA_{doors} + UA_{infiltration}$$

The UA value for the sub areas is calculated similar to the UA for the main area.

The total building heat transfer rate calculation depends on whether the sub areas are conditioned and, if unconditioned, whether the sub area is connected to the main area (with walls and or floors separating the areas). If the sub area is conditioned, its UA value is added to the main building to calculate the total building UA, whether the sub area is connected to the main building area or not. If the sub area is unconditioned, its UA value only affects the total building UA value when it is connected to the main building area. Then the total building UA calculation is given as:

$$UA_{building} = UA_{mainarea} + 1 / (1 / UA_{subArea} + 1 / UA_{common})$$

Where UA_{common} is the heat transfer rate of the walls and floors separating the main area and adjacent sub area. For the Aldo Leopold Legacy Center, both sub areas, the classroom and the workshop/garage, are unconditioned and unconnected. The total building UA is equal to the main area (offices) UA as the offices are the only conditioned space.

The main area identifying name, building area used as metric area and main metric area are provided above the input cells for the main area enclosure (Figure 22).

Level 2 Case Study - Building Enclosure Heat Transfer

Aldo Leopold Legacy Center	
the Kubala Washatko Architects	
Baraboo	Wisconsin

Building Enclosure Heat Transfer Rate		
Office	UA	1,699 Btu/hr-F
Classroom	UA	1,652 Btu/hr-F
Workshop/Garage	UA	1,680 Btu/hr-F
Building	UA Building	1,699 Btu/hr-F

Main Building Area Exterior Enclosure Surface Takeoffs, Infiltration Rates and Heat Transfer Calculations

Area Name:	Office	Gross Measured Area	9,562 SF

Main Area ENCLOSURE HEAT LOSS RATE TROUGH THE GROUND PER UNIT LENGTH OF PERIMETER

Condition		Length	Transfer Rate	UA_perimeter
1	Slab-on-Grade w/ext. Slab	207.7 Ft	0.35 Btu/hr-ft-F	73 Btu/hr-F
2	Slab-on-Grade	218.8 Ft	0.45 Btu/hr-ft-F	98 Btu/hr-F
3	Basement	61.8 Ft	0.70 Btu/hr-ft-F	43 Btu/hr-F
4	Crawl Space	0.0 Ft	0.10 Btu/hr-ft-F	0 Btu/hr-F
Total		488.2 Ft		214 Btu/hr-F

CONDITIONED ENCLOSURE SURFACES (Walls & Roof) Opaque Enclosure Calculations

Figure 22: CND Level 2 Enclosure tab Page 1 ~ UA outputs and ground heat loss rate.

Enclosure Heat Loss Rate through the Ground

Building heat transfer to the ground is estimated by a heat transfer rate per hour per °F temperature difference between building and environment per hour per foot of perimeter wall. The rate of heat loss will depend on whether the foundation is a slab on grade, a crawl space or a full basement and what the insulation conditions of the foundation are. Both the *ASHRAE Handbook of Fundamentals* and *Mechanical and Electrical Equipment for Buildings* provide values of heat transfer rates through the ground to ambient per unit length of building perimeter for different foundation conditions. For the Aldo Leopold Legacy Center main building area illustrated in Figure 22, there are four distinct building foundation conditions. Each is described with the associated perimeter length and heat transfer rate. The spreadsheet calculates the UA value for each perimeter ground heat loss condition. The total perimeter length of the main area and the total heat loss rate through the ground ($UA_{perimeter}$) are summed.

Total					488.2 Ft		214 Btu/hr-F	
CONDITIONED ENCLOSURE SURFACES (Walls & Roof)					**Opaque Enclosure Calculations**			**Do**
Orientation	Gross Surface Area	Window Area	Percent Operable Windows	Door Area	Net Enclosure Surface Area	Enclosure Surface R Value	UA enclosure Surface	Door R
South	452 SF	48 SF	0%	25 SF	379 SF	32.13 hr-SF-F/Btu	12 Btu/hr-F	2.00 hr
South	1,186 SF	393 SF	50%	74 SF	719 SF	25.38 hr-SF-F/Btu	28 Btu/hr-F	2.00 hr
South	70 SF	27 SF	16%	0 SF	43 SF	32.13 hr-SF-F/Btu	1 Btu/hr-F	2.00 hr
South	420 SF	110 SF	40%	25 SF	285 SF	32.13 hr-SF-F/Btu	9 Btu/hr-F	2.00 hr
East	477 SF	40 SF	17%	0 SF	437 SF	32.13 hr-SF-F/Btu	14 Btu/hr-F	2.00 hr
East	304 SF	50 SF	0%	27 SF	227 SF	12.00 hr-SF-F/Btu	19 Btu/hr-F	2.00 hr
East	473 SF	146 SF	50%	51 SF	276 SF	32.13 hr-SF-F/Btu	9 Btu/hr-F	2.00 hr
East	165 SF	55 SF	50%	0 SF	110 SF	25.38 hr-SF-F/Btu	4 Btu/hr-F	2.00 hr
West	357 SF	0 SF	0%	26 SF	331 SF	29.00 hr-SF-F/Btu	11 Btu/hr-F	2.00 hr
West	348 SF	110 SF	43%	0 SF	238 SF	32.13 hr-SF-F/Btu	7 Btu/hr-F	2.00 hr
West	200 SF	55 SF	50%	25 SF	120 SF	25.38 hr-SF-F/Btu	5 Btu/hr-F	2.00 hr
West	473 SF	126 SF	50%	0 SF	347 SF	32.13 hr-SF-F/Btu	11 Btu/hr-F	2.00 hr
North	555 SF	34 SF	40%	0 SF	521 SF	29.00 hr-SF-F/Btu	18 Btu/hr-F	2.00 hr
North	250 SF	92 SF	27%	0 SF	158 SF	32.13 hr-SF-F/Btu	5 Btu/hr-F	2.00 hr
North	275 SF	0 SF	0%	48 SF	227 SF	6.75 hr-SF-F/Btu	34 Btu/hr-F	4.00 hr
North	690 SF	230 SF	47%	0 SF	460 SF	29.00 hr-SF-F/Btu	16 Btu/hr-F	2.00 hr
North	677 SF	167 SF	15%	0 SF	510 SF	32.13 hr-SF-F/Btu	16 Btu/hr-F	2.00 hr
North	420 SF	30 SF	50%	0 SF	390 SF	32.13 hr-SF-F/Btu	12 Btu/hr-F	2.00 hr
Horizontal	9,501 SF	0 SF	0%	0 SF	9,501 SF	45.00 hr-SF-F/Btu	211 Btu/hr-F	2.00 hr
Horizontal	295 SF	0 SF	0%	0 SF	295 SF	28.00 hr-SF-F/Btu	11 Btu/hr-F	2.00 hr
Horizontal	1,523 SF	0 SF	0%	0 SF	1,523 SF	39.38 hr-SF-F/Btu	39 Btu/hr-F	2.00 hr
TOTAL	19,111 SF	1,713 SF		301 SF	17,097 SF		491 Btu/hr-F	

Figure 23: CND Level 2 Enclosure tab Page 1 ~ Main Building Area enclosure area takeoffs and UA calculations.

Building Main Area Conditioned Enclosure Surfaces

Enclosure surface area take-offs input is illustrated in Figure 23 for the Aldo Leopold Legacy Center. Each surface has an orientation, gross area, window area, percentage of window area that can be opened, door area and the thermal resistance or R-values of the wall, window and door. The orientation of each surface is chosen from a drop-down menu with choices of North, South, East, West and Horizontal. Assume any surface sloped less than 45° to be horizontal. All other surfaces are assumed to be vertical with one of the four general compass coordinates. Assume any vertical surface with an orientation between southeast and southwest to be facing south. The other three orientations are treated similarly. The spreadsheet calculates the net wall enclosure surface area and the UA product for each enclosure surface.

Figure 24 provides a continuation of the enclosure surface input and calculations for the main building area. The spreadsheet calculates the door and window UA products for each surface, the operable window area for each surface and the window area for each orientation. Sums of wall, door window and operable window surfaces are calculated as well as the total wall, door and window UA products and the total window area for each of the five general orientations.

	Door Calculations		**Window Calculations**			**Window Area for Each Orientation**				
ure ce	Door R Value	UA Door	Window R Value	UA Window	Operable Window Area	South	West	North	East	Horizontal
F	2.00 hr-SF-F/Btu	13 Btu/hr-F	2.98 hr-SF-F/Btu	16 Btu/hr-F	0 SF	48 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	37 Btu/hr-F	2.98 hr-SF-F/Btu	132 Btu/hr-F	197 SF	393 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	9 Btu/hr-F	4 SF	27 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	13 Btu/hr-F	2.98 hr-SF-F/Btu	37 Btu/hr-F	44 SF	110 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	13 Btu/hr-F	7 SF	0 SF	0 SF	0 SF	40 SF	0 SF
F	2.00 hr-SF-F/Btu	14 Btu/hr-F	2.98 hr-SF-F/Btu	17 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	50 SF	0 SF
F	2.00 hr-SF-F/Btu	26 Btu/hr-F	2.98 hr-SF-F/Btu	49 Btu/hr-F	73 SF	0 SF	0 SF	0 SF	146 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	18 Btu/hr-F	28 SF	0 SF	0 SF	0 SF	55 SF	0 SF
F	2.00 hr-SF-F/Btu	13 Btu/hr-F	2.98 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	37 Btu/hr-F	47 SF	0 SF	110 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	13 Btu/hr-F	2.98 hr-SF-F/Btu	18 Btu/hr-F	28 SF	0 SF	55 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	42 Btu/hr-F	63 SF	0 SF	126 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	11 Btu/hr-F	14 SF	0 SF	0 SF	34 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	31 Btu/hr-F	25 SF	0 SF	0 SF	92 SF	0 SF	0 SF
F	4.00 hr-SF-F/Btu	12 Btu/hr-F	2.98 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	77 Btu/hr-F	108 SF	0 SF	0 SF	230 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	56 Btu/hr-F	25 SF	0 SF	0 SF	167 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.98 hr-SF-F/Btu	10 Btu/hr-F	15 SF	0 SF	0 SF	30 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
F		139 Btu/hr-F		575 Btu/hr-F	677 SF	578 SF	291 SF	553 SF	291 SF	0 SF

Figure 24: CND Level 2 Enclosure tab Page 1 ~ Main Building Area enclosure area takeoffs and UA calculations

MAIN AREA AIR VOLUME & INFILTRATION	
Average Ceiling Height	11.0 ft
Conditioned Air Volume	104,027 CF
Infiltration Rate	0.15 A.C.H
UA_infiltration	280.9 Btu/hr-F

Figure 25: CND Level 2 Enclosure tab Main Building Area Infiltration

Building Main Area Infiltration

Infiltration rate is estimated as the product of the enclosure main area air volume and the infiltration rate in air changes per hour (A.C.H.). The input area for the main building area infiltration is indicated in Figure 25. The average floor-to-ceiling height and the infiltration air change rates are input. The total occupied area of the main building area is multiplied by the height to estimate the main building area air volume. Without actual measured infiltration rates from blower door tests, the heat loss rate due to infiltration estimate has a high degree of inaccuracy. Infiltration rate is inversely proportional to building volume. The ASHRAE Handbook of Fundamentals provides direction and methods for estimating the building infiltration rate.

SubArea 1	Relation to Main Area		Classroom	UA_subArea_1	1,652 Btu/hr-F
	Unconnected, Unconditioned	Floor Area	1,209 SF	UA_Common_1	0 Btu/hr-F

SubArea 1 HEAT LOSS RATE TO THE GROUND PER UNIT LENGTH OF PERIMETER				
Condition		Length	Transfer Rate	UA_perimeter
1	Slab-on-Grade w/ext. Slab	47.6 Ft	0.85 Btu/hr-ft-F	40 Btu/hr-F
2	Retaining Wall	101.7 Ft	0.91 Btu/hr-ft-F	93 Btu/hr-F
Total		149.3 Ft		133 Btu/hr-F

SubArea 1 ENCLOSURE HEAT TRANSFER RATE					Opaque Enclosure Calculations			Door Calculations		Window Calculations			Window Area for Each Orientation				
Orientation	Gross Surface Area	Window Area	Percent Operable Windows	Door Area	Net Enclosure Surface Area	Enclosure Surface R Value	UA enclosure Surface	Door R Value	UA Door	Window R Value	UA Window	Operable Window Area	South	West	North	East	Horizontal
South	675 SF	128 SF	25%	0 SF	547 SF	1.60 hr-SF-F/Btu	342 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	64 Btu/hr-F	32 SF	128 SF	0 SF	0 SF	0 SF	0 SF
West	335 SF	168 SF	3%	0 SF	167 SF	1.60 hr-SF-F/Btu	104 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	84 Btu/hr-F	5 SF	0 SF	168 SF	0 SF	0 SF	0 SF
North	507 SF	338 SF	12%	48 SF	121 SF	1.60 hr-SF-F/Btu	76 Btu/hr-F	2.00 hr-SF-F/Btu	24 Btu/hr-F	2.00 hr-SF-F/Btu	169 Btu/hr-F	41 SF	0 SF	0 SF	338 SF	0 SF	0 SF
East	335 SF	168 SF	3%	0 SF	167 SF	1.60 hr-SF-F/Btu	104 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	84 Btu/hr-F	5 SF	0 SF	0 SF	0 SF	168 SF	0 SF
Horizontal	1,400 SF	0 SF		0 SF	1,400 SF	4.00 hr-SF-F/Btu	350 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
TOTAL	3,252 SF	802 SF		48 SF	2,402 SF		976 Btu/hr-F		24 Btu/hr-F		401 Btu/hr-F	83 SF	128 SF	168 SF	338 SF	168 SF	0 SF

COMMON WALL BETWEEN SubArea 1 & Main Area								Door Calculations		Window Calculations			Window Area for Each Orientation				
Orientation	Gross Surface Area	Window Area	Percent Operable Windows	Door Area	Net Enclosure Surface Area	Enclosure Surface R Value	UA enclosure Surface	Door R Value	UA Door	Window R Value	UA Window	Operable Window Area	South	West	North	East	Horizontal
South	0 SF	0 SF	50%	0 SF	0 SF	1.00 hr-SF-F/Btu	0 Btu/hr-F	4.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
West	0 SF	0 SF	0%	0 SF	0 SF	1.00 hr-SF-F/Btu	0 Btu/hr-F	4.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
North	0 SF	0 SF	0%	0 SF	0 SF	1.00 hr-SF-F/Btu	0 Btu/hr-F	4.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
TOTAL	0 SF	0 SF		0 SF	0 SF		0 Btu/hr-F		0 Btu/hr-F		0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF

SUB AREA 1 INFILTRATION	
Average Ceiling Height	12.0 ft
Unconditioned Air Volume	14,508 CF
Infiltration Rate	0.45 A.C.H
UA_infiltration	118 Btu/hr-F

Figure 26: CND Level 2 Enclosure tab - SubArea 1 Enclosure Inputs and Calculations.

