The Leap to Zero Carbon:
Preparing for the 2030 Challenge

Defining the FIRST STEPS to Carbon Neutral Design

Overview:

Designing to Zero Carbon standards as defined by the Architecture2030 Challenge, requires a modified approach to current sustainable and high performance design methods. This session will answer the question “What is Zero Carbon?” and through a series of key case studies differentiate the means by which sustainable/high performance and low carbon buildings are designed. Case studies will be used to demonstrate how new low-carbon strategies and systems are incorporated to reduce GHG emissions.

Learning Objectives

- **Differentiate between sustainable design and carbon neutral** (zero carbon) design.
- **Incorporate comprehensive sustainable strategies** into their projects based upon bioclimatic considerations that respond to passive environmental design basics.
- **Prioritize the critical design issues** and questions to meet advanced sustainable design targets, leading to the **potential to incorporate zero energy/zero emissions** and carbon neutral.
- **Identify key strategies** that must be included in architectural design in order to design buildings to carbon neutral, zero energy standards.
- **Assess the architectural implications and potential** of including Zero Carbon/Zero Energy strategies, materials and methods in a project.

Global Warming and Sustainable Design:

- A priority has been placed, above and beyond current trends in Sustainable Design, on the reduction of GHG emissions
- Buildings account for more than 40% of the GHG
- Green, Sustainable and High Performance Buildings are not going far enough, quickly enough in reducing their negative impact on the environment, and certainly not far enough to offset the balance of building that marches on in ignorance
- Carbon Neutrality focuses on the relationship between all aspects of “building/s” and CO_2 emissions
- Carbon Neutral Design strives to reverse trends in Global Warming

Differentiating *Sustainable* vs. *Zero Carbon/Carbon Neutral:*

Sustainable design is a *holistic* way of designing buildings to minimize their environmental impact through:

- **Reduced dependency on non-renewable resources**
- **A more bio-regional response to climate and site**
- **Increased efficiency in the design of the building envelope and energy systems**
- **A environmentally sensitive use of materials**
- **Focus on healthy interior environments**
- **Characterized by buildings that aim to *"live lightly on the earth"* and**

-***"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."***

United Nations World Commission on Environment and Development

From ZED to Carbon Neutral

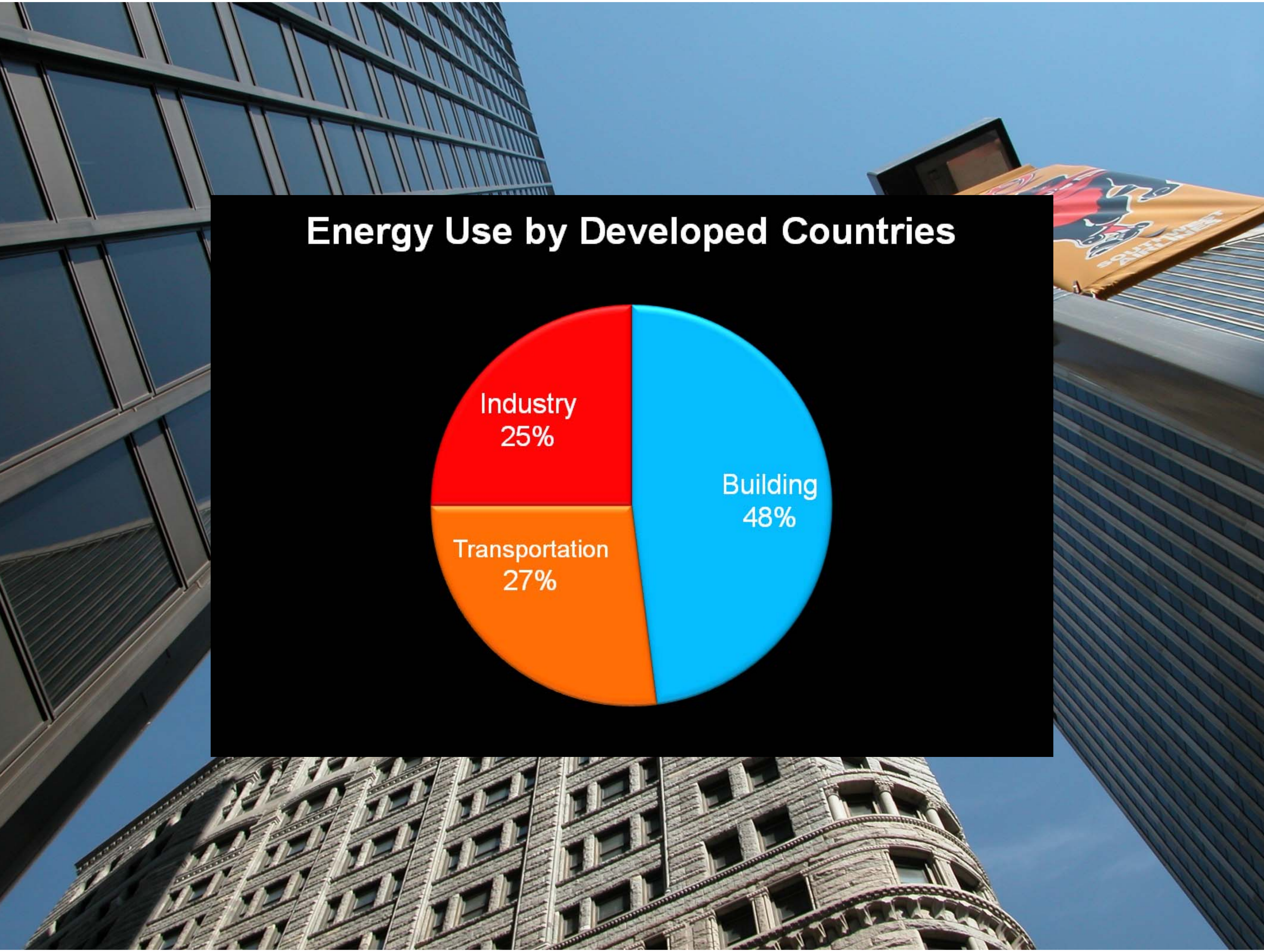
A **Near Zero Energy** building produces at least 75% of its required energy through the use of on-site renewable energy. Off-grid buildings that use some non-renewable energy generation for backup are considered near zero energy buildings because they typically cannot export excess renewable generation to account for fossil fuel energy use.

A **Carbon Neutral Building** derives 100% of its energy from non fossil fuel based renewables.

Why Assess Carbon Neutrality?

- Sustainable design does not go far enough
- Assessing carbon is complex, but necessary
- The next important goal to reverse the effects of global warming and reduce CO^2 emissions it to make our buildings **"carbon neutral"**
- **"architecture2030"** is focused on raising the stakes in sustainable design to challenge designers to radically reduce their carbon emissions by the year 2030

www.architecture2030.org


Energy Use by Developed Countries
Industry 25%
Building 48%
Transportation 27%

The Global Warming Pie....

These values look at <u>Secondary **Energy Use** by Sector in Canada (2006)</u>

(*energy used by the final consumer i.e. operating energy*)

The LEAP to Zero Carbon and beyond…

- Energy Efficient (mid 1970s "Oil Crisis" reaction)
- High Performance (accountable)
- **Green (environmentally responsive)**
- Sustainable (holistic and accountable)
- Carbon Neutral (Zero Fossil Fuel Energy)
- Restorative
- Regenerative (Living Buildings)

…a steady increase in the nature and
expectations of performance criteria

Fossil Fuel Reduction Standard:

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**).

Source: www.architecture2030.org

2030 Targets - Commercial

2030 CHALLENGE Targets: National Averages

U.S. Average Site Energy Use and 2030 Challenge Energy Reduction Targets by Space/Building Type (CBECS 2003)[1]

From the Environmental Protection Agency (EPA): Use this chart to find the site fossil-fuel energy targets.

Primary Space/Building Type [2]	Available in Target Finder [3]	Average Source EUI [4] (kBtu/Sq.Ft./Yr)	Average Percent Electric	Average Site EUI [4] (kBtu/Sq.Ft./Yr)	2030 Challenge Site EUI Targets (kBtu/Sq.Ft./Yr)				
					50% Target	60% Target	70% Target	80% Target	90% Target
Administrative/Professional & Government Office	✓								
Bank	✓								
Clinic/other outpatient health		219	76%	84.2	**42.1**	33.7	25.3	16.8	8.4
College/university (campus-level)		280	63%	120	**60**	48	36	24	12
Convenience store (with or without gas station)		753	90%	241.4	**120.7**	96.6	72.4	48.3	24.1
Distribution/shipping center		90	61%	44.2	**22.1**	17.7	13.3	8.8	4.4
Fast food		1306	64%	534.3	**267.2**	213.7	160.3	106.9	53.4
Fire station/police station		157	56%	77.9	**39.0**	31.2	23.4	15.6	7.8
Hospital/inpatient health	✓								
Hotel, Motel or inn	✓								
K-12 School	✓								
Medical Office	✓								

Target Finder is an online tool:
http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder

2030 Targets – Residential:

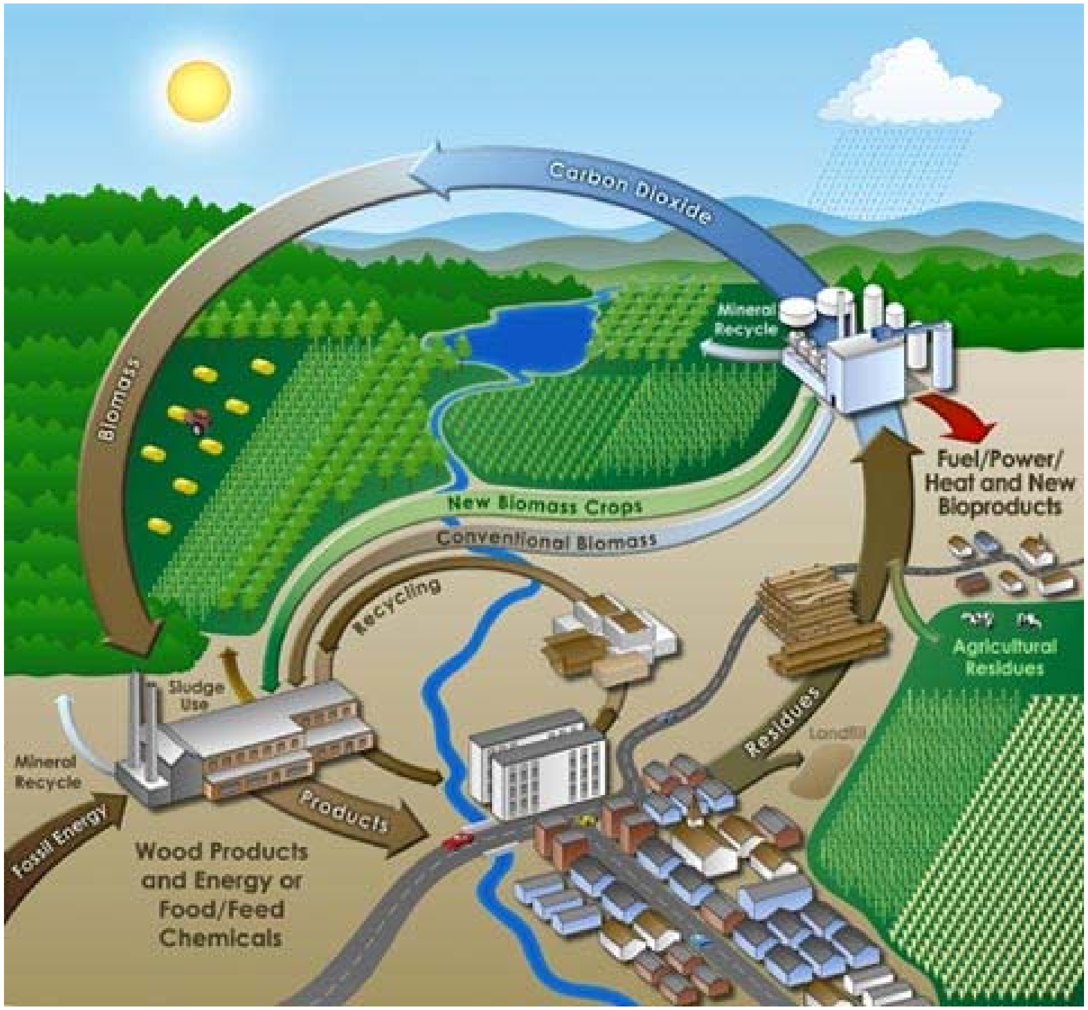
2030 CHALLENGE Targets: Residential Regional Averages

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

…etc.

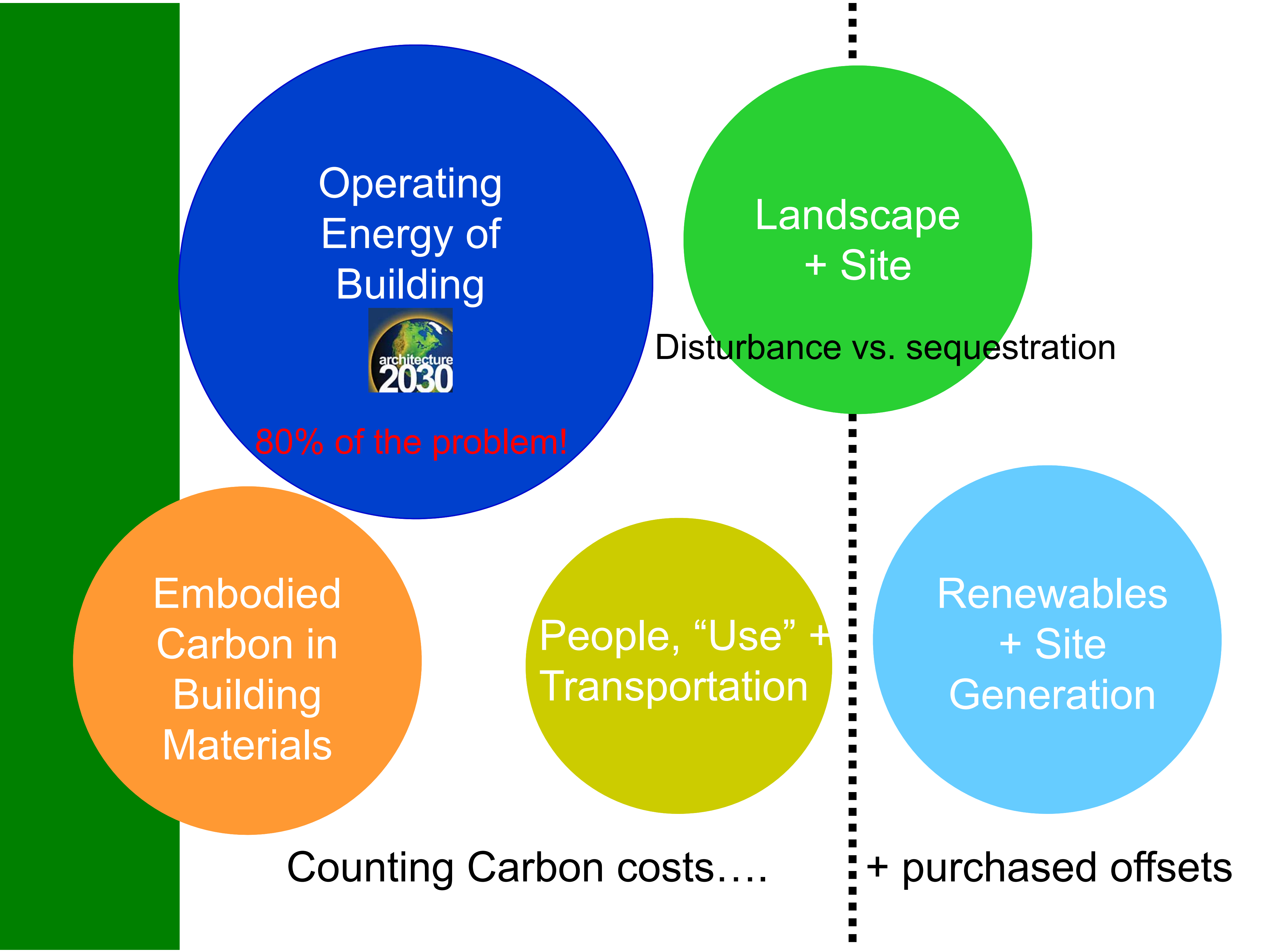
http://www.architecture2030.org/downloads/2030_Challenge_Targets_Res_Regional.pdf

Buildings / Processes and the Carbon Cycle:



http://www.repp.org/bioenergy/bioenergy-cycle-med2.jpg

As the way that buildings interact with carbon is highly complex, the first aim is to reduce operating energy as it is the most significant and easiest to control.


Operating Energy of Building
architecture 2030
80% of the problem!
Landscape + Site
Disturbance vs. sequestration
Embodied Carbon in Building Materials
People, "Use" + Transportation
Renewables + Site Generation
Counting Carbon costs….
+ purchased offsets

Energy vs Greenhouse Gas Emissions

In BUILDINGS, for the sake of argument

ENERGY CONSUMPTION = GHG EMISSIONS

BUILDING ENERGY IS COMPRISED OF

EMBODIED ENERGY

+

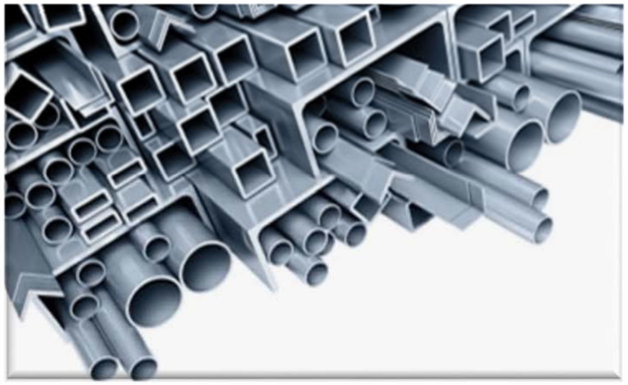
OPERATING ENERGY

Energy Use in Buildings

Embodied Energy

– **<u>Initial Embodied Energy</u>:** Non-renewable energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to site, and construction

– **<u>Recurring Embodied Energy</u>:** Non-renewable energy consumed to maintain, repair, restore, refurbish or replace materials, components, or systems during life of building

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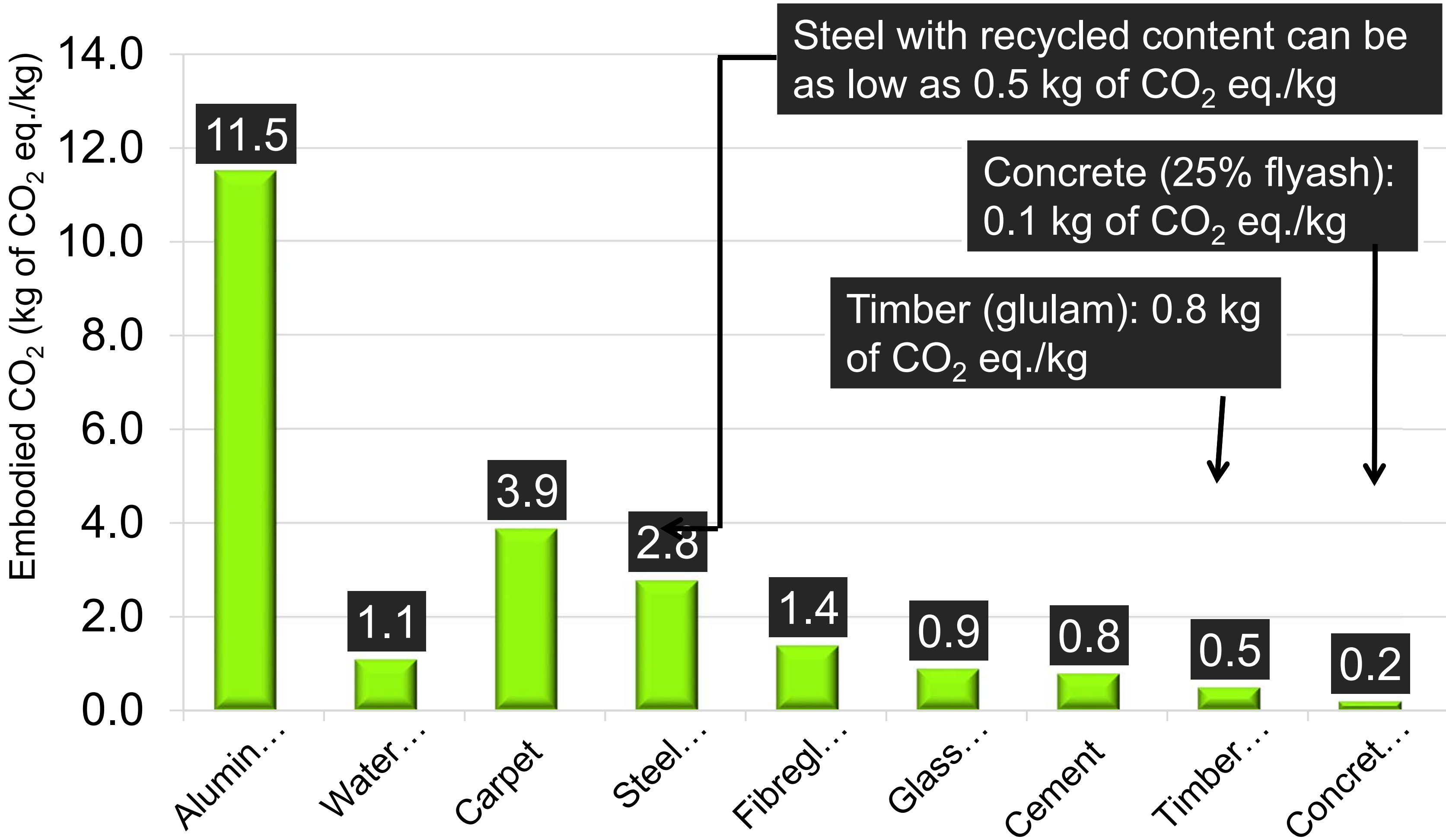
Initial Embodied Energy of Building Materials Per Unit Mass

Source: University of Wellington, NZ, Center for Building Performance Research (2004)

Embodied Carbon Dioxide of Building Materials Per Unit Mass



Source: University of Bath, UK, Inventory of Carbon and Energy (2008)

The Life Cycle of a Material

Life-Cycle Assessment (LCA)

– The main goal of a LCA is to quantify energy and material use as well as other environmental parameters at various stages of a product's life-cycle including: resource extraction, manufacturing, construction, operation, and post-use disposal

Life-Cycle Inventory (LCI) Database

– A database that provides a cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material. This database is a critical component of a Life-Cycle Assessment