SubArea 1	Relation to Main Area		Classroom	UA_subArea_1	1,652 Btu/hr-F
	Unconnected, Unconditioned	Floor Area	1,209 SF	UA_Common_1	0 Btu/hr-F

SubArea 1 HEAT LOSS RATE TO THE GROUND PER UNIT LENGTH OF PERIMETER				
Condition		Length	Transfer Rate	UA_perimeter
1	Slab-on-Grade w/ext. Slab	47.6 Ft	0.85 Btu/hr-ft-F	40 Btu/hr-F
2	Retaining Wall	101.7 Ft	0.91 Btu/hr-ft-F	93 Btu/hr-F
Total		149.3 Ft		133 Btu/hr-F

SubArea 1 ENCLOSURE HEAT TRANSFER RATE					Opaque Enclosure Calculations			Door Calculations		Window Calculations			Window Area for Each Orientation				
Orientation	Gross Surface Area	Window Area	Percent Operable Windows	Door Area	Net Enclosure Surface Area	Enclosure Surface R Value	UA enclosure Surface	Door R Value	UA Door	Window R Value	UA Window	Operable Window Area	South	West	North	East	Horizontal
South	675 SF	128 SF	25%	0 SF	547 SF	1.60 hr-SF-F/Btu	342 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	64 Btu/hr-F	32 SF	128 SF	0 SF	0 SF	0 SF	0 SF
West	335 SF	168 SF	3%	0 SF	167 SF	1.60 hr-SF-F/Btu	104 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	84 Btu/hr-F	5 SF	0 SF	168 SF	0 SF	0 SF	0 SF
North	507 SF	338 SF	12%	48 SF	121 SF	1.60 hr-SF-F/Btu	76 Btu/hr-F	2.00 hr-SF-F/Btu	24 Btu/hr-F	2.00 hr-SF-F/Btu	169 Btu/hr-F	41 SF	0 SF	0 SF	338 SF	0 SF	0 SF
East	335 SF	168 SF	3%	0 SF	167 SF	1.60 hr-SF-F/Btu	104 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	84 Btu/hr-F	5 SF	0 SF	0 SF	0 SF	168 SF	0 SF
Horizontal	1,400 SF	0 SF		0 SF	1,400 SF	4.00 hr-SF-F/Btu	350 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
TOTAL	3,252 SF	802 SF		48 SF	2,402 SF		976 Btu/hr-F		24 Btu/hr-F		401 Btu/hr-F	83 SF	128 SF	168 SF	338 SF	168 SF	0 SF

COMMON WALL BETWEEN SubArea 1 & Main Area								Door Calculations		Window Calculations			Window Area for Each Orientation				
Orientation	Gross Surface Area	Window Area	Percent Operable Windows	Door Area	Net Enclosure Surface Area	Enclosure Surface R Value	UA enclosure Surface	Door R Value	UA Door	Window R Value	UA Window	Operable Window Area	South	West	North	East	Horizontal
South	0 SF	0 SF	50%	0 SF	0 SF	1.00 hr-SF-F/Btu	0 Btu/hr-F	4.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
West	0 SF	0 SF	0%	0 SF	0 SF	1.00 hr-SF-F/Btu	0 Btu/hr-F	4.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
North	0 SF	0 SF	0%	0 SF	0 SF	1.00 hr-SF-F/Btu	0 Btu/hr-F	4.00 hr-SF-F/Btu	0 Btu/hr-F	2.00 hr-SF-F/Btu	0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF
TOTAL	0 SF	0 SF		0 SF	0 SF		0 Btu/hr-F		0 Btu/hr-F		0 Btu/hr-F	0 SF	0 SF	0 SF	0 SF	0 SF	0 SF

SUB AREA 1 INFILTRATION	
Average Ceiling Height	12.0 ft
Unconditioned Air Volume	14,508 CF
Infiltration Rate	0.45 A.C.H
UA_infiltration	118 Btu/hr-F

Figure 27: CND Level 2 Enclosure tab - SubArea 1 Enclosure Inputs and Calculations.

Building Sub Area Enclosure Calculations

Enclosure tab inputs and calculations for SubArea1 and SubArea2 are illustrated in Figures 26 and 27 respectively. Input and calculation for ground heat transfer rate, wall, door and window heat transfer rate and infiltration heat transfer rate are identical to the inputs and calculations for the main building area. The only difference is the calculation of heat transfer rates for common enclosure surfaces separating the sub area and the main building area. Inputs for the common surface areas are similar to the enclosure surface area inputs (wall, door, and window surfaces).

Level 2 - Lights

The Level 2 Lights tab page 1 and page 2 are illustrated in Figures 28 and 29 respectively. For the all input categories, input an identifier for each unique luminaire, the power per lamp, lamps per luminaire number of luminaires and type of luminaire control (manual, occupant sensor or daylight). The installed power for each luminaire is the product of the power, number of lamps and number of luminaires. Lights are entered for each sub area as well as exterior lights attached to the building and site lights. The values for lights in Figures 28 and 29 are for the Aldo Leopold Legacy Center.

Aldo Leopold Legacy Center	
the Kubala Washatko Architects	
Baraboo	Wisconsin

INSTALLED LIGHTING Main Building Area			Office		
Luminaire	Power per Lamp	Lamp/Luminaire	# Luminaires	Installed Power	Control
A	32 W	1	16	512 W	Manual
B	32 W	1	9	288 W	Occupant Sensor
B1	18 W	1	2	36 W	Manual
C	54 W	4	11	2,376 W	Daylight
C1	132 W	2	3	792 W	Daylight
C2	54 W	1	10	540 W	Daylight
D	32 W	2	9	576 W	Occupant Sensor
F	24 W	1	2	48 W	Occupant Sensor
G	32 W	2	13	832 W	Manual
H	32 W	1	9	288 W	Manual
H1	32 W	1	6	192 W	Manual
N	32 W	1	14	448 W	Manual
P	50 W	1	2	100 W	Manual
P1	35 W	1	2	70 W	Manual
R	50 W	1	19	950 W	Manual
S	32 W	1	9	288 W	Manual
T	35 W	4	2	280 W	Manual
T1	35 W	1	2	70 W	Manual
T2a	25 W	1	8	200 W	Manual
T2b	25 W	2	7	350 W	Manual
T2c	25 W	2	8	400 W	Manual
T3	60 W	1	5	300 W	Manual
T4	25 W	3	2	150 W	Manual
U	54 W	1	5	270 W	Manual
U1	54 W	2	1	108 W	Manual
U2	54 W	4	2	432 W	Manual
V	32 W	2	1	64 W	Occupant Sensor
X	10 W	1	15	150 W	Exit always on
Total Installed Lights, Main Area				11,110 W	

INSTALLED LIGHTING SubArea 1			Classroom		
Luminaire	Power per Lamp	Lamp/Luminaire	# Luminaires	Installed Power	Control
H1	32 W	1	17	544 W	Manual
S	25 W	1	1	25 W	Manual
L	18 W	1	3	54 W	Manual
Total - Lights in Sub Area 1				623 W	

Figure 28: CND Level 2 Lights tab - Page 1.

INSTALLED LIGHTING SubArea2		Workshop/Garage			
Luminaire	Power per Lamp	Lamp/Luminaire	# Luminaires	Installed Power	Control
K	32 W	2	10	640 W	Manual
K1	32 W	2	5	320 W	Occupant Sensor
J	26 W	1	5	130 W	Manual
Total - Lights in Sub Area 2				1,090 W	

Exterior Lights (attached to Buildings)					
Luminaire	Power per Lamp	Lamp/Luminaire	# Luminaires	Installed Power	Control
OB	35 W	1	12	420 W	
				0 W	
				0 W	
Total - Exterior Lights attached to Building				420 W	

INSTALLED LIGHTING - SITE					
Luminaire	Power per Lamp	Lamp/Luminaire	# Luminaires	Installed Power	Control
				0 W	
				0 W	
				0 W	
Total - Site Lighting				0 W	

TOTAL INSTALLED LIGHTING POWER	
Total Installed Illumination Power	13,243 W

Figure 29: CND Level 2 Lights tab - Page 2.

Level 2 - HVAC Systems

HVAC systems are sub-divided into ventilation fans, pumps, heating equipment, heat pumps, cooling equipment, miscellaneous equipment and service hot water. Within each subdivision, equipment is entered by main and sub building areas. Equipment energy demand is totaled for each sub area and the total building.

Aldo Leopold Legacy Center	
the Kubala Washatko Architects	
Baraboo	Wisconsin

HVAC	Ventilation Fans				
Main Building Area		**Office**			
Supply Fans	**Function**	**Max. Air Flow**	**Constant Volume, Variable or VFD**	**Motor HP**	**Motor Watts**
AHU1	*Air supply for offices & exhibit*	*1,195 cfm*	*VFD*	*1.50 Hp*	1,119 W
ERV1 - Supply	*Meeting Room ERV Supply Fan*	*500 cfm*	*Variable Speed*	*0.33 Hp*	249 W
ERV2 - Supply	*Exhibit Space ERV Supply Fan*	*675 cfm*	*Variable Speed*	*0.33 Hp*	249 W
Total Installed Supply Fan CFM & Power		**2,370 cfm**		**2.17 Hp**	**1,616 W**
				Supply Fans Heat Transfer Efficiency	**1.6 Btu/hr-F-W**
				Supply Fans Volume Flow Efficiency	**1.5 cfm/W**
Exhaust Fans	**Function**	**Max. Air Flow**	**Control: Constant, Variable or VFD**	**Motor HP**	**Motor Watts**
ERV1 - Exhaus	*Meeting Room Energy Recovery Ventilator Exhaust*	*500 cfm*	*Variable Speed*	*0.33 Hp*	246 W
ERV2 - Exhaus	*Exhibit Space Energy Recovery Ventilator Exhaust F*	*675 cfm*	*Variable Speed*	*0.33 Hp*	246 W
EF-1	*Staff Area Cooling Season Exhasut Fan*	*400 cfm*	*Constant Volume*	*0.03 Hp*	19 W
EF-2	*Copy Room Exhaust Fan*	*50 cfm*	*Constant Volume*	*0.01 Hp*	7 W
EF-3	*Janitor's Closet Exhaust Fan*	*50 cfm*	*Constant Volume*	*0.07 Hp*	50 W
EF-4	*Server Room Exhaust Fan*	*295 cfm*	*Constant Volume*	*0.16 Hp*	120 W
EF-5	*Basement Shower Room*	*75 cfm*	*Constant Volume*	*0.07 Hp*	50 W
EF-6	*Men's Restroom Exhaust Fan*	*150 cfm*	*Constant Volume*	*0.02 Hp*	12 W
EF-7	*Women's Restroom Exhaust Fan*	*150 cfm*	*Constant Volume*	*0.02 Hp*	12 W
TF-1	*Staff Area Transfer Fan to South Corridor - Heating S*	*400 cfm*	*Constant Volume*	*0.04 Hp*	30 W
Total Installed Exhaust Fan CFM & Power		**2,745 cfm**		**1.06 Hp**	**793 W**
				Exhaust Fans Heat Transfer Efficiency	**3.7 Btu/hr-F-W**
				Exhaust Fans Volume Flow Efficiency	**3.5 cfm/W**
Main Area Installed Fan CFM & Power		**5,115 cfm**		**3.23 Hp**	**2,408 W**
				All Fans Heat Transfer Efficiency	**2.3 Btu/hr-F-W**
Main Area Outdoor Air Supply				**All Fans Volume Flow Efficiency**	**2.1 cfm/W**
	Outdoor Air Ventilation Rate	***2,370 cfm***			
	Fraction of Supply Air that is Outdoor Air	***100%***			

Figure 30: CND Level 2 HVAC tab - Ventilation Fans, main building area.

Fans

Ventilation fans are broken down into supply fans and exhaust fans. Space is provided for fan designation and for function. For each fan provide maximum design (or rated) cfm, fan type and motor horse power. Fan type is either constant volume, variable speed or VFD (Variable Frequency Drive) and is chosen by drop-down menu. Fan power input by horse power rating is converted to watts. If the fan power is provided in watts, there are cells in column I of the HVAC tab that provide conversion from Watts to Hp. Finally, the maximum outdoor air ventilation rate in cfm is enter. The spreadsheet calculates total supply and exhaust cfm, percentage of supply cfm that is outdoor air, total installed supply and exhaust fan power (in Hp and Watt) and fan thermal and flow efficiency.

Ceiling fans, while providing destratification and air flow for thermal comfort, do not move air into or out of the building zones. Ceiling fans should be accounted under miscellaneous HVAC equipment.

The main building area fan input for the Aldo Leopold Legacy Center is illustrated in Figure 30. The Legacy Center is designed with a 100% outdoor air displacement ventilation system. Air is exhausted directly from the space. Supply air for the displacement system is delivered via under floor ducts. For this design, the exhaust fans have half the power and twice the efficiency to move the same quantity of air.

Fan inputs for sub area 1 and sub area 1 are illustrated in Figures 31 and 32 on the following page. Data input is similar to the main building area fan input illustrated above. In addition, calculation of total building fan supply and exhaust cfm, fan power, outdoor air ventilation rate and fan efficiencies are illustrated in Figure 32.