Life Cycle Assessment Methodology

Embodied Energy

– **ATHENA® Impact Estimator for Buildings**

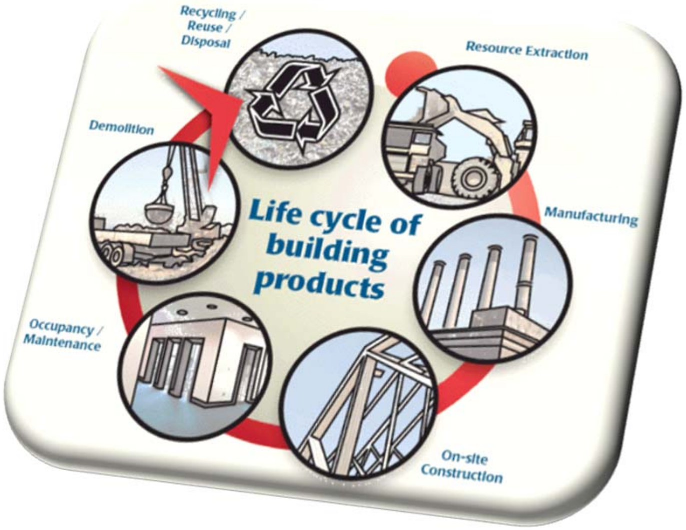
– **The only North American specific software tool that evaluates whole buildings and assemblies based on internationally recognized LCA methodology**

– **Non-profit organization that has been around for more than 10 years**

– **One of the most comprehensive LCI databases in the world with over $2 million spent on database development**

– **Considers the life-cycle impacts of:**

- ✓ Material manufacturing including resource extraction and recycled content
- ✓ Related transportation
- ✓ On-site construction
- ✓ Regional variation in energy use, transportation, and other factors
- ✓ Building type and assumed lifespan
- ✓ Maintenance, repair, and replacement effects
- ✓ Demolition and disposal
- ✓ Operating energy emissions and pre-combustion effects

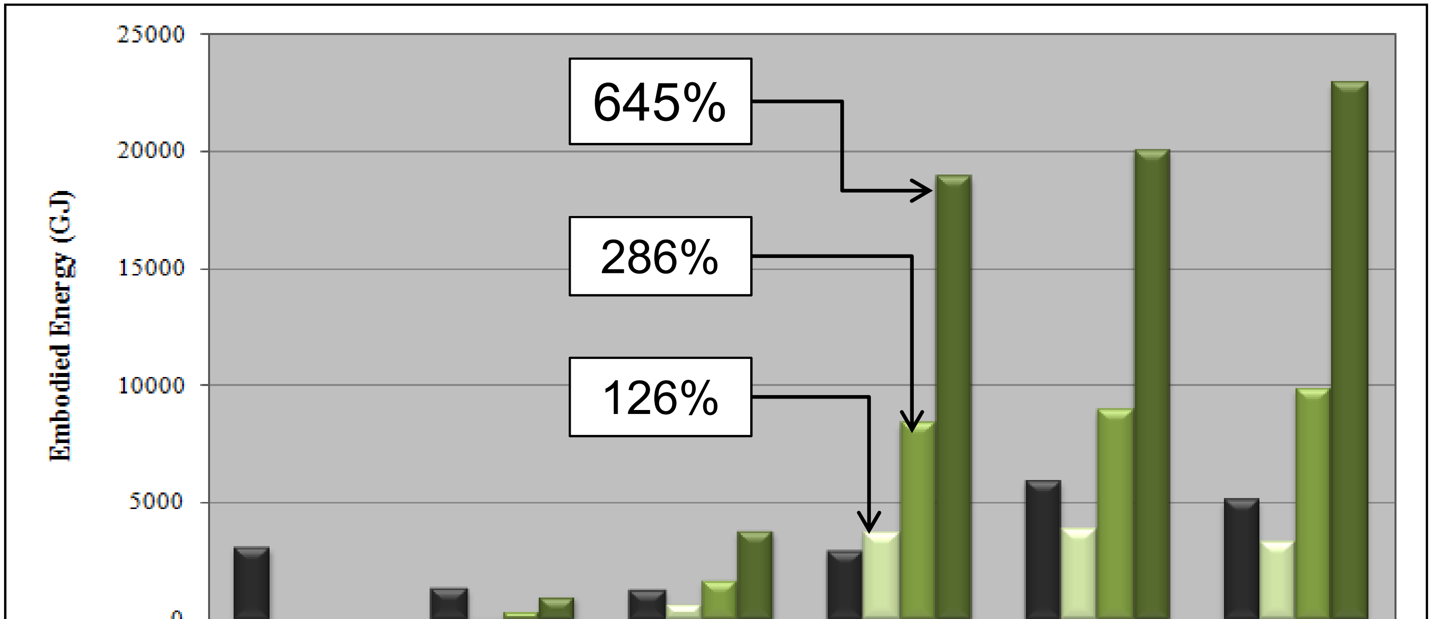


Source: The ATHENA Institute *http://www.athenasmi.org/tools/impactEstimator/index.html*

Energy in Common Building Components

Initial Embodied Energy vs. Recurring Embodied Energy of a Typical Canadian Office Building Constructed from Wood

Finishes, Envelope, & Services dominate the embodied energy over the building's lifespan



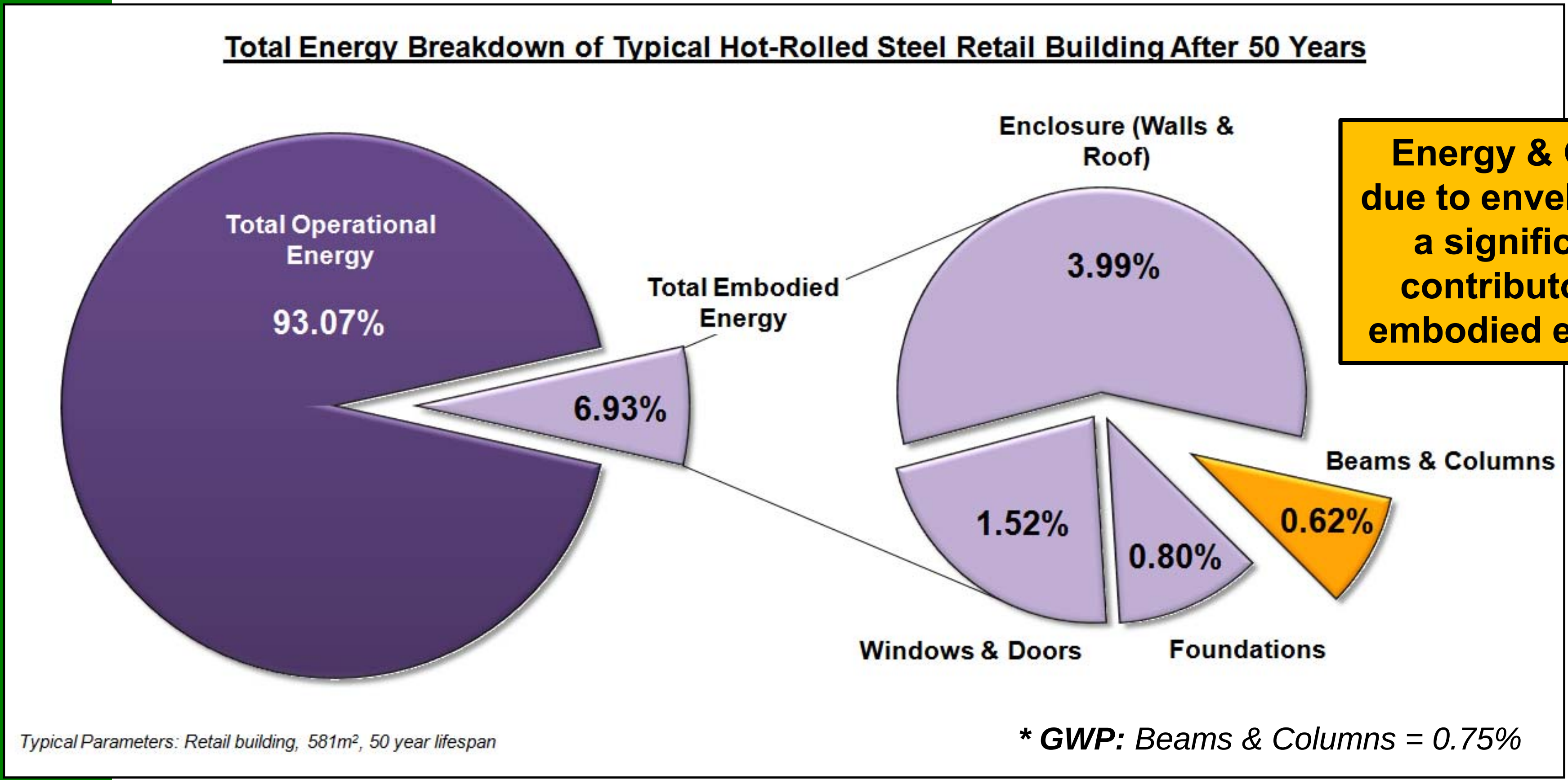
	Structure	Site Work	Construction	Finishes	Envelope	Services
Initial	3088	1344	1289	2935	5935	5110
25 Years	0	65	658	3696	3873	3338
50 Years	0	358	1653	8397	8943	9859
100 Years	0	1001	3777	18936	20060	22955

Source: Cole , R. & Kernan, P. (1996). Life-Cycle Energy Use in Office Buildings. Building and Environment, 31 (4), 307-317

Orders of Environmental Impact

<u>Total Energy Breakdown of Typical Hot-Rolled Steel Retail Building After 50 Years</u>

(other building types are similar)

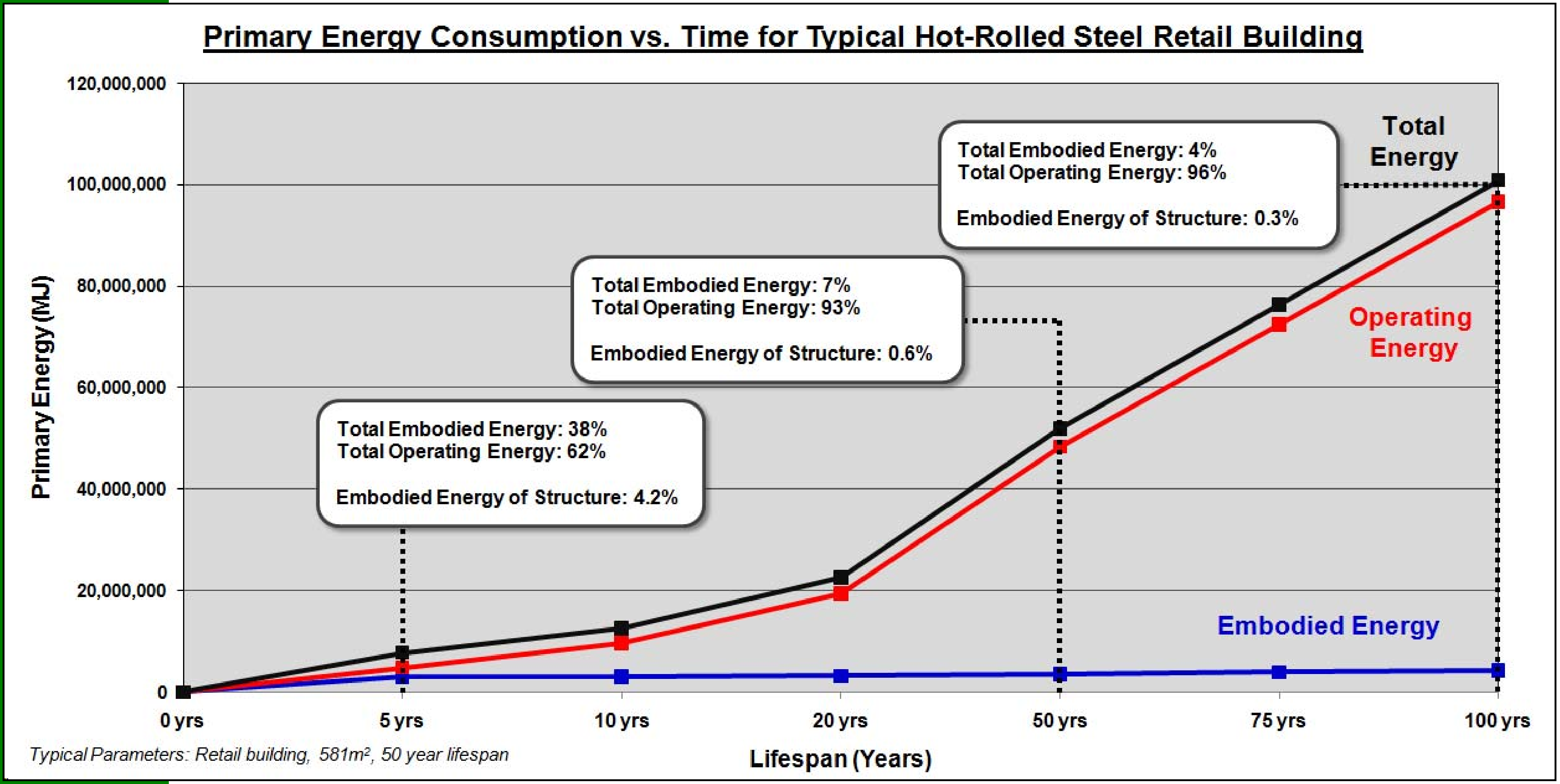


Energy & GWP due to envelope is a significant contributor to embodied energy

www.cn-sbs.cssbi.ca

Orders of Environmental Impact

Primary Energy Consumption vs. Time for Hot-Rolled Steel Retail Building (*other building types are similar)*



Source: Kevin Van Ootegham

www.cn-sbs.cssbi.ca

Embodied Energy Findings

In conventional buildings, the building envelope (walls and roof), building services, and building finishes contribute the most towards the total embodied life-cycle energy (and total embodied GWP) when looking at the Embodied Energy of the Entire Building, including Structure.

To lower GHG, choice of materials needs to reflect:

-issues of **DURABILITY**

- ability of material to assist **PASSIVE DESIGN**

- local sourcing to reduce **TRANSPORTATION**

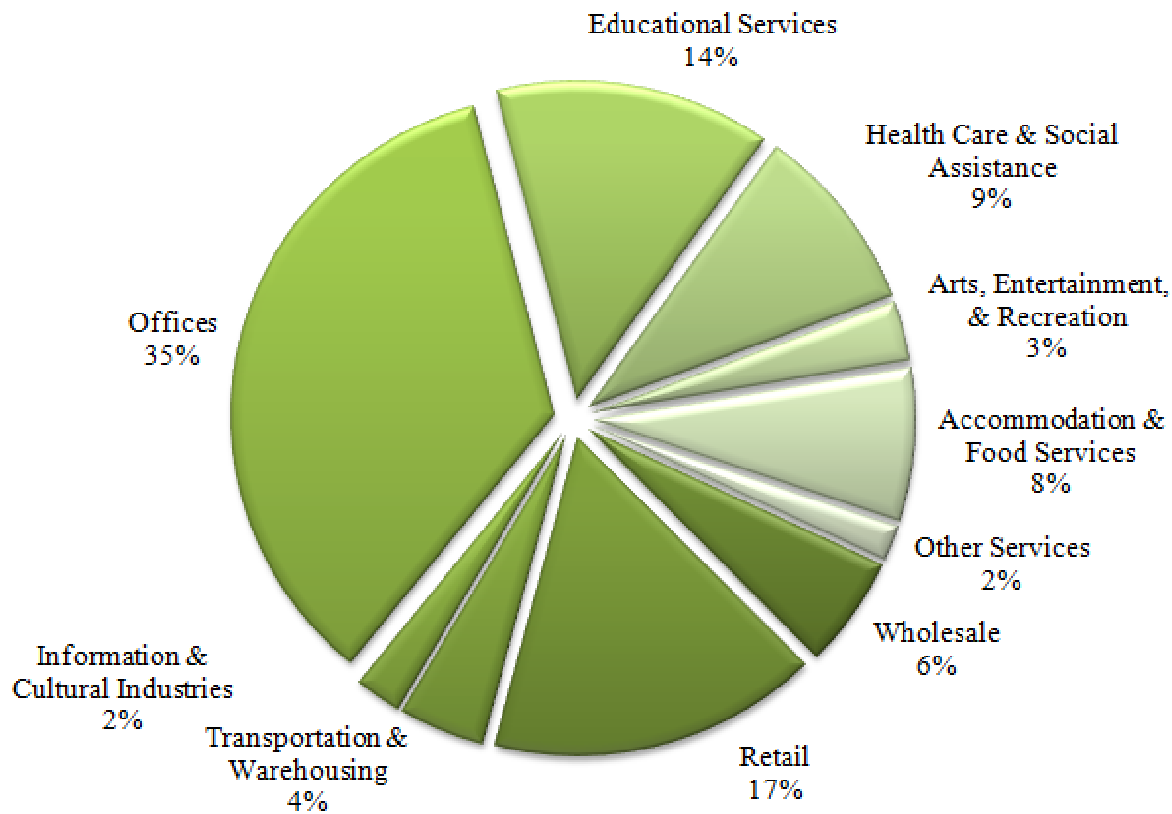
- **Cradle to Cradle concepts**

- ability of material to be 1st **REUSED** and 2nd RECYCLED

Energy Use in Buildings: Operating Energy

Amount of energy that is consumed by a building to satisfy the demand for heating, cooling, lighting, ventilation, equipment, etc.

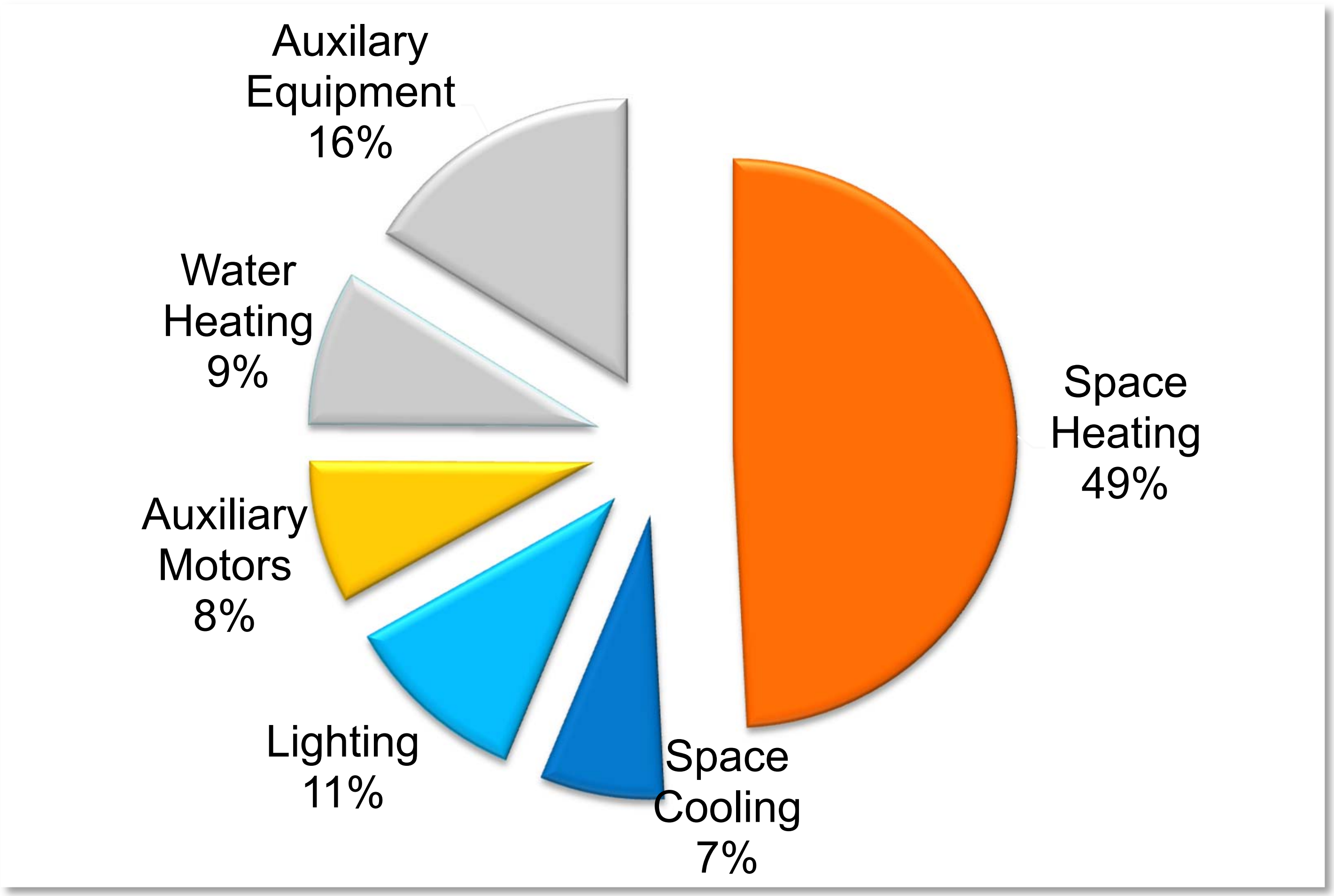
Total Commercial/Institutional Secondary Energy Use by Activity Type in Canada (2006)



Source: Natural Resources Canada, 2006

Energy Use in Buildings: Operating Energy

Total Commercial/Institutional Secondary Energy Use by End Use in Canada (2006)



Source: Natural Resources Canada, 2006

REDUCING OPERATING ENERGY

Four Key Steps – IN ORDER:

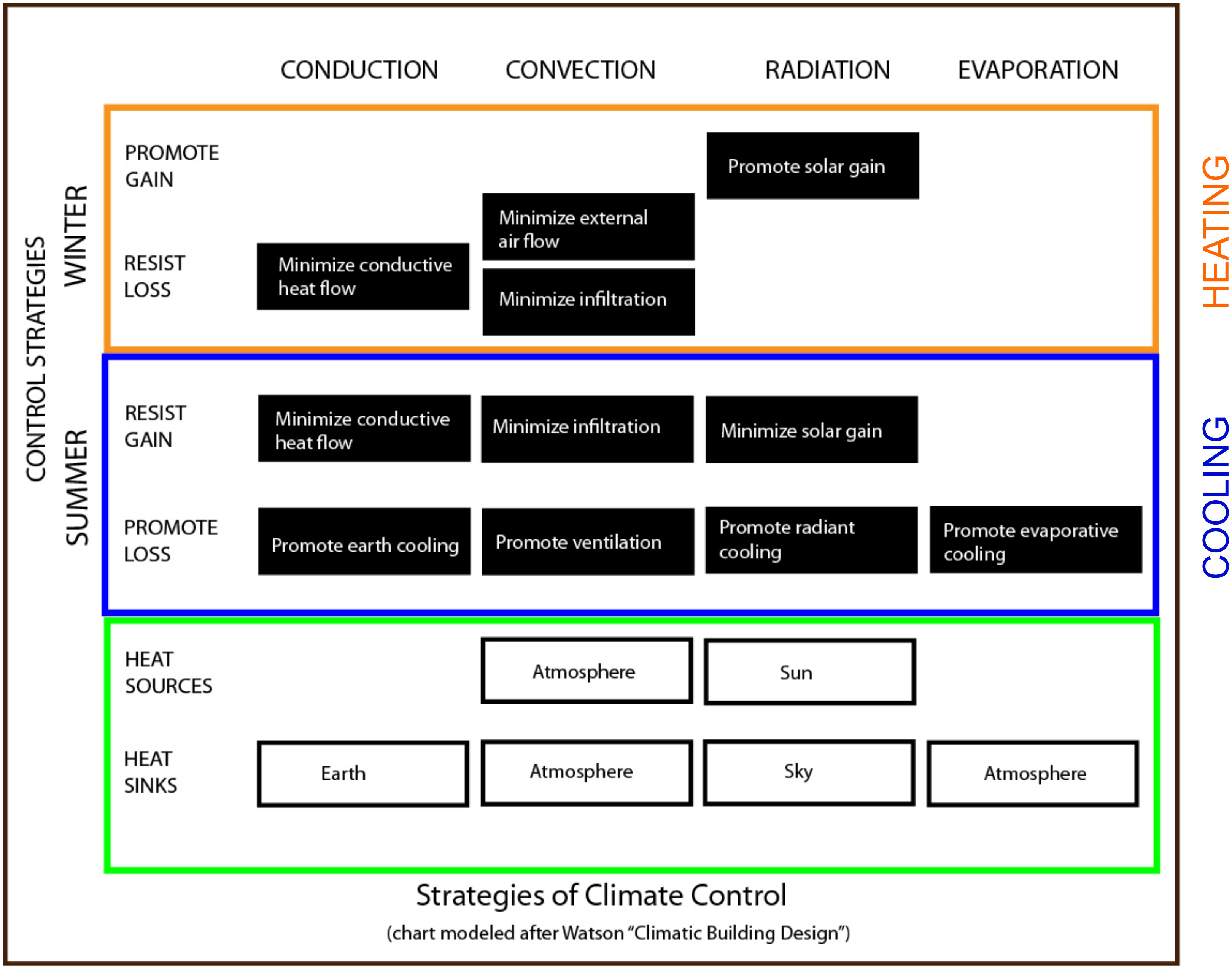
#1 - Reduce loads/demand first (conservation, passive design, daylighting, shading, orientation, etc.)