FANS - SubArea 1		Classroom			
Supply Fans	**Function**	**Max. Air Flow**	**Constant Volume, Variable or VFD**	**Motor HP**	**Motor Watts**
		0 cfm	*VFD*	*0.00 Hp*	0 W
		0 cfm	*Constant Volume*	*0.00 Hp*	0 W
Total Installed Supply Fan CFM & Power		**0 cfm**		**0.00 Hp**	**0 W**
				Supply Fans Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Supply Fans Volume Flow Efficiency	**0.0 cfm/W**
Exhaust Fans	**Function**	**Max. Air Flow**	**Control: Constant, Variable or VFD**	**Motor HP**	**Motor Watts**
		0 cfm	*VFD*	*0.00 Hp*	0 W
		0 cfm	*Constant Volume*	*0.00 Hp*	0 W
Total Installed Exhaust Fan CFM & Power		**0 cfm**		**0.00 Hp**	**0 W**
				Exhaust Fans Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Exhaust Fans Volume Flow Efficiency	**0.0 cfm/W**
SubArea 1 Installed Fan CFM & Power		**0 cfm**		**0.00 Hp**	**0 W**
				All Fans Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
SubArea 1 Outdoor Air Supply				**All Fans Volume Flow Efficiency**	**0.0 cfm/W**
	Outdoor Air Ventilation Rate	***0 cfm***			
	Fraction of Supply Air that is Outdoor Air	***0%***			

Figure 31: CND Level 2 HVAC tab - Ventilation Fans, sub area 1.

FANS - SubArea 2		Workshop/Garage			
Supply Fans	**Function**	**Max. Air Flow**	**Constant Volume, Variable or VFD**	**Motor HP**	**Motor Watts**
		0 cfm	*VFD*	*0.00 Hp*	0 W
		0 cfm	*Constant Volume*	*0.00 Hp*	0 W
Total Installed Supply Fan CFM & Power		**0 cfm**		**0.00 Hp**	**0 W**
				Supply Fans Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Supply Fans Volume Flow Efficiency	**0.0 cfm/W**
Exhaust Fans	**Function**	**Max. Air Flow**	**Constant Volume, Variable or VFD**	**Motor HP**	**Motor Watts**
		0 cfm	*VFD*	*0.00 Hp*	0 W
		0 cfm	*Constant Volume*	*0.00 Hp*	0 W
Total Installed Exhaust Fan CFM & Power		**0 cfm**		**0.00 Hp**	**0 W**
				Exhaust Fans Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Exhaust Fans Volume Flow Efficiency	**0.0 cfm/W**
SubArea 2 Installed Fan CFM & Power		**0 cfm**		**0.00 Hp**	**0 W**
				All Fans Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
SubArea 2 Outdoor Air Supply				**All Fans Volume Flow Efficiency**	**0.0 cfm/W**
	Outdoor Air Ventilation Rate	***0 cfm***			
	Fraction of Supply Air that is Outdoor Air	***0%***			
FANS - Total Building					
	Supply Fans CFM	**2,370 cfm**		**Supply Fans Power**	**1,616 W**
				Supply Fans Heat Transfer Efficiency	**1.6 Btu/hr-F-W**
				Supply Fans Volume Flow Efficiency	**1.5 cfm/W**
	Exhaust Fans CFM	**2,745 cfm**		**Exhaust Fans Power**	**793 W**
				Supply Fans Heat Transfer Efficiency	**3.7 Btu/hr-F-W**
				Supply Fans Volume Flow Efficiency	**3.5 cfm/W**
Total Building Installed Fan CFM & Power		**5,115 cfm**			**2,408 W**
				All Fans Heat Transfer Efficiency	**2.3 Btu/hr-F-W**
Total Building Outdoor Air Supply				**All Fans Volume Flow Efficiency**	**2.1 cfm/W**
	Outdoor Air Ventilation Rate	**2,370 cfm**			
	Fraction of Supply Air that is Outdoor Air	***100%***			
Fan Characteristics			**Flow Rate**	**Motor Watts**	**Flow Efficienncy**
		Constant Volume Fans	**1,570 cfm**	**300 W**	**5.2 cfm/W**
		Variable Frequency Drive Fans	**1,195 cfm**	**1,119 W**	**1.1 cfm/W**
		Variable Speed Fans	**2,350 cfm**	**989 W**	**2.4 cfm/W**
		All Fans	**5,115 cfm**	**2,408 W**	**2.1 cfm/W**

Figure 32: CND Level 2 HVAC tab - Ventilation Fans, sub area 2 and total building.

Pumps

Spreadsheet input and calculations of HVAC pumps for the main building area, sub area 1, sub area 2 and the total building are illustrated in Figures 33 and 34 below. Inputs are similar to fan inputs except that flow is input in gpm of liquid instead of cfm of air and there is no differentiation for supply and return. Redundant pumps are treated separately. Redundant pumps often occur in lead/lag configuration and are counted separately if they are not controlled to operate at the same time as the line pumps.

HVAC	Pumps				
Main Building Area		**Office**			
Line Pumps	Function	Flow Rate	Control	Motor HP	Motor Watts
P-1	*Main Geothermal Loop - Small Load*	*6.6 gpm*	*Constant*	*0.08 Hp*	62 W
P-2	*Main Geothermal Loop - Lead*	*36.6 gpm*	*VFD*	*0.75 Hp*	559 W
P-4	*Radiant Floor- Small Load*	*5.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-5	*Radiant Floor - Lead*	*21.4 gpm*	*VFD*	*0.33 Hp*	249 W
P-7	*AHU-1 - Main Coil*	*22.9 gpm*	*VFD*	*0.50 Hp*	373 W
P-8	*Heat Pump - 1 / Storage Tank Loop*	*7.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-9	*Heat Pump - 2 / Storage Tank Loop*	*7.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-10	*Heat Pump - 3 / Storage Tank Loop*	*7.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-11	*Ground Loop / Heat Pump 4*	*6.6 gpm*	*Constant*	*0.08 Hp*	62 W
P-12	*Heat Pump 4 / Meeting Room Storage Tank*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
P-13	*Meeting Room Storage Tank / Fin Tube Convectors*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
P-14	*Meeting Room Storage Tank / ERV Cooling Coil*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
P-15	*DHW Tank / Reheat Coil*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
PP-1	*DHW tank / Storage Tank*	*3.6 gpm*	*Constant*	*0.04 Hp*	30 W
PP-2	*Solar Collectors / Solar Storage Tank*	*3.5 gpm*	*Constant*	*0.04 Hp*	30 W
Total Line Pumps		**151.2 gpm**		**2.32 Hp**	**1,733 W**
				Pump Heat Transfer Efficiency	**43.7 Btu/hr-F-W**
				Pump Volume Flow Efficiency	**0.09 gpm/W**
Redundant (lead/lag) Pumps					
P-3	*Main Geothermal Loop - Lag*	*36.6 gpm*	*VFD*	*0.75 Hp*	559 W
P-6	*Radiant Floor - Lag*	*21.4 gpm*	*VFD*	*0.33 Hp*	249 W
Total - Redundant Pumps		**58.0 gpm**		**1.08 Hp**	**808 W**
Total - Main Building Area Pumps		**209.3 gpm**		**3.41 Hp**	**2,540 W**

Figure 33: CND Level 2 HVAC tab - Pumps, main building area.

PUMPS - SubArea 1		Classroom			
Line Pumps	Function	Flow Rate	Control	Motor HP	Motor Watts
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total Line Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
				Pump Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Pump Volume Flow Efficiency	**0.00 gpm/W**
Redundant (lead/lag) Pumps					
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total - Redundant Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
Total - SubArea1 Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
PUMPS - SubArea 2		**Workshop/Garage**			
Line Pumps	Function	Flow Rate	Control	Motor HP	Motor Watts
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total Line Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
				Pump Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Pump Volume Flow Efficiency	**0.00 gpm/W**
Redundant (lead/lag) Pumps					
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total - Redundant Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
Total- SubArea2 Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**

PUMPS - Total Building		Flow Rate	Motor Watts	Flow Efficiency
Line Pumps	**Constant Speed**	**70.3 gpm**	**552 W**	**0.13 gpm/W**
	Variable Frequency Drive	**80.9 gpm**	**1,181 W**	**0.07 gpm/W**
	Variable Speed	**0.0 gpm**	**0 W**	**0.00 gpm/W**
	Total - Line Pumps	**151.2 gpm**	**1,733 W**	**0.09 gpm/W**
Redundant Pumps		**58.0 gpm**	**808 W**	

Figure 34: CND Level 2 HVAC tab - Pumps, sub areas 1 & 2 and total building.

Heating Equipment

Heating equipment input for the main building area and each sub area is illustrated in Figures 35 and 36 below.

HVAC	Providing Heat: Boilers, Furnaces, Radiant & Electric Heaters				
Main Building Area		**Office**			
Boiler	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Boilers			0 kBtu/hr	0 kBtu/hr	
Furnace	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Furnaces			0 kBtu/hr	0 kBtu/hr	
Radiant Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Radiant Heaters			0 kBtu/hr	0 kBtu/hr	
Electric Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Electric Heaters			0 kBtu/hr	0 kBtu/hr	
Total - Main Building Area Heat Production			**0 kBtu/hr**	**0 kBtu/hr**	**0%**
SubArea 1		**Classroom**			
Boiler	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Boilers			0 kBtu/hr	0 kBtu/hr	
Furnace	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Furnaces			0 kBtu/hr	0 kBtu/hr	
Radiant Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Radiant Heaters			0 kBtu/hr	0 kBtu/hr	
Electric Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Electric Heaters			0 kBtu/hr	0 kBtu/hr	
Total - SubArea 1 Heat Production			**0 kBtu/hr**	**0 kBtu/hr**	**0%**

Figure 35: CND Level 2 HVAC tab - Heating Equipment, main building area and sub area 1.

SubArea 2		Workshop/Garage			
Boiler	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Boilers			0 kBtu/hr	0 kBtu/hr	
Furnace	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Furnaces			0 kBtu/hr	0 kBtu/hr	
Radiant Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Radiant Heaters			0 kBtu/hr	0 kBtu/hr	
Electric Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Electric Heaters			0 kBtu/hr	0 kBtu/hr	
Total - SubArea 2 Heat Production			**0 kBtu/hr**	**0 kBtu/hr**	**0%**
Total Building Heat Production			Rated Output	Input	Efficiency
		Boilers	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Furnaces	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Radiant Heaters	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Electric Heaters	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Total	**0 kBtu/hr**	**0 kBtu/hr**	**0%**

Figure 36: CND Level 2 HVAC tab - Heating Equipment, sub area 2 and total building.

Pumps

Spreadsheet input and calculations of HVAC pumps for the main building area, sub area 1, sub area 2 and the total building are illustrated in Figures 33 and 34 below. Inputs are similar to fan inputs except that flow is input in gpm of liquid instead of cfm of air and there is no differentiation for supply and return. Redundant pumps are treated separately. Redundant pumps often occur in lead/lag configuration and are counted separately if they are not controlled to operate at the same time as the line pumps.

HVAC	Pumps				
Main Building Area		**Office**			
Line Pumps	Function	Flow Rate	Control	Motor HP	Motor Watts
P-1	*Main Geothermal Loop - Small Load*	*6.6 gpm*	*Constant*	*0.08 Hp*	62 W
P-2	*Main Geothermal Loop - Lead*	*36.6 gpm*	*VFD*	*0.75 Hp*	559 W
P-4	*Radiant Floor- Small Load*	*5.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-5	*Radiant Floor - Lead*	*21.4 gpm*	*VFD*	*0.33 Hp*	249 W
P-7	*AHU-1 - Main Coil*	*22.9 gpm*	*VFD*	*0.50 Hp*	373 W
P-8	*Heat Pump - 1 / Storage Tank Loop*	*7.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-9	*Heat Pump - 2 / Storage Tank Loop*	*7.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-10	*Heat Pump - 3 / Storage Tank Loop*	*7.0 gpm*	*Constant*	*0.04 Hp*	30 W
P-11	*Ground Loop / Heat Pump 4*	*6.6 gpm*	*Constant*	*0.08 Hp*	62 W
P-12	*Heat Pump 4 / Meeting Room Storage Tank*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
P-13	*Meeting Room Storage Tank / Fin Tube Convectors*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
P-14	*Meeting Room Storage Tank / ERV Cooling Coil*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
P-15	*DHW Tank / Reheat Coil*	*6.0 gpm*	*Constant*	*0.08 Hp*	62 W
PP-1	*DHW tank / Storage Tank*	*3.6 gpm*	*Constant*	*0.04 Hp*	30 W
PP-2	*Solar Collectors / Solar Storage Tank*	*3.5 gpm*	*Constant*	*0.04 Hp*	30 W
Total Line Pumps		**151.2 gpm**		**2.32 Hp**	**1,733 W**
				Pump Heat Transfer Efficiency	**43.7 Btu/hr-F-W**
				Pump Volume Flow Efficiency	**0.09 gpm/W**
Redundant (lead/lag) Pumps					
P-3	*Main Geothermal Loop - Lag*	*36.6 gpm*	*VFD*	*0.75 Hp*	559 W
P-6	*Radiant Floor - Lag*	*21.4 gpm*	*VFD*	*0.33 Hp*	249 W
Total - Redundant Pumps		**58.0 gpm**		**1.08 Hp**	**808 W**
Total - Main Building Area Pumps		**209.3 gpm**		**3.41 Hp**	**2,540 W**

Figure 33: CND Level 2 HVAC tab - Pumps, main building area.