#2 - **Meet loads efficiently and *effectively*** (energy efficient lighting, high-efficiency MEP equipment, controls, etc.)

#3 - **Use renewables to meet energy needs** (doing the above steps *before* will result in the need for much smaller renewable energy systems, making carbon neutrality achievable.)

#4 - **Use purchased Offsets** as a *last resort* when all other means have been looked at on site, or where the scope of building exceeds the site available resources.

Begin with Passive Strategies for Climate Control to Reduce Energy Requirements



REDUCING OPERATING ENERGY

Carbon Reduction: The Tier Approach

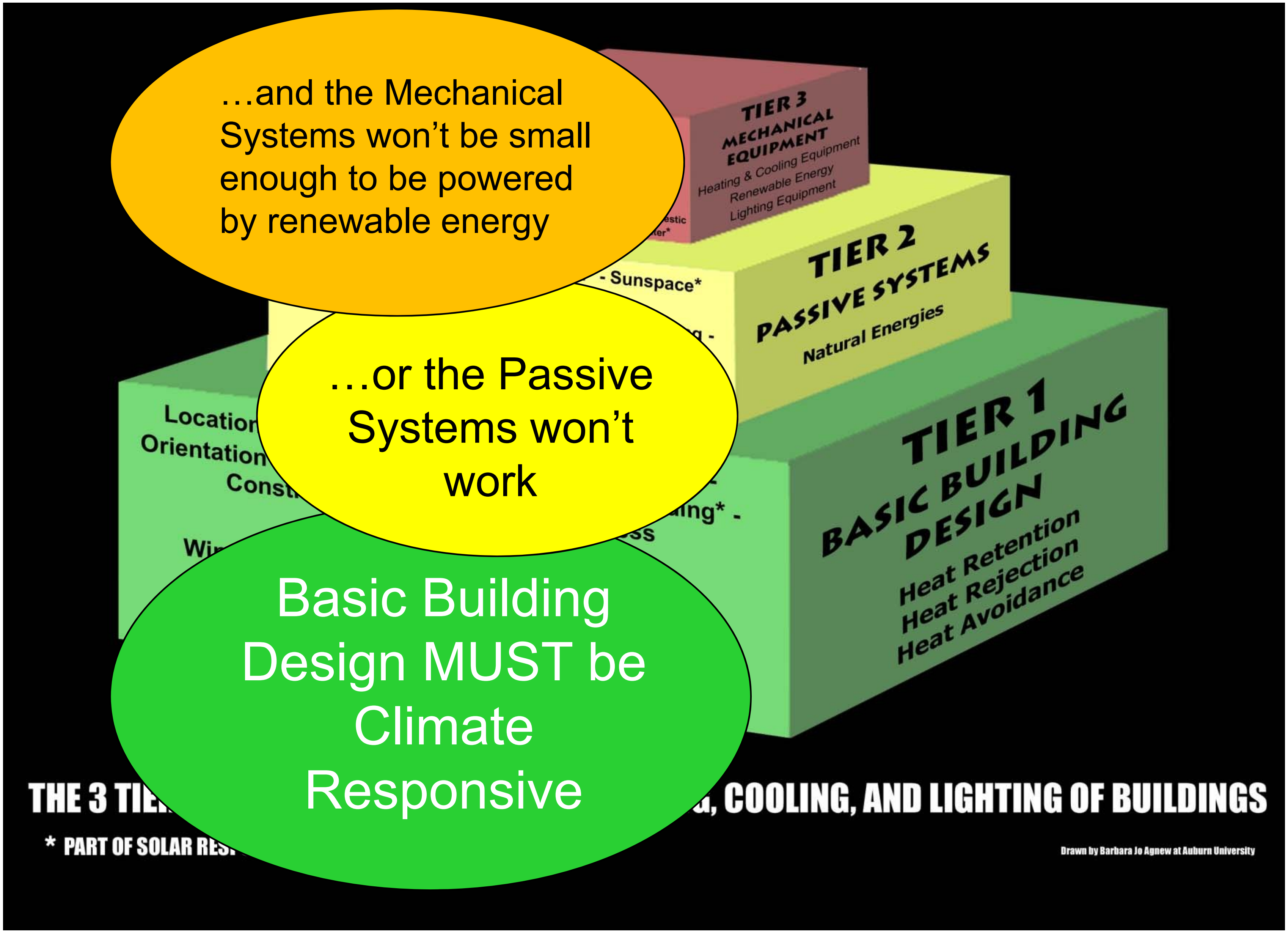
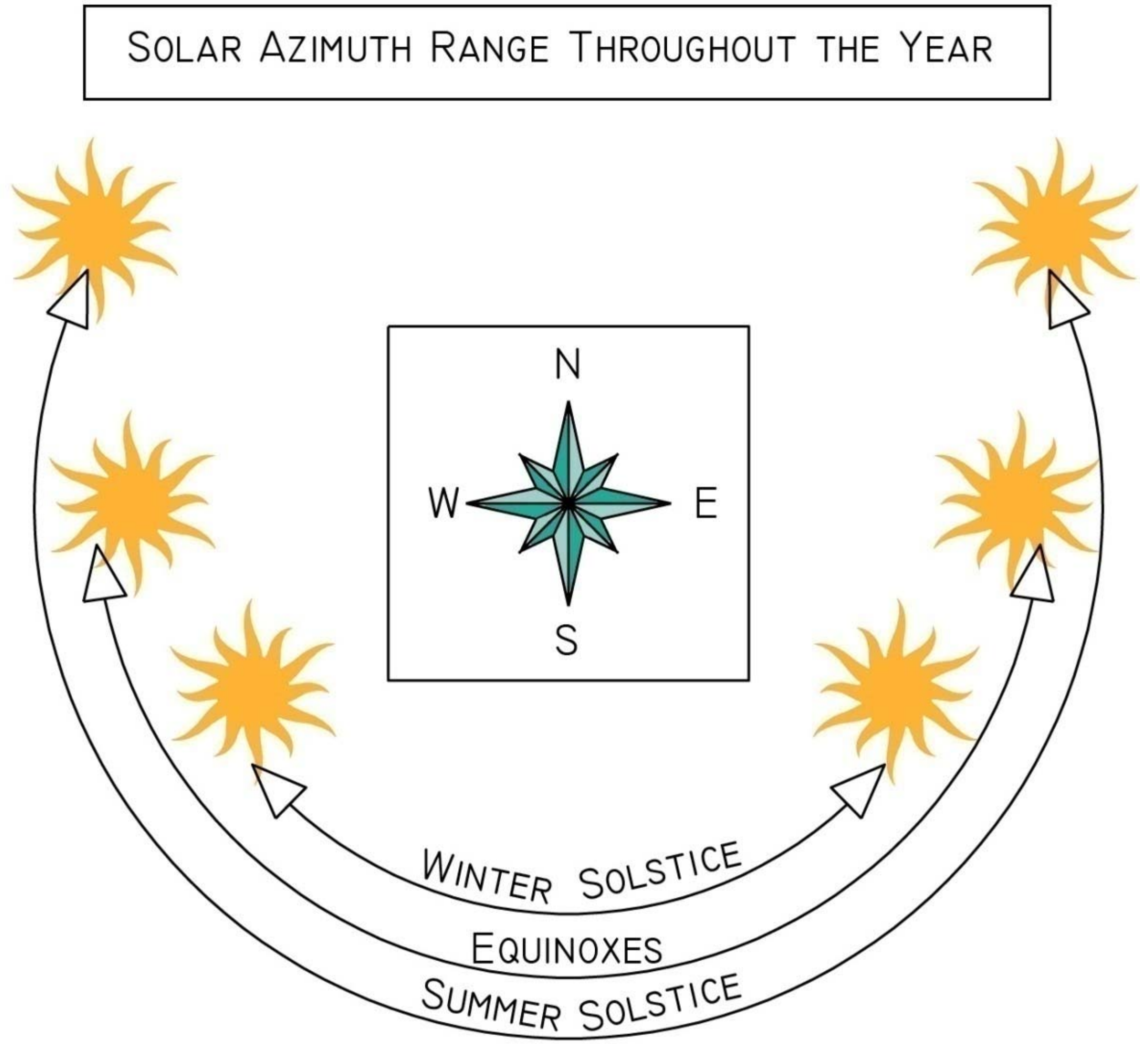


Image: Norbert Lechner, "Heating, Cooling, Lighting"

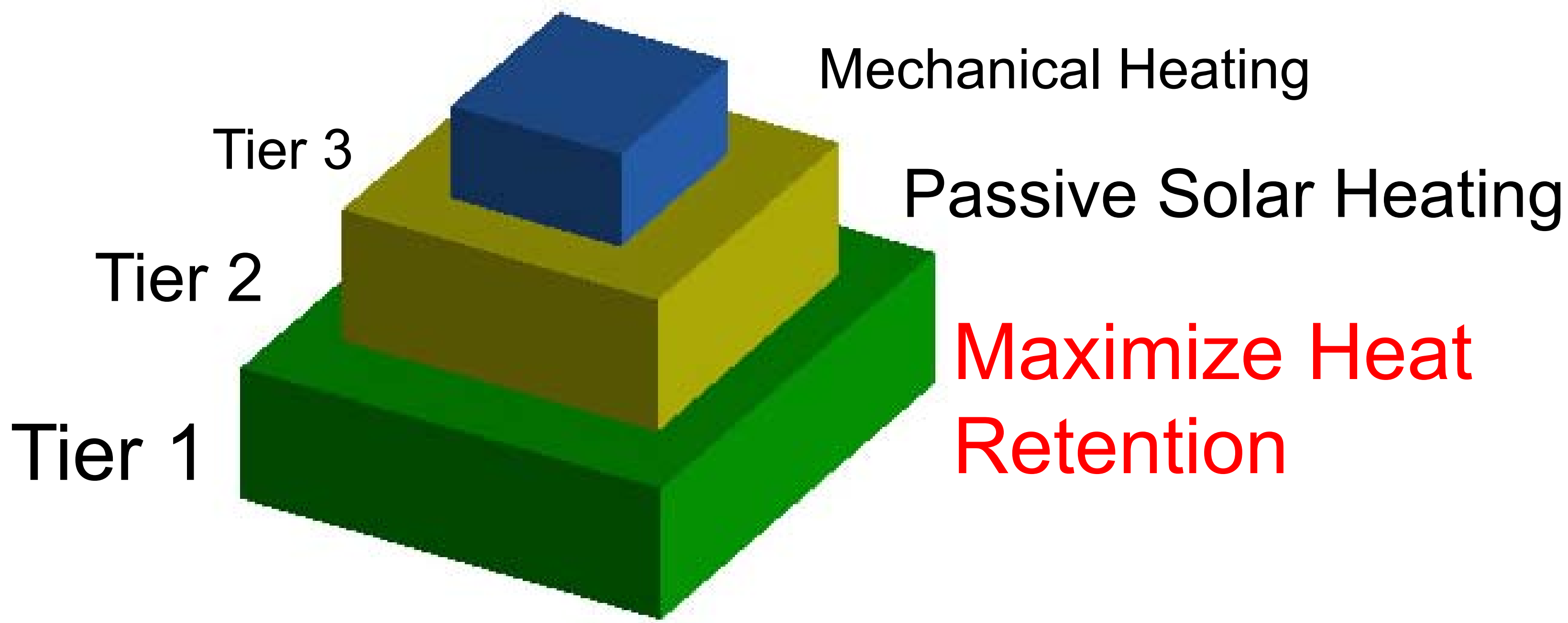
#1 Starting Point – Locate the SUN



… and just deal with it!

Reduce loads: Passive Strategies

The tiered approach to reducing carbon for **HEATING**:



First reduce the overall energy required, then maximize the amount of energy required for mechanical heating that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

Passive Heating Strategies:
Maximize Heat Retention

1. Super insulated envelope (*as high as <u>double</u> current standards*)
2. Tight envelope / controlled air changes
3. Provide thermal mass **inside** of thermal insulation to store heat
4. Top quality windows with high R-values – up to triple glazed with argon fill and low-e coatings on two surfaces

Premise – what you don’t “lose” you don’t have to create or power…. So make sure that you keep it! *(…NEGAwatts)*

Passive Heating Strategies:
Maximize Solar Gain

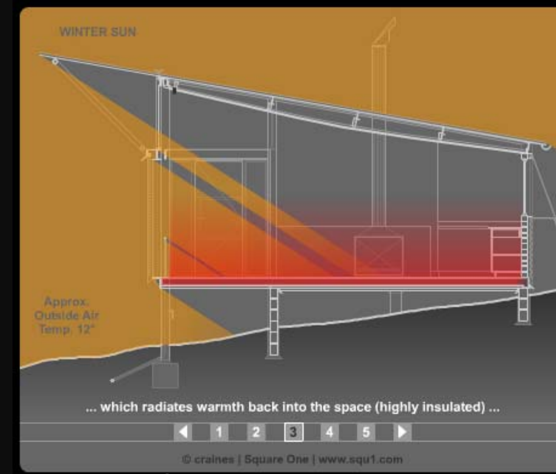
1. primarily south facing windows
2. proportion windows to suit thermal mass and size of room(s)

3 MAIN STRATEGIES:

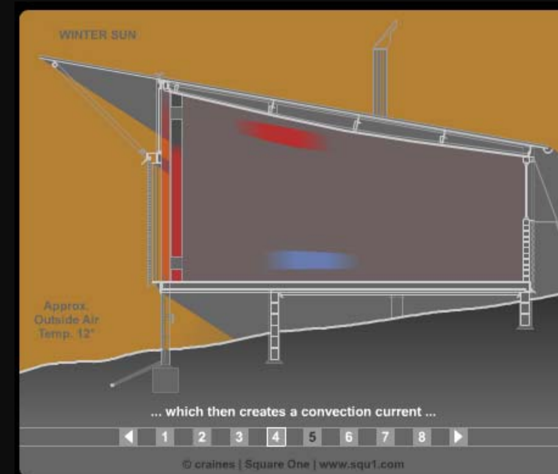
Direct Gain

Thermal Storage Wall

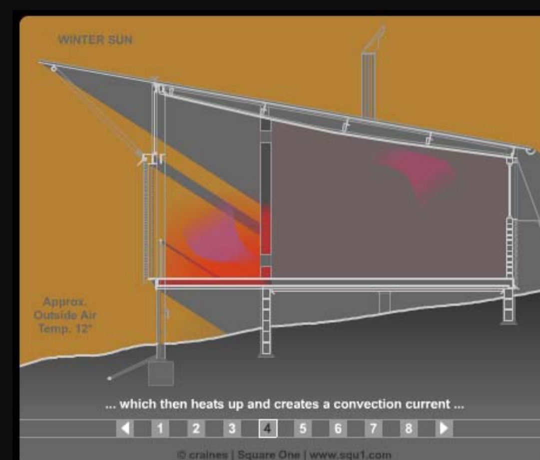
Sunspace



Direct Gain



Trombe Wall



Sun Space

Source: Square One Archives (http://squ1.com/archive/)

Thermal Mass is Critical!

To ensure comfort to the occupants….

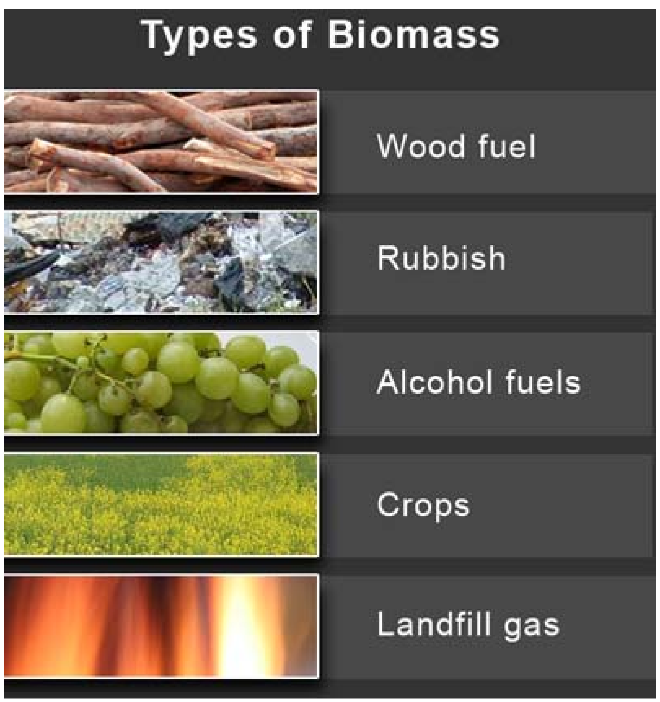
People are 80% water so if they are the only thermal sink in the room, they will be the target.

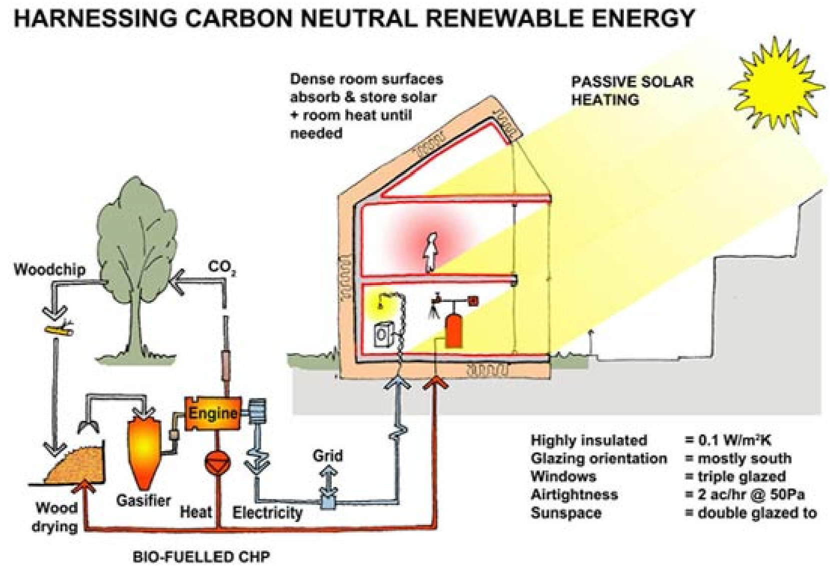
And to store the FREE energy for slow release distribution….

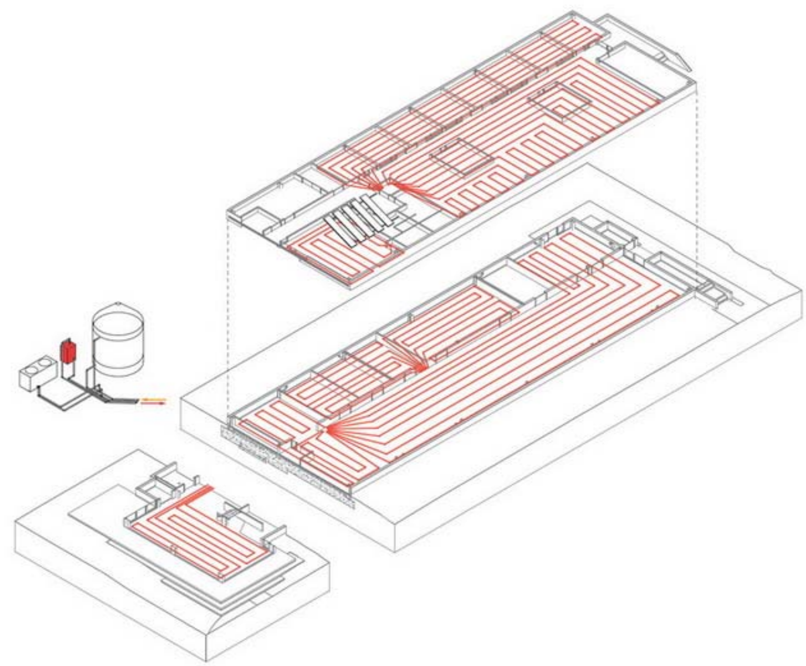
Aldo Leopold Legacy Center: Concrete floors complement the insulative wood walls

Passive Heating Strategies:
Use Renewables for Additional Heating

- Combined heat and power
- Biomass
- Geo exchange systems
- Radiant heating systems
- Verify carbon status of source