PUMPS - SubArea 1		**Classroom**			
Line Pumps	Function	Flow Rate	Control	Motor HP	Motor Watts
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total Line Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
				Pump Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Pump Volume Flow Efficiency	**0.00 gpm/W**
Redundant (lead/lag) Pumps					
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total - Redundant Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
Total - SubArea1 Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
PUMPS - SubArea 2		**Workshop/Garage**			
Line Pumps	Function	Flow Rate	Control	Motor HP	Motor Watts
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total Line Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
				Pump Heat Transfer Efficiency	**0.0 Btu/hr-F-W**
				Pump Volume Flow Efficiency	**0.00 gpm/W**
Redundant (lead/lag) Pumps					
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
		0.0 gpm	*VFD*	*0.00 Hp*	0 W
Total - Redundant Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**
Total- SubArea2 Pumps		**0.0 gpm**		**0.00 Hp**	**0 W**

PUMPS - Total Building		**Flow Rate**	**Motor Watts**	**Flow Efficiency**
Line Pumps	**Constant Speed**	**70.3 gpm**	**552 W**	**0.13 gpm/W**
	Variable Frequency Drive	**80.9 gpm**	**1,181 W**	**0.07 gpm/W**
	Variable Speed	**0.0 gpm**	**0 W**	**0.00 gpm/W**
	Total - Line Pumps	**151.2 gpm**	**1,733 W**	**0.09 gpm/W**
Redundant Pumps		**58.0 gpm**	**808 W**	

Figure 34: CND Level 2 HVAC tab - Pumps, sub areas 1 & 2 and total building.

Heating Equipment

Heating equipment input for the main building area and each sub area is illustrated in Figures 35 and 36 below.

HVAC	Providing Heat: Boilers, Furnaces, Radiant & Electric Heaters				
Main Building Area		**Office**			
Boiler	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Boilers			0 kBtu/hr	0 kBtu/hr	
Furnace	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Furnaces			0 kBtu/hr	0 kBtu/hr	
Radiant Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Radiant Heaters			0 kBtu/hr	0 kBtu/hr	
Electric Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Electric Heaters			0 kBtu/hr	0 kBtu/hr	
Total - Main Building Area Heat Production			**0 kBtu/hr**	**0 kBtu/hr**	**0%**
SubArea 1		**Classroom**			
Boiler	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Boilers			0 kBtu/hr	0 kBtu/hr	
Furnace	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Furnaces			0 kBtu/hr	0 kBtu/hr	
Radiant Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Radiant Heaters			0 kBtu/hr	0 kBtu/hr	
Electric Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Electric Heaters			0 kBtu/hr	0 kBtu/hr	
Total - SubArea 1 Heat Production			**0 kBtu/hr**	**0 kBtu/hr**	**0%**

Figure 35: CND Level 2 HVAC tab - Heating Equipment, main building area and sub area 1.

SubArea 2		**Workshop/Garage**			
Boiler	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Boilers			0 kBtu/hr	0 kBtu/hr	
Furnace	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Furnaces			0 kBtu/hr	0 kBtu/hr	
Radiant Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Radiant Heaters			0 kBtu/hr	0 kBtu/hr	
Electric Heater	Function	Fuel	Rated Output	Input	Efficiency
			0 kBtu/hr	*0 kBtu/hr*	*0%*
					0%
Total Electric Heaters			0 kBtu/hr	0 kBtu/hr	
Total - SubArea 2 Heat Production			**0 kBtu/hr**	**0 kBtu/hr**	**0%**
Total Building Heat Production			Rated Output	Input	Efficiency
		Boilers	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Furnaces	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Radiant Heaters	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Electric Heaters	**0 kBtu/hr**	**0 kBtu/hr**	**0%**
		Total	**0 kBtu/hr**	**0 kBtu/hr**	**0%**

Figure 36: CND Level 2 HVAC tab - Heating Equipment, sub area 2 and total building.

Heat Pumps

Heat pump system input for the main building area and each sub area of the building is illustrated in Figure 37 below. Inputs include equipment reference and description, refrigerant, rated input (compressor) power, design heating capacity and design cooling capacity. Calculated values include total rated power, maximum heating hapacity and maximum cooling capacity for each sub area of the building and the total building. Figure 37 illustrates the water-water ground source heat pumps for the Aldo Leopold Legacy Center. The heat pumps maintain a hot water tank in the heating season and a chilled water tank in the cooling season. Water is pumped from the tank to the air handling unit coil and to the radiant slabs to heat or cool the building.

HVAC	Heat Pump Systems: Air-Air, Water-Air & Water-water				
Main Building Area		**Office**			
Heat Pump	Heating or Cooling Function	Refrigerant	Rated Input Power	Heat Capacity	Cool Capacity
WHP-1	*Heating or Chilling Storage Tank*	*R-410A*	*5,241 W*	*49 kBtu/hr*	*51 kBtu/hr*
WHP-2	*Heating or Chilling Storage Tank*	*R-410A*	*5,241 W*	*49 kBtu/hr*	*51 kBtu/hr*
WHP-3	*Heating or Chilling Storage Tank*	*R-410A*	*5,241 W*	*49 kBtu/hr*	*51 kBtu/hr*
WHP-4	*Heating or Chilling Storage Tank*	*R-410A*	*5,241 W*	*24 kBtu/hr*	*31 kBtu/hr*
Total - Main Area Heat Pump Systems			**20,964 W**	**172 kBtu/hr**	**185 kBtu/hr**
SubArea 1		**Classroom**			
Heat Pump	Heating or Cooling Function	Refrigerant	Rated Input Power	Heat Capacity	Cool Capacity
			0 W	*0 kBtu/hr*	*0 kBtu/hr*
Total - SubArea 1 Heat Pump Systems			**0 W**	**0 kBtu/hr**	**0 kBtu/hr**
SubArea 2		**Workshop/Garage**			
Heat Pump	Heating or Cooling Function	Refrigerant	Rated Input Power	Heat Capacity	Cool Capacity
			0 W	*0 kBtu/hr*	*0 kBtu/hr*
Total - SubArea 2 Heat Pump Systems			**0 W**	**0 kBtu/hr**	**0 kBtu/hr**
Total Building Heat Pumps			Rated Input Power	Heat Capacity	Cool Capacity
		Total Building	**20,964 W**	**172 kBtu/hr**	**185 kBtu/hr**

Figure 37: CND Level 2 HVAC tab - Heat Pumps.

Cooling Equipment

Cooling equipment descriptions and capacities for the main building area and sub areas is illustrated in Figure 38 below and Figure 39 on the following page. Equipment is entered for the main building area and each sub area. For each piece of cooling equipment, enter an equipment identifying number and description. For chillers and DX units enter the refrigerant, rated input (compressor) power and SEER (seasonal energy efficiency ratio) and cooling capacity. For absorption chillers, enter the absorber fluid, rated heat input (in watts) SEER and cooling capacity. For evaporative coolers and cooling towers enter the fan power and the rated cooling capacity. For each sub area and the total building, the spreadsheet calculates total input power and total cooling capacity.

HVAC	Producing Cooling: Chillers, DX Coolers, Evaporative Coolers and Cooling Towers				
Main Building Area		**Office**			
Chillers		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Chillers - Main Area			**0 W**		0 kBtu/hr
DX Air-Conditioning		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total DX Air-Conditioning - Main Area			**0 W**		0 kBtu/hr
Absorption Air-Conditioning		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Absorption Air-Conditioning - Main Area			**0 W**		0 kBtu/hr
Evaporative Coolers			Fan Power		Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Evaporative Coolers - Main Area			**0 W**		0 kBtu/hr
Cooling Towers used for direct cooling			Fan Power		Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Cooling Towers - Main Area			**0 W**		0 kBtu/hr
Total - Cooling Capacity - Main Area			**0 W**		**0 kBtu/hr**
SubArea 1		**Classroom**			
Chillers		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Chillers - SubArea 1			**0 W**		0 kBtu/hr
DX AC		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total DX Air-Conditioning - SubArea 1			**0 W**		0 kBtu/hr
Absorption Air-Conditioning		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Absorption Air-Conditioning - SubArea 1			**0 W**		0 kBtu/hr
Evaporative Coolers			Fan Power		Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Evaporative Coolers - SubArea 1			**0 W**		0 kBtu/hr

Figure 38: CND Level 2 HVAC tab - Cooling Equipment, main building area and sub area 1.

Cooling Towers used for direct cooling			Fan Power		Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Cooling Towers - SubArea 1			**0 W**		0 kBtu/hr
Total - Cooling Capacity - SubArea 1			**0 W**		**0 kBtu/hr**
SubArea 2	**Workshop/Garage**				
Chillers		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Chillers - SubArea 2			**0 W**		0 kBtu/hr
DX AC		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total DX Air-Conditioning - SubArea 2			**0 W**		0 kBtu/hr
Absorption Air-Conditioning		Refrigerant	Rated Input Power	SEER	Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Absorption Air-Conditioning - SubArea 2			**0 W**		0 kBtu/hr
Evaporative Coolers			Fan Power		Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Evaporative Coolers - SubArea 2			**0 W**		0 kBtu/hr
Cooling Towers used for direct cooling			Fan Power		Cool Capacity
	Notes		*0 W*		*0 kBtu/hr*
Total Cooling Towers - SubArea 2			**0 W**		0 kBtu/hr
Total - Cooling Capacity - SubArea 2			**0 W**		**0 kBtu/hr**
Total Building Cooling Production			Rated Input		Cooling Capacity
			0 W		**0 kBtu/hr**
HVAC	**Installed Heating and Cooling Capacity**		**Peak Capacity**		
	Heating Systems		**172 kBtu/hr**		
	Cooling Systems		**185 kBtu/hr**		

Figure 39: CND Level 2 HVAC tab - Cooling Equipment, sub area 2 and total building

Miscellaneous HVAC Equipment

Miscellaneous HVAC and equipment includes all equipment not covered under ventilation fans, pumps, heating equipment, heat pumps and cooling equipment. Items such as wood burning stoves and ceiling fans are included here. Spreadsheet inputs and calculations for miscellaneous equipment are illustrated in Figure 40 below. For each piece of equipment, inter the rated maximum input power, heating capacity and/or cooling capacity as appropriate.

HVAC	**Other Systems (eg. wood burning stoves; ceiling fans; district system heat exchangers, etc.**			
Device	Function	Power Rating	Heating Capacity	Cooling Capacity
Fireplace	*Located in lobby, Rumsford design, used rarely*	*0 W*	*0 kBtu/hr*	*0 kBtu/hr*
Wood Stove	*Located in staff kitchen, used on chilly mornings*			
Wood Stove	*Located in Meeting Room, used during occupancy in winter*			
Wood Stove	*Located in Seed Hall, used on cool spring and fall days*			
Total - Other Systems		**0 W**	**0 kBtu/hr**	**0 kBtu/hr**

Figure 40: CND Level 2 HVAC tab - Miscellaneous HVAC Equipment

Service Hot Water Equipment

Service Hot Water Equipment inputs include equipment reference, description, refrigerant (if used), heater input rating and heating capacity. Spreadsheet inputs and calculated values are illustrated in Figure 41 below.

Level 2 Case Study - HVAC and Service Hot Water Systems

Service Hot Water System				
Device	Function	Fuel/Refrigerant	Input Rating	Heating Capacity
WHP-5	DHW Back-up Heat Pump	R-410A	*10,300 W*	*24 kBtu/hr*
				0 kBtu/hr
Total - Service Hot Water			**10,300 W**	**24 kBtu/hr**

Figure 41: CND Level 2 HVAC tab - Service Hot Water.

Level 2 - Plug, Process, Elevators and Escalators

The Level 2 Plug, Process, Elevator and Escalator loads cover all other installed power and combustion equipment. Elevators and escalators include all people moving equipment. Process equipment includes electrical and combustion equipment used as part of the building occupancy function, for example, industrial equipment, kitchen equipment in a restaurant, refrigeration equipment for coolers and freezers in a supermarket, etc. Plug equipment is equipment such as computers, copiers and appliances that are connected to electrical outlets in the building.

Aldo Leopold Legacy Center	
the Kubala Washatko Architects	
Baraboo	Wisconsin

Plug Loads		**Main Building Area**		**Office**
Device	**Function**	**Num. of Units**	**Watts/Unit**	**Installed Watts**
Computer Worstation		14	*225 W*	3.2 kW
Servers		2	*180 W*	0.4 kW
Copier		1	*750 W*	0.8 kW
LCD Screens		2	*250 W*	0.5 kW
Refrigerator		1	*800 W*	0.8 kW
Stove		1	*1,800 W*	1.8 kW
Microwave		1	*1,200 W*	1.2 kW
Coffee Maker		1	*150 W*	0.2 kW
		0	*0 W*	0.0 kW
Total Installed Plug Load Devices (kW) in Main Building Area				**8.7 kW**
Plug Loads		**SubArea 1**		**Classroom**
Device	**Function**	**Num. of Units**	**Watts/Unit**	**Installed Watts**
		0	*0 W*	0.0 kW
		0	*0 W*	0.0 kW
		0	*0 W*	0.0 kW
Total Installed Plug Load Devices (kW) in subArea 1				**0.0 kW**
Plug Loads		**SubArea2**		**Workshop/Garage**
Device	**Function**	**Num. of Units**	**Watts/Unit**	**Installed Watts**
		0	*0 W*	0.0 kW
		0	*0 W*	0.0 kW
		0	*0 W*	0.0 kW
Total Installed Plug Load Devices (kW) in subArea 2				**0.0 kW**
Plug Loads		**Total Building**		
Total Installed Plug Load Devices (kW) in Building				**8.7 kW**

Figure 42: CND Level 2 Plug_Process tab - Plug Loads.

Plug

Plug loads includes all appliances and equipment connected by electrical outlet to the grid: computers, copiers, printers, etc. Plug loads inputs and calculations are illustrated in Figure 42 above.

Elevators and Escalators		Main Building Area		Office
Device	Function	Num. of Units	Watts/Unit	Installed Watts
		0	0 W	0.0 kW
		0	0 W	0.0 kW
Total Elevators and Escalators (kW) in Main Building Area				0.0 kW
Elevators and Escalators		SubArea 1		Classroom
Device	Function	Num. of Units	Watts/Unit	Installed Watts
		0	0 W	0.0 kW
		0	0 W	0.0 kW
Total Elevators and Escalators (kW) in subArea 1				0.0 kW
Elevators and Escalators		SubArea2		Workshop/Garage
Device	Function	Num. of Units	Watts/Unit	Installed Watts
		0	0 W	0.0 kW
		0	0 W	0.0 kW
Total Elevators and Escalators (kW) in subArea 2				0.0 kW
Elevators and Escalators		Total Building		
Total Elevators and Escalators (kW) in Building				0.0 kW

Figure 43: CND Level 2 Plug_Process tab - Elevator and Escalator Equipment.