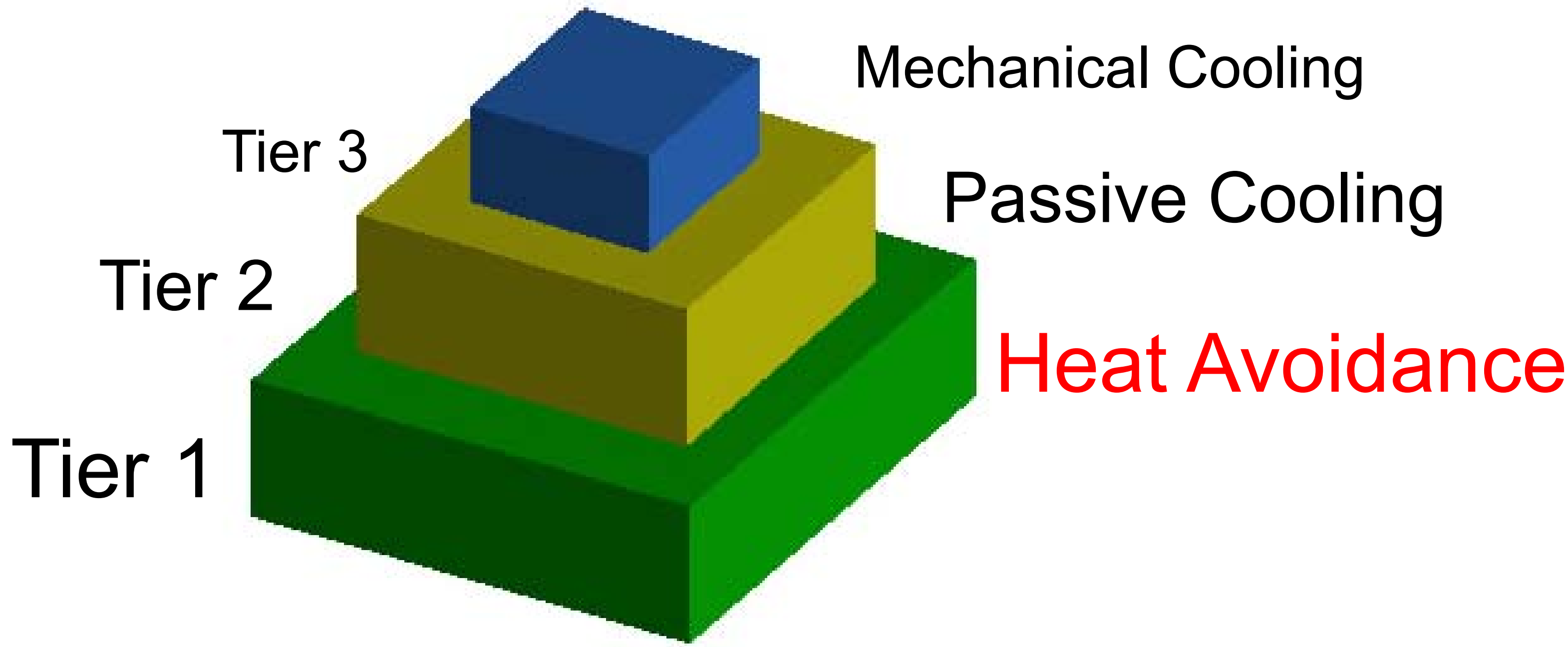






Reduce loads: Passive Strategies

The tiered approach to reducing carbon for COOLING:

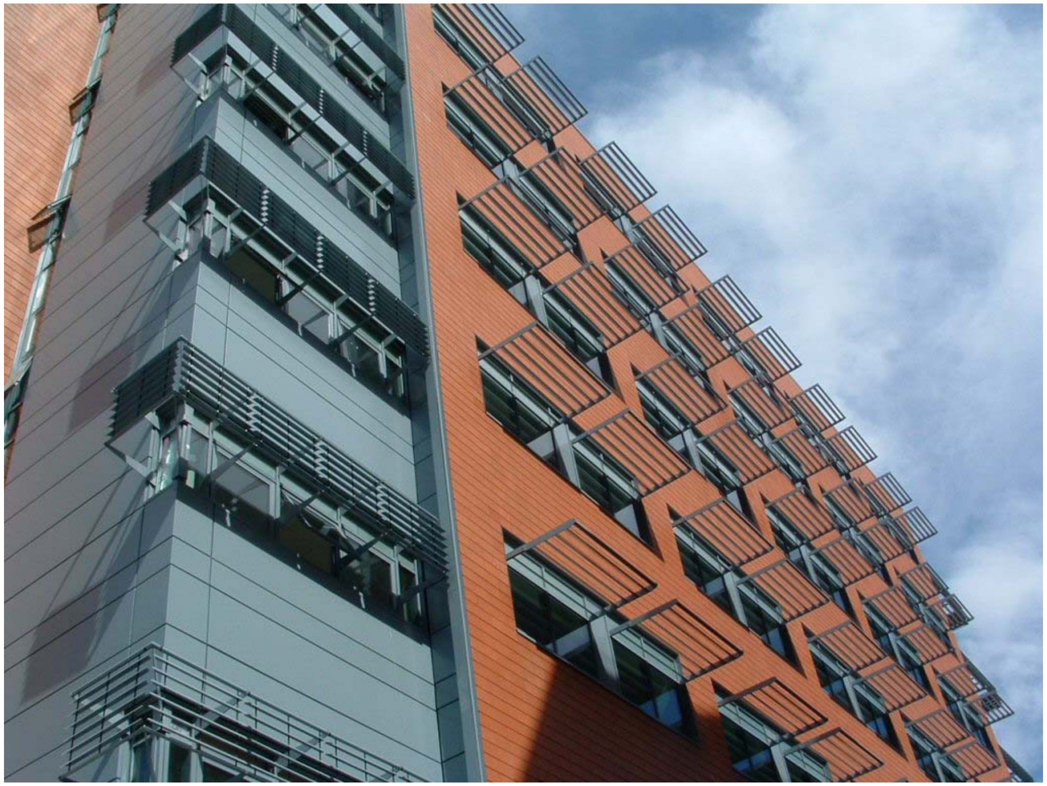


Maximize the amount of energy required for mechanical cooling that comes from renewable sources.

Source: Lechner. Heating, Cooling, Lighting.

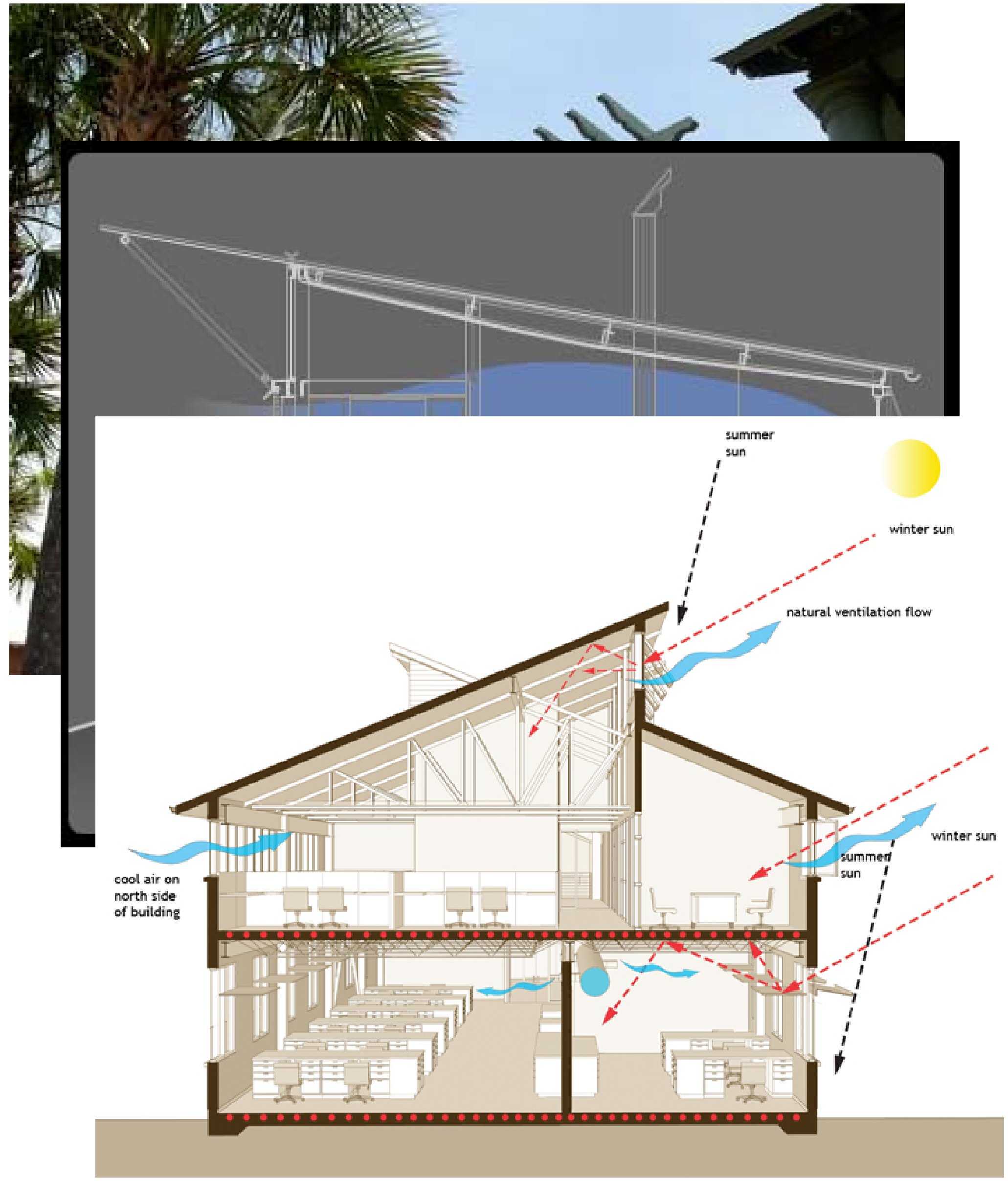
Passive Cooling Strategies:
Heat Avoidance

1. shade windows from the sun during hot months
2. design materials and plantings to cool the local microclimate
3. locate trees and trellis' to shade east and west façades during morning and afternoon low sun



If you don't invite the heat in, you don't have to get rid of it…..

Passive Cooling Strategies:
Passive Cooling



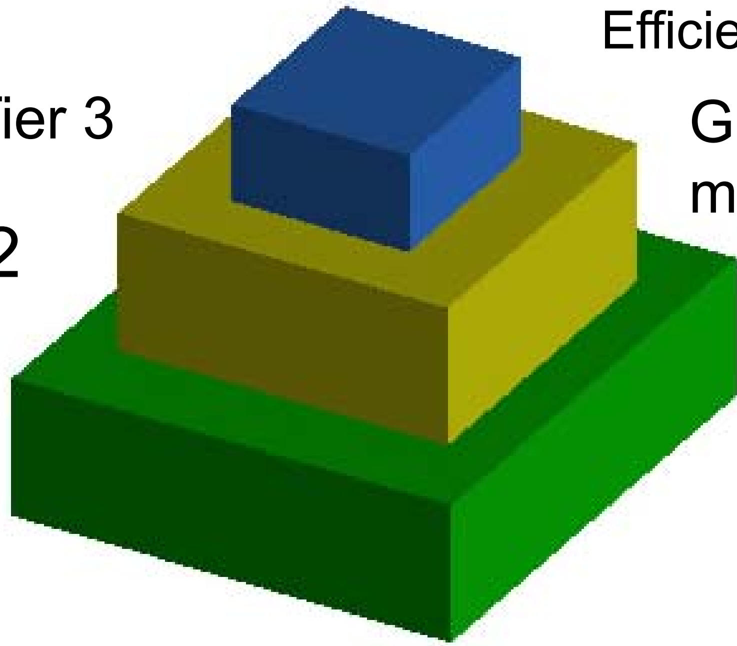
1. design for maximum ventilation
2. keep plans as open as possible for unrestricted air flow
3. use easily operable windows at low levels with high level clerestory windows to induce stack effect cooling

Passive Cooling Strategies:
Use Innovative Means for Cooling

1. wind cowls
2. solar chimneys
3. water features

Reduce loads: Daylighting

The tiered approach to reducing carbon with **DAYLIGHTING**:



Use energy efficient fixtures!

Maximize the amount of energy/electricity required for artificial lighting that comes from renewable sources.