Elevators and Escalators

Elevator and escalator inputs and outputs for the main building area and sub areas are illustrated in Figure 43 above. Inputs include an equipment identifier, description, number of units and rated maximum power. The spreadsheet calculates installed kW for each sub area and for the total building.

Process Loads		Main Building Area		Office
Device	Function	Num. of Units	Watts/Unit	Installed Watts
		0	0 W	0.0 kW
		0	0 W	0.0 kW
		0	0 W	0.0 kW
Total Installed Process Loads (kW) in Main Building Area				0 kW

Process Loads		SubArea 1		Classroom
Device	Function	Num. of Units	Watts/Unit	Installed Watts
		0	0 W	0.0 kW
		0	0 W	0.0 kW
		0	0 W	0.0 kW
Total Installed Process Loads (kW) in subArea 1				0.0 kW

Process Loads		SubArea 2		Workshop/Garage
Device	Function	Num. of Units	Watts/Unit	Installed Watts
		0	0 W	0.0 kW
		0	0 W	0.0 kW
		0	0 W	0.0 kW
Total Installed Process Loads (kW) in subArea 2				0.0 kW

Figure 44: CND Level 2 Plug_Process tab - Process Loads.

Process Loads

Process load inputs and outputs for building main and sub areas are illustrated in Figure 44 above. Inputs include equipment identifier, description, number of units, rated power of the unit in watts (combustion equipment will need to have rated power converted from heat units to electrical units). The spreadsheet calculates installed kW for each sub area and for the total building.

Level 2 Case Study - Building Design Variables

Aldo Leopold Legacy Center		Basis of Analysis		Gross Measured Area
the Kubala Washatko Architects		Parking Garage Included in Analysis?		No
Baraboo	Wisconsin			

Renewable Resource Variables per Gross Measured Area		IP Units	Metric Units
Solar PV Density		3.20 Wpeak/SF	34.4 Wpeak/m^2
Wind Electric Density		0.00 Wpeak/SF	0.0 Wpeak/m^2
Solar Thermal Density		0.008 SF/SF	0.008 m^2/m^2

Building Enclosure Variables per Gross Measured Area		IP Units	Metric Units
Enclosure Area per Gross Measured Area	Total Building	2.15 SF/SF	2.15 m^2/m^2
Main Area	Office	2.00 SF/SF	2.00 m^2/m^2
SubArea 1	Classroom	2.69 SF/SF	2.69 m^2/m^2
SubArea 2	Workshop/Garage	2.66 SF/SF	2.66 m^2/m^2
Heat Transfer Rate per Gross Measured Area	Total Building	0.14 Btu/hr-sf-°F	0.78 W/m^2-°C
Main Area	Office	0.18 Btu/hr-sf-°F	1.01 W/m^2-°C
SubArea 1	Classroom	1.37 Btu/hr-sf-°F	7.76 W/m^2-°C
SubArea 2	Workshop/Garage	1.37 Btu/hr-sf-°F	7.76 W/m^2-°C

Illumination Variables per Gross Measured Area		IP Units	Metric Units
Lighting Power Density	Total	1.075 Watt/SF	11.57 Watt/m^2
Main Area	Office	1.162 Watt/SF	12.51 Watt/m^2
SubArea 1	Classroom	0.515 Watt/SF	5.55 Watt/m^2
SubArea 2	Workshop/Garage	0.703 Watt/SF	7.56 Watt/m^2

Building Glazing per Gross Measured Area		Main Area	Subarea 1	Subarea 2
	Total Building	Office	Classroom	Workshop/Garage
South	5.7%	6.0%	10.6%	0.0%
East	3.7%	3.0%	13.9%	0.0%
North	7.3%	5.8%	28.0%	0.7%
West	4.2%	3.0%	13.9%	3.9%
Horizontal	0.0%	0.0%	0.0%	0.0%
Total Glazing	21.0%	17.9%	66.3%	4.6%

Ventilation Variables per Gross Measured Area		IP Units	Metric Units
Operable Window Area	Total	6.3%	6.3%
Main Area	Office	7.1%	7.1%
SubArea 1	Classroom	6.8%	6.8%
SubArea 2	Workshop/Garage	1.0%	1.0%
Outdoor Air Ventilation Rate	Total	0.19 cfm/SF	0.98 l/s-m^2
Main Area	Office	0.25 cfm/SF	1.26 l/s-m^2
SubArea 1	Classroom	0.00 cfm/SF	0.00 l/s-m^2
SubArea 2	Workshop/Garage	0.00 cfm/SF	0.00 l/s-m^2
Supply Air Ventilation Capacity	Total	0.19 cfm/SF	0.98 l/s-m^2
Main Area	Office	0.25 cfm/SF	1.26 l/s-m^2
SubArea 1	Classroom	0.00 cfm/SF	0.00 l/s-m^2
SubArea 2	Workshop/Garage	0.00 cfm/SF	0.00 l/s-m^2

Heating Capacities per Gross Measured Area		IP Units	Metric Units
Heating Capacity	Total	4.08 Watt/SF	43.9 W/m^2
Main Area	Office	5.26 Watt/SF	56.6 W/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.0 W/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.0 W/m^2
Heating Installed Power	Total	1.70 Watt/SF	18.3 W/m^2
Main Area	Office	2.19 Watt/SF	23.6 W/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.0 W/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.0 W/m^2

CND Case Study Level 2 Metrics 12/5/10 Page 1

Figure 45: CND Level 2 - Metrics tab - Page 1.

Level 2 Case Study - Building Design Variables

Cooling Capacities per Gross Measured Area		IP Units	Metric Units
Cooling Capacity	Total	801 SF/Ton	21.2 m^2/kW
Main Area	Office	622 SF/Ton	16.4 m^2/kW
SubArea 1	Classroom	0 SF/Ton	0.0 m^2/kW
SubArea 2	Workshop/Garage	0 SF/Ton	0.0 m^2/kW
Installed Power	Total	1.70 Watt/SF	18.3 W/m^2
Main Area	Office	2.19 Watt/SF	23.6 W/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.0 W/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.0 W/m^2

Fan Efficiencies per Gross Measured Area		IP Units	Metric Units
Fan Power Density (supply & exhaust)	Total	0.20 Watt/SF	2.10 Watt/m^2
Main Area	Office	0.25 Watt/SF	2.71 Watt/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.00 Watt/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.00 Watt/m^2
Fan Volume Flow Efficiency	Total	2.1 cfm/W	1.00 Liter/s/W
Main Area	Office	2.1 cfm/W	1.00 Liter/s/W
SubArea 1	Classroom	0.0 cfm/W	0.00 Liter/s/W
SubArea 2	Workshop/Garage	0.0 cfm/W	0.00 Liter/s/W
Fan Thermal Transfer Efficiency	Total	2.3 Btu/hr-°F-W	4.36 kJ/hr-°C-W
Main Area	Office	2.3 Btu/hr-°F-W	4.36 kJ/hr-°C-W
SubArea 1	Classroom	0.0 Btu/hr-°F-W	0.00 kJ/hr-°C-W
SubArea 2	Workshop/Garage	0.0 Btu/hr-°F-W	0.00 kJ/hr-°C-W
Fan Characteristics	Flow Rate	Motor Watts	Flow Efficienncy
Constant Volume Fans	1,570 cfm	300 W	5.2 cfm/W
Variable Frequency Drive Fans	1,195 cfm	1,119 W	1.1 cfm/W
Variable Speed Fans	2,350 cfm	989 W	2.4 cfm/W

Pump Efficiencies per Gross Measured Area		IP Units	Metric Units
Pump Power Density	Total	0.14 Watt/SF	1.51 Watt/m^2
Main Area	Office	0.18 Watt/SF	1.95 Watt/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.00 Watt/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.00 Watt/m^2
Pump Volume Flow Efficiency	Total	0.09 gpm/W	0.01 Liter/s/W
Main Area	Office	0.09 gpm/W	0.01 Liter/s/W
SubArea 1	Classroom	0.00 gpm/W	0.00 Liter/s/W
SubArea 2	Workshop/Garage	0.00 gpm/W	0.00 Liter/s/W
Pump Thermal Transfer Efficiency	Total	43.7 Btu/hr-°F-W	82.95 kJ/hr-°C-W
Main Area	Office	43.7 Btu/hr-°F-W	82.95 kJ/hr-°C-W
SubArea 1	Classroom	0.0 Btu/hr-°F-W	0.00 kJ/hr-°C-W
SubArea 2	Workshop/Garage	0.0 Btu/hr-°F-W	0.00 kJ/hr-°C-W
Pump Characteristics	Flow Rate	Motor Watts	Flow Efficienncy
Constant FlowPumps	70.3 gpm	552 W	0.13 gpm/W
Variable Frequency Drive Pumps	80.9 gpm	1,181 W	0.07 gpm/W
Variable Speed Pumps	0.0 gpm	0 W	0.00 gpm/W

Figure 46: CND Level 2 - Level 2 Metrics tab - Page 2.

Level 2 - Metrics

The Level 2 Metrics for the building enclosure and systems are illustrated in Figures 45, 46 and 47. The values illustrated are for the Aldo Leopold Legacy Center. The metric area used as a basis of analysis and whether parking garage areas are included in the calculation of metrics are listed along with project data. In the case of the Legacy Center, the Gross Measured Area is the metric area of analysis.

Site renewable energy capacity per unit area is given for solar electric, wind electric and solar thermal systems.

Building Enclosure variables are given for the total building and each sub area. Enclosure variables include enclosure area per metric area and heat transfer rate per metric area. Note the difference in heat transfer rate per metric area for the Aldo Leopold Legacy Center main building and unconditioned classroom and garage.

Illumination variables include lighting power density and glazing area per metric area for total building and sub areas. For the Legacy Center, only the unconditioned classroom building has a glazing to metric area ratio larger than 20%.

Ventilation variables include operable window area per metric area, outdoor air ventilation rate per metric area and supply air ventilation capacity per metric area. Values presented are for the Legacy Center.

Heating capacity and installed power are presented for the total building and each sub area. As the main building area is the only conditioned area, the values presented illustrate the difference between considering the total building and only the main building area, which is the only sub area that is heated.

Cooling capacities include both the mazimum cooling capacity per unit metric area and the installed rated (compressor or absorption) power per unit metric area.

Fan variable metrics calculated include power density, volume flow efficiency, thermal transfer efficiency and breakdown by fan control type (constant volume, variable speed and variable frequency drive).

Pump variable metrics calculated include power density, volume flow efficiency, thermal transfer efficiency and breakdown by fan control type (constant volume, variable speed and variable frequency drive).

Finally, installed plug power density, elevator power density and process power density are given for each buildig subarea and the total building (Figure 47 on the following page).

Level 2 Case Study - Building Design Variables

Plug Load Power per Gross Measured Area		IP Units	Metric Units
	Total	0.71 Watt/SF	7.61 Watt/m^2
Main Area	Office	0.91 Watt/SF	9.80 Watt/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.00 Watt/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.00 Watt/m^2

Elevator & Escalator Power per Gross Measured Area		IP Units	Metric Units
	Total	0.00 Watt/SF	0.00 Watt/m^2
Main Area	Office	0.00 Watt/SF	0.00 Watt/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.00 Watt/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.00 Watt/m^2

Process Load Power per Gross Measured Area		IP Units	Metric Units
	Total	0.00 Watt/SF	0.00 Watt/m^2
Main Area	Office	0.00 Watt/SF	0.00 Watt/m^2
SubArea 1	Classroom	0.00 Watt/SF	0.00 Watt/m^2
SubArea 2	Workshop/Garage	0.00 Watt/SF	0.00 Watt/m^2

CND Case Study Level 2 Metrics 12/4/10 Page 3

Figure 47: CND Level 2 - Metrics tab - Page 3.

Level 2 - Graphs

The Level 2 Graphs for the building enclosure and systems are illustrated in Figures 48 and 49. Figure 48 presets the heat transfer rate for the total building and each building sub area in terms of each heat flow path. Figure 49 illustrates installed power for all flow paths.

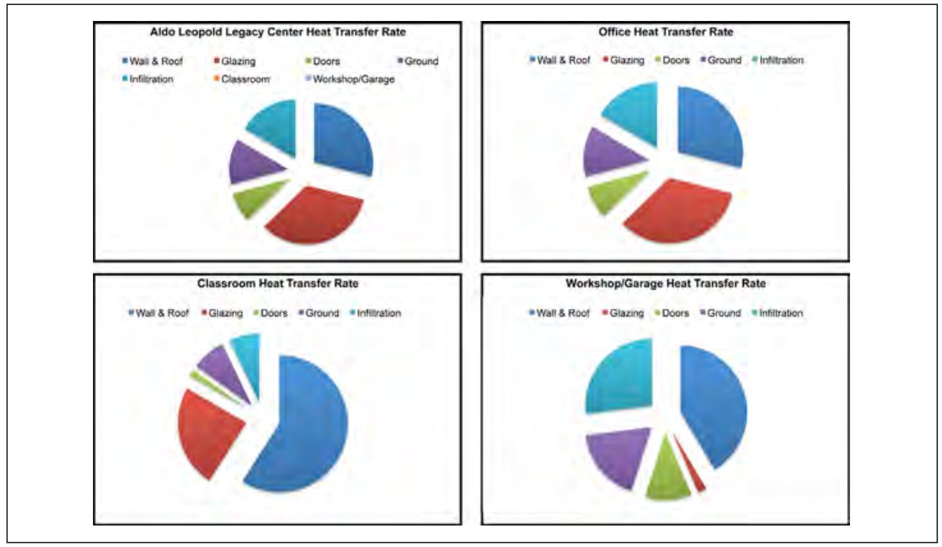


Figure 48: CND Level 2 - Graphs - Building and Sub Area Heat Transfer Rates by Flow Path.

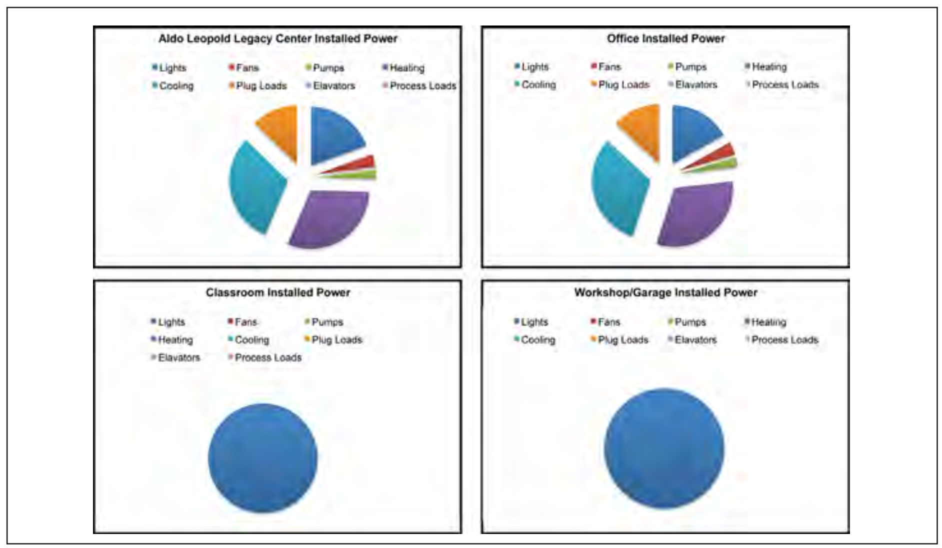


Figure 49: CND Level 2 - Graphs - Installed Power Capacities for the building and sub areas by system.

Other Resources

Alternate Frameworks for Pursuing High Performance Housing

Resources Specific to the CND Affordable Housing Guide

Resources from the CND Webiste

Glossary

Alternate Frameworks for Pursuing High Performance Housing

Energy Star Homes

(http://www.energystar.gov/index.cfm?c=new_homes.hm_index)
U.S. Environmental Protection Agency and Department of Energy

Energy Star Homes is a certification program for homes run by the Energy Star program of the US Environmental Protection Agency (EPA) and Department of Energy (DOE). Energy Star homes are required to be 15% more efficient than the 2004 International Residential Code, although they typically achieve a reduction of 20-30%. The recommended methods for achieving Energy Star Homes certification is through installing energy efficient features, like windows, heating and cooling equipment, and appliances, as well as constructing a tight building envelope and using insulation.

Energy Star Homes result in a reduction of typical home energy use through primarily active measures. CND uses passive features, including solar gain and solar orientation, and also uses carbon-neutral energy resources.
Passive House
Design philosophy

Passive House

Passive House emphasizes energy independence through extremely energy efficient design and construction. It emphasizes using a large amount of insulation, ultra-high performance windows, and heat recovery ventilation systems.

Passive House does not emphasize use of renewable energy sources for any energy needs the building may have.

ZED

Zero Energy Design (ZED) is a building philosophy in which the goal is to achieve a building design that uses no net fossil fuel energy to operate. The occupants' energy use over the course of one year less than or equal to the building's energy-generating capabilities.

ZED focuses on the building's operating energy use. Some forms of renewable energy emit carbon, like biomass and wood. Further, focusing on the operating energy ignores construction and end of life impacts.
The 2030 Challenge (http://architecture2030.org/)

Architecture 2030

The 2030 Challenge is a call to the building sector to become fully carbon neutral by 2030. They recommend designing and renovating buildings to reduce the amount of fossil fuel consumption over time, ultimately achieving 100% carbon neutrality by 2030. Fossil fuel reductions are achieved through innovative design strategies, on-site renewable (non-carbon emitting) energy generation, and offsite renewable energy, through contracting with a renewable energy provider or the purchase of renewable energy certificates.

LEED for Homes

(http://www.usgbc.org/DisplayPage.aspx?CMSPageID=147)
US Green Building Council

A certification program for homes using a point-based system in eight categories, including Innovation & Design Process, Location & Linkages, Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, and Awareness & Education. Buildings must be audited in the field for certain performance measures prior to certification. For energy, LEED for Homes requires at a minimum that projects meet the requirements of the Energy Star Homes program, described above. Projects can obtain additional points for higher reductions in energy use.

Each category has minimum requirements, but points may obtained from a number of different building elements. In terms of energy, LEED projects focus on energy performance of the building, with points being awarded for a minimum of 15% energy reduction (although a LEED project certified at Gold and Platinum may have greater energy reductions). A CND project will always have the same achievement of zero net carbon emissions.

Living Building Challenge

(http://ilbi.org/lbc)
International Living Building Institute

ILBI is a philosophy and a certification program for building projects of all scales. The goal is to design buildings that are "socially just, culturally rich, and ecologically benign." Buildings achieving the Living Building certification meet all of the program's requirements in seven categories, Site, Water, Energy, Health, Materials, Equity and Beauty. Buildings must be operational for 12 months prior to becoming certified, as this program requires meeting certain performance standards using actual data (not just projections). Requirements include building on brownfields, minimum F.A.R.'s, net zero water and energy use, and operable windows.

LBC looks at a large variety of a building and its occupants' habits, including indoor air quality, education, and sustainable sourcing. In terms of energy, it requires that a building generate on-site the amount of energy used by the building over the course of a year, not including forms of combustion (wood, biomass, etc). An LBC project will also offset the carbon used to construct the building. A CND building will offset its carbon emissions as well, however, it will do so for all carbon impacts of the building, including material extraction, waste flows, and occupant use.

Resources Specific to the CND Affordable Housing Guide

General Housing and Energy Information

US Department of Health and Human Services, LIHEAP Home Energy Notebook 2008, http://www.acf.hhs.gov/programs/ocs/liheap/guidance/information_memoranda/2008_notebook1.pdf
Energy Information Administration, National Energy Information Center, http://www.eia.gov/oiaf/1605/ggccebro/chapter1.html
US Environmental Protection Agency, Human-Related Sources and Sinks of Carbon Dioxide, http://www.epa.gov/climatechange/emissions/co2_human.html
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Chris Scheuer, Gregory A. Keoleian, Peter Reppe, "Life cycle energy and environmental performance of a new university building: modeling challenges and design implications", Energy and Buildings, Vol. 35, 2003
K. Adalberth, "Energy use during the Life Cycle of Single-Unit Dwellings: Examples", Energy and Buildings, Vol. 32, 1997
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American Physical Society Physics, "Energy Units", http://www.aps.org/policy/reports/popa-reports/energy/units.cfm

Collaboration, Design, and Evaluate

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Center for the Built Environment, "Occupant Indoor Environmental Quality (IEQ) Survey™", http://www.cbe.berkeley.edu/research/survey.htm

Landscape and Site Design

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US Environmental Protection Agency, Landscaping with Native Plants, http://www.epa.gov/greenacres/

Renewable Energy Generation

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US Environmental Protection Agency, Green Power Partnership, http://www.epa.gov/greenpower/pubs/
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US Department of Energy, US Environmental Protection Agency, World Resources Institute, and Center for Resource Solutions, “Guide to Purchasing Green Power”, http://pdf.wri.org/guide_purchase_green.pdf
Database of State Incentives for Renewables & Efficiency, http://www.dsireusa.org/
National Renewable Energy Laboratory, http://www.nrel.gov/rredc/ and Photovoltaics Research, http://www.nrel.gov/pv/thin_film/docs/lce2006.pdf
US Department of Energy, Energy Efficiency & Renewable Energy, “The Green Power Network”, http://apps3.eere.energy.gov/greenpower/about/index.shtml and “Own Your Power!: A Consumer Guide to Solar Electricity for the Home”, http://www1.eere.energy.gov/solar/pdfs/43844.pdf and “Wind Program Website”, http://www1.eere.energy.gov/windandhydro/pdfs/
World Resources Institute, “Harnessing Nature’s Power: Deploying and Financing On-Site Renewable Energy”, http://www.wri.org/publication/harnessing-natures-power
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Renewable Energy and Carbon Offsets

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Carbonfund.org, http://www.carbonfund.org/
Regional Greenhouse Gas Initiative, http://www.rggi.org/

Construction, Materials, and Waste

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US Environmental Protection Agency, “ENERGY STAR”, http://www.energystar.gov/
US Environmental Protection Agency, “Environmentally Preferable Purchasing”, http://www.epa.gov/epp/pubs/greenguides.htm
John Quale, Matthew Eckelman, Kyle Williams, Greg Sloditskie, and Julie Zimmerman, “Construction Matters: Comparing Environmental Impacts of Building Modular and Conventional Homes in the United States”, 2011
American Planning Association, “Policy Guide on Solid and Hazardous Waste Management”, 2002
Brenda Pratt, David Ciplet, Kate M. Bailey, “Stop Trashing the Climate”, Institute for Self-Reliance, 2008
Tom Napier, “Construction Waste Management”, Whole Building Design Guide, 2011
US Environmental Protection Agency, “Wastes - Resource Conservation - Reduce, Reuse, Recycle - Construction & Demolition Materials”, http://www.epa.gov/epawaste/conserve/rrr/imr/cdm/bytype.htm
Construction Materials Recycling Association, http://www.cdrecycling.org/
Whole Building Design Guide, “Construction Waste Management Database”, http://www.wbdg.org/tools/cwm.php

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A2. Online Resources: Carbon Neutral

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- ASHRAE Standard Project Committee 189.1 (SPC 189.1) Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings, Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, http://spc189.ashraepcs.org/
- Athena Eco Calculator for Assemblies, http://www.athenasmi.org/tools
- Barley, C.D.; Deru, M.; Pless, S.; Torcellini, P. (2005). Procedure for Measuring and Reporting Commercial Building Energy Performance. Technical Report NREL/TP-550-38601. Golden, CO: National Renewable Energy Lab www.nrel.gov/docs/fy06osti/38601.pdf
- Bryan, Harvey. "Developing an Operational and Material CO2 Calculation Protocol for Buildings, Sustainable Building 2008 (SB08) Conference, September 21-25, 2008, Melbourne, Australia, http://www.thegbi.org/green-resource-library/pdf/Final-SB-2008-CO2-Protocol-paper.pdf
- Build Carbon Neutral, http://buildcarbonneutral.org
- California Energy Commission, California's Energy Efficiency Standards for Residential and Nonresidential Buildings, http://www.energy.ca.gov/title24/
- Canadian Architect, Measures of Sustainability, http://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_embodied.htm#top
- Carbon Design, www.zerocarbondesign.org
- Climate Trust, Carbon Counter, http://www.carboncounter.org
- Deru, M. and P. Torcellini. (2006). Source Energy and Emission Factors for Energy Use in Buildings. Technical Report NREL/TP-550-38617. Golden, CO: National Renewable Energy Laboratory. www.nrel.gov/docs/fy06osti/38617.pdf
- Eco Calculator, www.ecoCalculator/index.html
- EPA WARM Model, http://epa.gov/climatechange/wycd
- EPA Personal Emissions Calculator, http://www.epa.gov/climatechange/emissions/ind_calculator.html
- Green Globes – Green Building Initiative, www.greenglobes.com
- LEED Green Building Rating System For New Construction & Major Renovations Version 3 (or most current) and Reference Guide, www.usgbc.org
- Meyer Boake, Terri. "The Leap to Zero Carbon and Zero Emissions: Understanding How to Go Beyond Existing Sustainable Design Protocols," Journal of Green Building, http://www.atypon-link.com/CPUB/doi/abs/10.3992/jgb.3.4.64

Click Here!
CND WEBSITE: LINKS

- Mithūn Architects, Construction Carbon Calculator (beta), http://buildcarbonneutral.org
- Open Carbon World, http://www.opencarbonworld.com/wiki/co2e-carbon-dioxide-equivalent.html
- Torcellini, P. S. Pless, and M. Deru, National Renewable Energy Laboratory D. Crawley U.S. Department of Energy. Zero Energy Buildings: A Critical Look at the Definition, preprint to be presented at ACEEE Summer Study Pacific Grove, California August 14–18, 2006, http://www.nrel.gov/docs/fy06osti/39833.pdf
- U.S. Department of Energy, www.eere.energy.gov/buildings/info/design/wholebuilding/
- U.S. Department of Energy, Net Zero Energy Commercial Building Initiative, http://www1.eere.energy.gov/buildings/commercial_initiative/
- Secretary of State for the Environment, Food and Rural Affairs, "Climate Change: The UK Program 2006," http://www.defra.gov.uk/environment/climatechange/uk/ukccp/pdf/ukccp06-all.pdf

B. THERMAL DESIGN, ENERGY, AND SYSTEMS INTEGRATION

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- Abraham, Loren E. (adaptation) and Thomas Schmitz-Gunther, editor. Living Spaces: Ecological Building and Design Cologne, Germany: Konemann Verlag., 1999.
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- Mazria, Ed. The Passive Solar Energy Book (expanded professional edition), Emmaus, PA, Rodale Press, 1979.
- McLennan, Jason. The Dumb Architect's Guide to Glazing Selection, Ecotone, 2004.
- Selkowitz, Stephen and Eleonor Lee, Dariush Arasteh, Todd Wilmert, and John Carmody. Window Systems for High-Performance Buildings, New York: W.W. Norton and Company, 2003.
- Stein, B., J. Reynolds, W. Grondzik, and A. Kwok. Mechanical and Electrical Equipment for Buildings, 10th Ed., New York: John Wiley and Sons, 2006.

A2. Online Resources: Thermal

- Architecture 2030, www.architecture2030.org
- ASHRAE. (2001). ANSI/ASHRAE/IESNA Standard 90.1-2001 Energy Standard for Buildings Except Low-Rise Residential. Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, http://spc189.ashraepcs.org/index.html
- ASHRAE Standard Project Committee 189.1 (SPC 189.1) Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings, Atlanta, GA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, http://spc189.ashraepcs.org/
- Barley, C.D.; Deru, M.; Pless, S.; Torcellini, P. (2005). Procedure for Measuring and Reporting Commercial Building Energy Performance. Technical Report NREL/TP-550-38601. Golden, CO: National Renewable Energy Lab www.nrel.gov/docs/fy06osti/38601.pdf
- Building Design Advisor, www.gaia.lbl.gov
- California Energy Commission, California's Energy Efficiency Standards for Residential and Nonresidential Buildings, http://www.energy.ca.gov/title24/
- Climate Consultant, http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=123/pagename_menu=mac/pagename=platforms
- City of Boulder. (2006). Solar Access Guide, Building Services Center, Boulder, Colorado http://joomla.ci.boulder.co.us/files/PDS/codes/solrshad.pdf
- Deru, M. and P. Torcellini. (2004). Improving Sustainability of Buildings through a Performance-Based Design Approach: Preprint. NREL Report

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- Efficient Windows Collaborative, http://www.efficientwindows.org/
- Heschong Mahone Group, www.h-m-g.com
- Home Energy Efficient Design (HEED): http://mackintosh.aud.ucla.edu/heed/
- ECOTECT, Autodesk, 2009, http://www.ecotect.com/
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- National Renewable Energy Lab, www.nrel.gov
- National Renewable Energy Lab, "Learning About Renewable Energy": www.nrel.gov/learning/re_basics.html
- National Wind Association, www.awea.org
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- RETScreen: www.retscreen.net/ang/home.php
- Torcellini, P., M. Deru, B. Griffith, N. Long, S. Pless, R. Judkoff, and D. Crawley. (2004). Lessons Learned from Field Evaluation of Six High-Performance Buildings. Paper #358, Proceedings (CD-ROM), ACEEE Summer Study on Energy Efficiency in Buildings, August 22-27, 2004, Pacific Grove, CA. Golden, CO: National Renewable Energy Laboratory, www.nrel.gov/docs/fy04osti/36290.pdf
- Torcellini, P. S. Pless, and M. Deru, National Renewable Energy Laboratory D. Crawley U.S. Department of Energy. Zero Energy Buildings: A Critical Look at the Definition, preprint to be presented at ACEEE Summer Study Pacific Grove, California August 14–18, 2006, http://www.nrel.gov/docs/fy06osti/39833.pdf
- U.S. Department of Energy, Integrated Buildings, www.eere.energy.gov/buildings/info/design/integratedbuilding
- U.S. Department of Energy (DOE) Sponsored Tools (from the U.S. DOE Website). http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm
  - BESTEST, http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored_bestest.cfm; Through the National Renewable Energy Laboratory, the Department of Energy has been working with the International Energy Agency Solar Cooling and Heating Programme Implementing Agreement (IEA SHC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for more than the last 10 years to develop standard methods of test for building energy analysis computer software.
  - Building Design Advisor, http://gaia.lbl.gov/BDA/; Provides building decision-makers with the energy-related information they need beginning in the initial, schematic phases of building design through the detailed specification of building components and systems.
  - COMCheck-EZ, http://www.energycodes.gov/comcheck/; COMcheck-EZ offers an easy-to-understand process for demonstrating compliance with ASHRAE 90.1-1989 and IECC commercial energy code requirements for envelope, lighting, and mechanical systems.
  - COMCheck-Plus, http://www.energycodes.gov/comcheck/; COMCheck-Plus is designed to simplify the process of demonstrating compliance with commercial building energy codes using the whole building performance method.
  - DOE-2, http://simulationresearch.lbl.gov/; An hourly, whole-building energy analysis program which calculates energy performance and life-cycle cost of operation. The current version is DOE-2.1E.
  - EnergyPlus, http://apps1.eere.energy.gov/buildings/energyplus/; A new-generation building energy simulation program from the creators of BLAST and DOE-2.
  - Energy-10, http://www.nrel.gov/buildings/energy10.html; A program for small commercial and residential buildings that integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient envelope design, and mechanical equipment.

This allows for detailed simulation and performance analysis.

- SPARK, http://simulationresearch.lbl.gov/; Models complex building envelopes and mechanical systems that are beyond the scope of EnergyPlus and DOE-2. Good for modeling short time-step dynamics. Runs 10-20 times faster than similar programs.
- REScheck (formerly MECcheck), http://www.energycodes.gov/rescheck/; The MECcheck product group makes it fast and easy for designers and builders to determine whether new homes and additions meet the requirements of the Model Energy Codes (MEC) and International Energy Conservation Codes (IECC)
- RESFEN, http://windows.lbl.gov/software/resfen/resfen.html; Calculates the heating and cooling energy use and associated costs as well as the peak heating and cooling demand for specific window products in residential buildings.
- Therm, http://windows.lbl.gov/software/therm/therm.html; Performs analysis of two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern.
- WINDOW, http://windows.lbl.gov/software/window/window.html; WINDOW 4.1 is a publicly available IBM PC compatible computer program for calculating total window thermal performance indices (i.e. U-values, solar heat gain coefficients, shading coefficients, and visible transmittances).

- Wind Power, http://www.windpower.org/en/tour/wres/index.htm

C. PASSIVE HEATING AND PASSIVE COOLING

C1. Books and Articles: Passive

- Anderson Bruce and Malcolm Wells. Passive Solar Energy: The Homeowner's Guide to Natural Heating and Cooling, NH: Brick House, 1996.
- Brown, G. Z. and DeKay, M. Sun, Wind & Light: Architectural Design Strategies, 2nd Edition. New York, NY: John Wiley and Sons, 2000.
- Chiras, Daniel. The Solar House: Passive Heating and Cooling, VT: Chelsea Green, 2002.
- European Commission. The Climatic Dwelling, London: James & James, 1998.
- Givoni B. Climate Considerations in Building and Urban Design, New York: Van Nostrand Reinhold, 1998.
- Givoni B. Passive and Low Energy Cooling of Buildings, New York: Van Nostrand Reinhold, 1995.
- La Roche, P., C. Quirós, G. Bravo, M. Machado, G. Gonzalez. PLEA Note 6, Keeping Cool: Principles to Avoid Overheating in Buildings, Kangaroo Valley, Australia: Passive Low Energy Architecture Association & Research Consulting and Communications, 2001, 60.
- Lomas, K. and M. Cook, D. Fiala. Architectural Design of an Advanced Naturally Ventilated Building Form, Energy and Buildings. 2007.
- Lynch, Kevin. Site Planning, Cambridge, MA: MIT Press, 1984.
- Mazria, Ed. Passive Solar Energy Book, Emmaus: Rodale Press, 1979.
- McHarg, Ian. Design with Nature, Garden City: Doubleday/Natural History Press, 1969.
- Olgay, Victor. Design with Climate, Princeton N.J.: Princeton University Press, 1965.
- Sale, Kirkpatrick. Dwellers in the Land: The Bioregional Vision, Athens: The University of Georgia Press, 2000.
- Short, C.A. and K. Lomas. Low Energy Architecture for a Severe US Climate: Design and Evaluation of a Hybrid Ventilation Strategy. Energy and Buildings. 2007.
- Steven Winter Associates. The Passive Solar Design and Construction Handbook, New York: John Wiley and Sons, 1997.
- Watson, Donald and Labs Kenneth. Climatic Building Design: Energy-Efficient Building Principles and Practices, New York: McGraw-Hill, 1993.

C2. Online Resources: Passive

- American Solar Energy Society, http://www.ases.org
- Archi-Physics Solar Tools, www.archiphysics.com

- Bioregional Congress Homepage, http://www.bioregional-congress.org/index.htm
- City of Boulder. (2006). Solar Access Guide, Building Services Center, Boulder, Colorado http://joomla.ci.boulder.co.us/files/PDS/codes/solrshad.pdf
- Climate Consultant, http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=123/pagename_menu=mac/pagename=platforms
- ECOTECT, Autodesk, 2009, http://www.ecotect.com/
- Heschong Mahone Group, www.h-m-g.com
- Home Energy Efficient Design (HEED), http://mackintosh.aud.ucla.edu/heed/
- International Solar Energy Society, www.ises.org
- National Hydrogen Association, www.hydrogenassociation.org
- National Renewable Energy Lab, www.nrel.gov
- National Renewable Energy Lab, "Learning About Renewable Energy": www.nrel.gov/learning/re_basics.html
- National Wind Association, www.awea.org
- Natural Resources Canada, www.advancedbuildings.org
- Ramlow Bob with Benjamin Nusz. Solar Water Heating, a Comprehensive Guide to Solar Water & Space Heating Systems, www.arthaonline.com
- Torcellini, P. S. Pless, and M. Deru, National Renewable Energy Laboratory D. Crawley U.S. Department of Energy. Zero Energy Buildings: A Critical Look at the Definition, preprint to be presented at ACEEE Summer Study Pacific Grove, California August 14–18, 2006, http://www.nrel.gov/docs/fy06osti/39833.pdf
- U.S. Department of Energy, Energy Plus Weather Data, http://apps1.eere.energy.gov/buildings/energyplus/cfm/r_data.cfm
- U.S. Department of Energy (DOE) Sponsored Tools (from the U.S. DOE Website). http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm
    - Building Design Advisor, http://gaia.lbl.gov/BDA/; Provides building decision-makers with the energy-related information they need beginning in the initial, schematic phases of building design through the detailed specification of building components and systems.
    - COMCheck-EZ, http://www.energycodes.gov/comcheck/; COMcheck-EZ offers an easy-to-understand process for demonstrating compliance with ASHRAE 90.1-1989 and IECC commercial energy code requirements for envelope, lighting, and mechanical systems.
    - COMCheck-Plus, http://www.energycodes.gov/comcheck/; COMCheck-Plus is designed to simplify the process of demonstrating compliance with commercial building energy codes using the whole building performance method.
    - DOE-2, http://simulationresearch.lbl.gov/; An hourly, whole-building energy analysis program which calculates energy performance and life-cycle cost of operation. The current version is DOE-2.1E.
    - EnergyPlus, http://apps1.eere.energy.gov/buildings/energyplus/; A new-generation building energy simulation program from the creators of BLAST and DOE-2.
    - Energy-10, http://www.nrel.gov/buildings/energy10.html; A program for small commercial and residential buildings that integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient envelope design, and mechanical equipment. This allows for detailed simulation and performance analysis.
    - SPARK, http://simulationresearch.lbl.gov/; Models complex building envelopes and mechanical systems that are beyond the scope of EnergyPlus and DOE-2. Good for modeling short time-step dynamics. Runs 10-20 times faster than similar programs.
    - REScheck (formerly MECcheck), http://www.energycodes.gov/rescheck/; The MECcheck product group makes it fast and easy for designers and builders to determine whether new homes and additions meet the requirements of the Model Energy Codes (MEC) and International Energy Conservation Codes (IECC)
    - RESFEN, http://windows.lbl.gov/software/resfen/resfen.html; Calculates the heating and cooling energy use and associated costs as well as the peak heating and cooling demand for specific window products in residential buildings.

- Therm, http://windows.lbl.gov/software/therm/therm.html; Performs analysis of two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern.
- WINDOW, http://windows.lbl.gov/software/window/window.html; WINDOW 4.1 is a publicly available IBM PC compatible computer program for calculating total window thermal performance indices (i.e. U-values, solar heat gain coefficients, shading coefficients, and visible transmittances).

- Wind Power: http://www.windpower.org/en/tour/wres/index.htm

D. DAYLIGHTING DESIGN

D1. Books and Articles: Daylighting

- Ander, Gregg. Daylighting, Performance and Design, New York: Van Nostrand Reinhold, 1995.
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- Baker, N.V., A. Fanchiotti, and K. Steemers, editors. Daylighting in Architecture: A European Reference Book. London: James & James, 2001.
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- Egan, David and Victor Olgyay. Daylight in Buildings. International Energy Agency, 2000. Architectural Lighting, Second Edition. McGraw Hill, 2nd Ed, 2002.
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- Daylighting Collaborative, www.daylighting.org
- Department of Energy, www.eere.energy.gov/buildings/info/design/integratedbuilding/passivedaylighting.html
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- Efficient Windows Collaborative, http://www.efficientwindows.org/
- Glass Resources, www.glass-resource.com
- Heschong Mahone Group, www.h-m-g.com
- Home Energy Efficient Design (HEED), http://mackintosh.aud.ucla.edu/heed/
- Insulating Glass Manufacturers Association, www.igmaonline.com

- International Solar Energy Society, www.ises.org
- Lawrence Berkeley Laboratory, Tips for Daylighting with Windows, www.lbl.gov
- Lighting Research Center, www.lrc.rpi.edu
- Lighting Research Center, Guide for Daylighting Schools, Innovative Design, 2004, www.lrc.rpi.edu
- National Fenestration Rating Council, www.nfrc.org
- Natural Resources Canada, Daylighting Guide for Canadian Commercial Buildings, www.advancedbuildings.org
- Reinhart, C., Advanced Daylight Simulation using ECOTECT, Radiance, Autodesk, 2009, Autodesk ECOTECT Wiki, http://squ1.org/front_.
- U.S. Department of Energy, 2009, Energy Plus Weather Data, http://apps1.eere.energy.gov/buildings/energyplus/cfm/r_data.cfm
- U.S. Department of Energy (DOE) Sponsored Tools (from the U.S. DOE Website), http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm
    - Building Design Advisor, http://gaia.lbl.gov/BDA/; Provides building decision-makers with the energy-related information they need beginning in the initial, schematic phases of building design through the detailed specification of building components and systems.
    - DOE-2, http://simulationresearch.lbl.gov/; An hourly, whole-building energy analysis program which calculates energy performance and life-cycle cost of operation. The current version is DOE-2.1E.
    - EnergyPlus, http://apps1.eere.energy.gov/buildings/energyplus/; A new-generation building energy simulation program from the creators of BLAST and DOE-2.
    - Energy-10, http://www.nrel.gov/buildings/energy10.html; A program for small commercial and residential buildings that integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient envelope design, and mechanical equipment. This allows for detailed simulation and performance analysis.
    - SPARK, http://simulationresearch.lbl.gov/; Models complex building envelopes and mechanical systems that are beyond the scope of EnergyPlus and DOE-2. Good for modeling short time-step dynamics. Runs 10-20 times faster than similar programs.
    - RESFEN, http://windows.lbl.gov/software/resfen/resfen.html; Calculates the heating and cooling energy use and associated costs as well as the peak heating and cooling demand for specific window products in residential buildings.
    - WINDOW, http://windows.lbl.gov/software/window/window.html; WINDOW 4.1 is a publicly available IBM PC compatible computer program for calculating total window thermal performance indices (i.e. U-values, solar heat gain coefficients, shading coefficients, and visible transmittances).

E. ENVELOPE DESIGN

E1. Books and Articles: Envelope

- Balkow et al. Glass Construction Manual, Boston: Birkhäuser, 1999.
- Carmody, John, Stephen Selkowitz, Dariush Arasteh and Lisa Heschong. Residential Windows: A Guide to New Technologies and Energy Performance, Norton, 2000, 2007.
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E2. Online Resources: Envelope

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- Home Energy Efficient Design (HEED), http://mackintosh.aud.ucla.edu/heed/
- Insulating Glass Manufacturers Association, www.igmaonline.com
- National Fenestration Rating Council, www.nfrc.org
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- Reinhart, C., Advanced Daylight Simulation using ECOTECT, Radiance, Autodesk, 2009, Autodesk ECOTECT Wiki, http://squ1.org/front_.
- U.S. Department of Energy, 2009, Energy Plus Weather Data, http://apps1.eere.energy.gov/buildings/energyplus/cfm/r_data.cfm
- U.S. Department of Energy (DOE) Sponsored Tools (from the U.S. DOE Website), http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm
    - Building Design Advisor, http://gaia.lbl.gov/BDA/; Provides building decision-makers with the energy-related information they need beginning in the initial, schematic phases of building design through the detailed specification of building components and systems.
    - DOE-2, http://simulationresearch.lbl.gov/; An hourly, whole-building energy analysis program which calculates energy performance and life-cycle cost of operation. The current version is DOE-2.1E.
    - EnergyPlus, http://apps1.eere.energy.gov/buildings/energyplus/; A new-generation building energy simulation program from the creators of BLAST and DOE-2.
    - Energy-10, http://www.nrel.gov/buildings/energy10.html; A program for small commercial and residential buildings that integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient envelope design, and mechanical equipment. This allows for detailed simulation and performance analysis.
    - SPARK, http://simulationresearch.lbl.gov/; Models complex building envelopes and mechanical systems that are beyond the scope of EnergyPlus and DOE-2. Good for modeling short time-step dynamics. Runs 10-20 times faster than similar programs.
    - RESFEN, http://windows.lbl.gov/software/resfen/resfen.html; Calculates the heating and cooling energy use and associated costs as well as the peak heating and cooling demand for specific window products in residential buildings.
    - Therm, http://windows.lbl.gov/software/therm/therm.html; Performs analysis of two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern.
    - WINDOW, http://windows.lbl.gov/software/window/window.html; WINDOW 4.1 is a publicly available IBM PC compatible computer program for calculating total window thermal performance indices (i.e. U-values, solar heat gain coefficients, shading coefficients, and visible transmittances).
- Viracon Glass, www.viracon.com
- Visteon Glass, www.visteon.com

F. SUSTAINABLE DESIGN

F1. Books and Articles: Sustainable

- Benyus, Janine. Biomimicry, New York: William Marrow, 1997.
- Capra, Fritjof. The Web of Life, New York: Doubleday, 1996.
- Elgin, Duane. Promise Ahead: A Vision of Hope and Action for Humanity's Future, New York: William Marrow, 2000.
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F2. Online Resources: Sustainable

- Biomimicry, http://www.biomimicry.net
- BuildingGreen Suite, www.buildinggreen.com
- Canadian Architect, Measures of Sustainability, http://www.canadianarchitect.com/asf/perspectives_sustainibility/measures_of_sustainablity/measures_of_sustainablity_embodied.htm#top
- Hawken, Paul. Taking the Natural Step, In Context: A Quarterly of Humane Sustainable Culture, http://www.context.org/ICLIB/IC41/Hawken2.htm
- Integrating Habitats, http://www.integratinghabitats.org/
- Leadership in Energy and Environmental Design (LEED), U.S. Green Building Council, www.usbc.org/LEED/LEED_main.asp
- U.S. Environmental Protection Agency, www.epa.gov
- Worldwatch Institute, http://www.worldwatch.org.
- Global Footprint Network, www.footprintnetwork.org/gfn_sub.php?content+global_footprint

G. DESIGN TOOLS

Online Resources - Tools

- Archi-Physics Solar Tools, www.archiphysics.com

- Athena Eco Calculator for Assemblies, http://www.athenasmi.org/tools/
- Build Carbon Neutral, http://buildcarbonneutral.org/
- BuildingGreen Suite, www.buildinggreen.com
- Carbon Design, www.zerocarbondesign.org
- Climate Trust, Carbon Counter, http://www.carboncounter.org/
- DAYSIM, Getting Started, McGill University, http://www.arch.mcgill.ca/prof/reinhart/software/GettingStarted.pdf
- Eco Calculator, www.ecoCalculator/index.html
- ECOTECT, Autodesk, 2009, http://www.ecotect.com/
- EPA WARM Model, http://epa.gov/climatechange/wycd/
- EPA Personal Emissions Calculator, http://www.epa.gov/climatechange/emissions/ind_calculator.html
- Green Globes – Green Building Initiative, www.greenglobes.com
- Home Energy Efficient Design (HEED), http://mackintosh.aud.ucla.edu/heed/
- James J. Hirsch and Associates, eQUEST, quick energy simulation tool: introductory tutorial, http://www.doe2.com/download/equest/eQUESTv3-40_Tutorial.exe.
- LEED Green Building Rating System For New Construction & Major Renovations Version 2.2 (or most current) and Reference Guide, www.usgbc.org
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- Mithūn Architects, Construction Carbon Calculator (beta), http://buildcarbonneutral.org/
- Reinhart, C., Advanced daylight simulation using ECOTECT, Radiance, Autodesk, 2009, Autodesk ECOTECT Wiki, http://squ1.org/front_.
- RETScreen, www.retscreen.net/ang/home.php.
- US Department of Energy, 2009, Energy Plus Weather Data, http://apps1.eere.energy.gov/buildings/energyplus/cfm/r_data.cfm
- U.S. Department of Energy, Whole Building, www.eere.energy.gov/buildings/info/design/wholebuilding/
- U.S. Department of Energy (DOE) Sponsored Tools (from the U.S. DOE Website), http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm
    - BESTEST, http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored_bestest.cfm; Through the National Renewable Energy Laboratory, the Department of Energy has been working with the International Energy Agency Solar Cooling and Heating Programme Implementing Agreement (IEA SHC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for more than the last 10 years to develop standard methods of test for building energy analysis computer software.
    - Building Design Advisor, http://gaia.lbl.gov/BDA/; Provides building decision-makers with the energy-related information they need beginning in the initial, schematic phases of building design through the detailed specification of building components and systems.
    - COMCheck-EZ, http://www.energycodes.gov/comcheck/; COMcheck-EZ offers an easy-to-understand process for demonstrating compliance with ASHRAE 90.1-1989 and IECC commercial energy code requirements for envelope, lighting, and mechanical systems.
    - COMCheck-Plus, http://www.energycodes.gov/comcheck/; COMCheck-Plus is designed to simplify the process of demonstrating compliance with commercial building energy codes using the whole building performance method.
    - DOE-2, http://simulationresearch.lbl.gov/; An hourly, whole-building energy analysis program which calculates energy performance and life-cycle cost of operation. The current version is DOE-2.1E.
    - EnergyPlus, http://apps1.eere.energy.gov/buildings/energyplus/; A new-generation building energy simulation program from the creators of BLAST and DOE-2.
    - Energy-10, http://www.nrel.gov/buildings/energy10.html; A program for small commercial and residential buildings that integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient envelope design, and mechanical equipment.

Glossary

Building Envelope

The building envelope is the critical first line of defense in building an energy efficient structure. The envelope, or the exterior elements, includes walls, windows and doors, roof, foundation, insulation, and shading.

Building Systems

Building systems include the passive, mechanical, and/or electrical services that are integrated into a building's design for occupant comfort. Building systems regulate light and airflow and provide services like plumbing and electricity.

Carbon

The term 'carbon' in this guidebook is often used to reference carbon dioxide (CO_2), which is a naturally occurring gas with many important uses. Since the industrial revolution however the concentration of CO_2 has built up significantly in the earth's atmosphere. This increase, a byproduct of burning fossil fuels and biomass, land-use changes, and other industrial processes, is one of the reasons scientists are so concerned about the changes in greenhouse gases. CO_2 is also used as the reference gas against which the other greenhouse gases are measured for Global Warming Potential (GWP). Therefore the term carbon is sometimes used to describe the combined effect of CO_2 with other greenhouse gases such as methane, nitrous oxides (NOx), and sulphur oxides (SOx).

CO2 Equivalent (CO2e)

The unit of measurement used to indicate the global warming potential (GWP) of a greenhouse gas. The climate change impact of all greenhouse gases is measured in terms of equivalency to the impact of carbon dioxide (CO_2). For example, one million tons of emitted methane, a far more potent greenhouse gas than carbon dioxide, is measured as 23 million metric tons of CO_2 equivalent, or 23 million $MtCO_2e$.

Carbon Footprint

A carbon footprint seeks to quantify the impact of an activity or series of activities by identifying the greenhouse gas emissions generated. This is done to document the direct and indirect emissions generated and seek ways to reduce the activity's climate impacts.

Carbon Neutral- Operating Energy + Embodied Energy

This definition for Carbon Neutrality builds upon the definition above and also adds the carbon that is a result of the embodied energy associated with the materials used to construct the building. This value is far more difficult to calculate. The initial embodied energy in buildings represents the non-renewable energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction. 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 consumption increases. Clearly, for buildings claiming to be "zero-energy" or "autonomous", the energy used in construction and final disposal takes on a new significance.

Carbon Neutral- Operating Energy + Site Energy + Occupant Travel

This definition of Carbon Neutrality builds upon the inclusion of operating energy and embodied energy, and also reflects the carbon costs associated with a building's location. This requires a calculation of the personal carbon emissions associated with the means and distance of travel of all employees and visitors to the building.

Carbon Offset

Carbon offsets help to pay for carbon sequestration projects elsewhere. Offset purchasers buy certificates for tons of carbon reduced through methane capture, renewable energy generation, and landfill gas utilization

Carbon sequestration

The capture of carbon dioxide. This happens naturally in organic matter but can be done intentionally to prevent carbon dioxide emissions to the atmosphere through various carbon capture technologies or the use of carbon sinks.

Carbon sink

A place to store carbon for an indefinite period of time. Natural carbon sinks include organic matter and oceans.

Energy Units

Joule (J) – the basic unit of energy used in the metric system
British thermal unit (Btu) – a unit used to describe heat energy, often how much energy is required to raise the temperature of 1 g of water by 1°C; is often used to quantify natural gas, gas, and oil consumption. 1 Btu = 1055.06 J
Kilowatt-hour – the standard unit of electricity production and consumption. 1 kWh = 1.6 x 106

Greenfield development

Greenfield development occurs outside of the urbanized area of a community. This typically includes sites that have never been developed that were previously open space or agricultural or forest land. Greenfield sites may be less expensive to acquire, but typically rely on infrastructure extensions to be successful.

Global Warming Potential (GWP)

Global Warming Potential is a way to measure the ability of greenhouse gases to contribute to climate change. It is a relative scale that uses CO_2 as a baseline.

Infill development

Infill development occurs within the urbanized area of a community. This includes sites that were previously developed and sites that have been not. Infill development sites can typically connect to existing infrastructure, including utility and transportation, easily and at a lower cost.

LEED

LEED is an acronym for Leadership in Energy and Environmental Design and is a certification system for building design, construction, and operation by the U.S. Green Building Council, a non-profit organization. Projects seeking LEED certification can get points in a variety of categories, including energy use, materials, and systems.

Life Cycle Assessment

(http://www.epa.gov/nrmrl/lcaccess/pdfs/600r06060.pdf)

Life Cycle Assessment is a quantitative framework for analyzing a product or material's cumulative environmental impacts throughout its life cycle, generally from raw material extraction to product manufacturing, consumer use, and disposal. LCA compiles information on energy use, material inputs, and environmental releases at each stage in a product's life and generates values of different emissions and waste streams. LCA is a tool that can be used to determine environmental impacts. By generating a number, typically in carbon equivalent, two products can be compared side-by-side for their environmental impacts. CND uses LCA as a tool to quantify the impacts of materials used in a building project in order to offset the carbon impacts.

Net Zero Energy Cost

In a net zero energy cost building, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.

Net Zero Energy Emissions- the 2030 Challenge Standard

A net zero energy emissions building produces at least as much emissions-free renewable energy as it uses from emission-producing energy sources annually. CO_2, NO_x, and SO_x are common emissions that ZEBs offset.
Carbon Neutral: Operating Energy: Carbon neutral with respect to operating energy means using no fossil fuel greenhouse gas emitting energy to operate the building. Building operation includes all energy used, such as heating, cooling and lighting. It is believed that currently operating energy accounts for approximately 70% of the carbon emissions associated with a building.

Passive design

Designs that do not require electrical or mechanical energy to function. Examples include using windows for daylighting and ventilation and shades to regulate temperature.

Passive solar design

Passive solar design is a system of building elements that together help regulate the internal temperature of a space without added electrical or mechanical energy. Elements include aperture, absorber, thermal mass, distribution, and control.

Phantom load

The electricity consumed by an electronic device when it is turned off. This can include the power used on standby lights and wireless receivers.

Renewable Energy offset

Renewable energy offsets help to pay for renewable energy generation projects elsewhere. Offset purchasers buy certificates for megawatts of energy generated by large-scale projects, including wind and solar farms.

if we were to do both of these projects over again, we would do them as net-zero energy projects. And we would succeed. We'd know how to do it. And we finally have the terminology and the marketing ability to say how much value is added.

What wasn't available when these projects were designed was the word zero.

-Brian Bowen
Project Architect,
Wild Sage Co-Housing Community