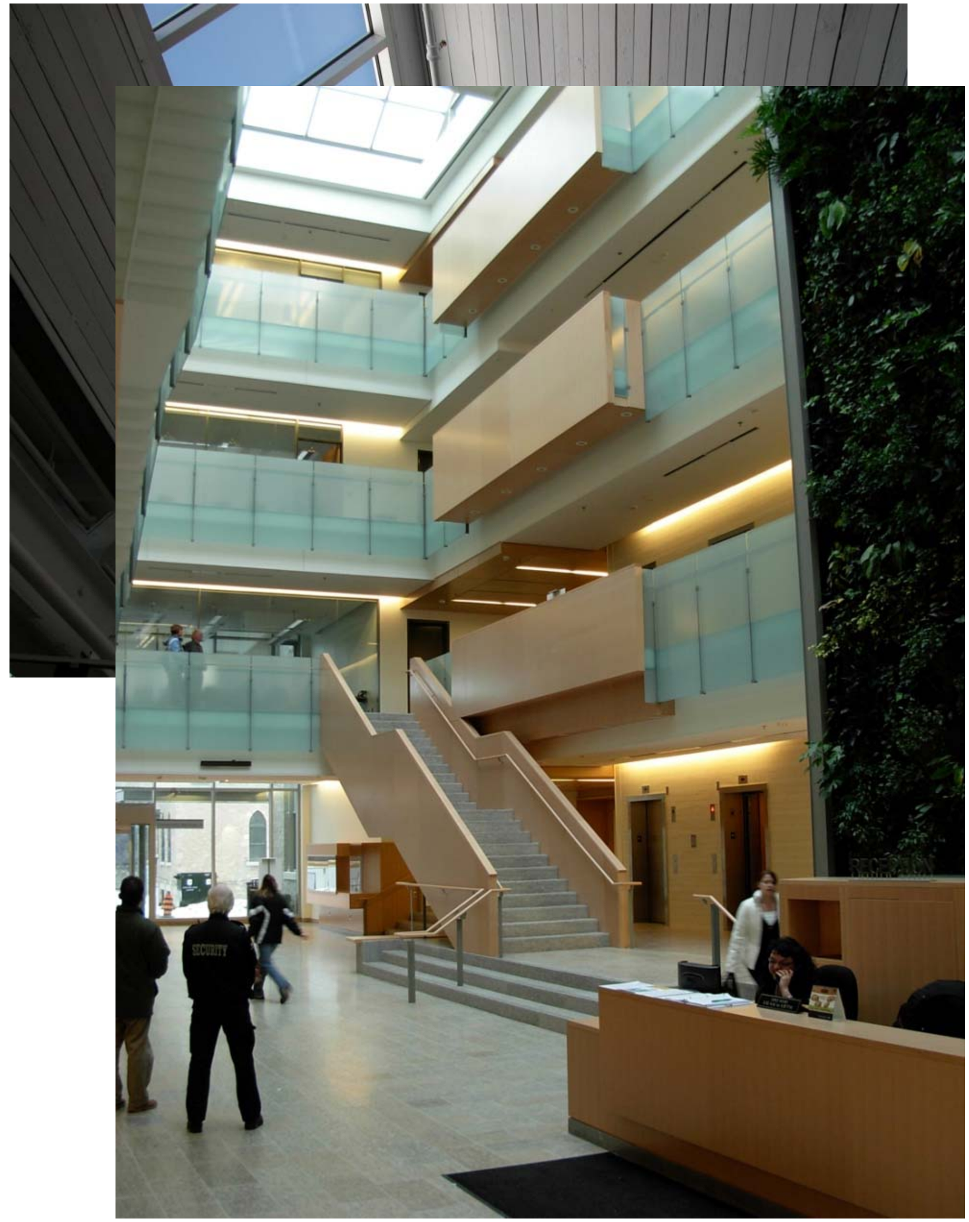
Source: Lechner. Heating, Cooling, Lighting.

Passive Lighting Strategies:
Orientation and building planning

- start with solar geometry
- understand context, sky dome, adjacent buildings and potential overshadowing
- be able to differentiate between sunlight (heat) and daylight (seeing)
- understand occupancy/use requirements
- maximize areas served by daylight
- explore different glazing strategies: side, clerestory, top
- consider light shelves and reflected light

Passive Lighting Strategies:
Glare, color, reflectivity and materials

- incorporate light dynamics
- avoid glare
- understand the function of material selection; ie. reflectivity and surface qualities
- balance color and reflectivity with amount of daylight provided



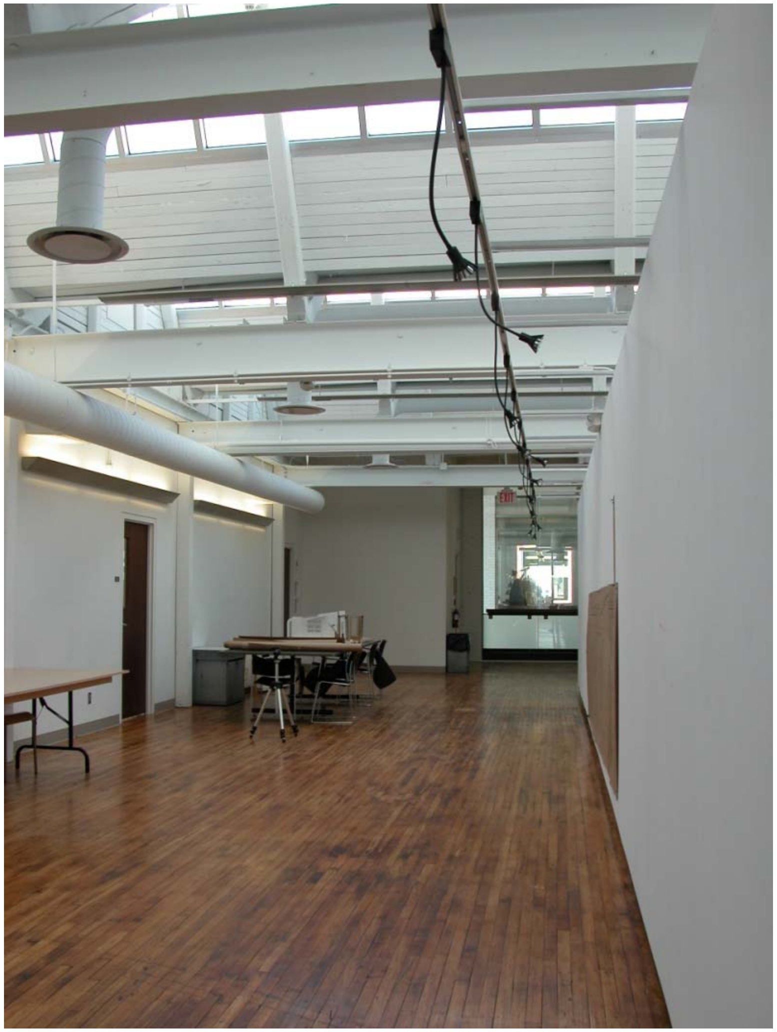
Passive Lighting Strategies:
Energy efficiency and renewables

- use energy efficient light fixtures (and effectively!)

- use occupant sensors *combined with light level sensors*

- aim to only have lights switch on only when daylight is insufficient

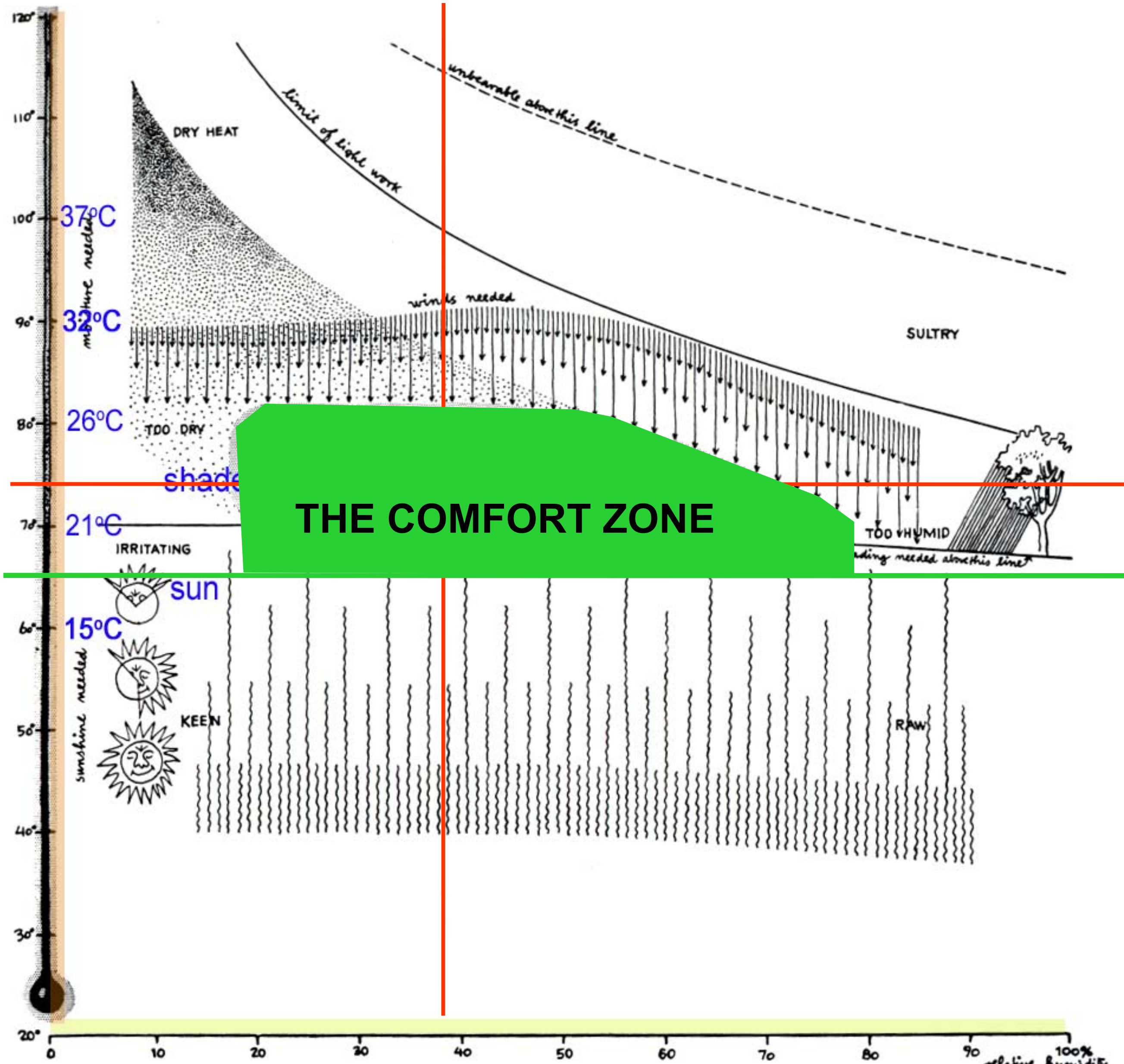
- provide electricity via renewable means: wind, PV, CHP



Lights on due to occupant sensors when there is adequate daylight – WASTES ENERGY!

REDUCING OPERATING ENERGY

Designing to the **Comfort Zone** vs. Comfort Point:



46. Schematic bioclimatic index.

This famous illustration is taken from "Design with Climate", by Victor Olgyay, published in 1963.

This is the finite point of expected comfort for 100% mechanical heating and cooling.

To achieve CN, we must work within the broader area AND DECREASE the "line" to 18C – point of calculation of heating degree days.

Passive Bio-climatic Design: COMFORT ZONE

Comfort expectations may have to be reassessed to allow for the wider “zone” that is characteristic of buildings that are not exclusively controlled via mechanical systems.

Creation of new **“buffer spaces”** to make a hierarchy of comfort levels within buildings.

Require **higher occupant involvement** to adjust the building to modify the temperature and air flow.

Climate as the Starting Point for a Climate Responsive Design

North American Bio-climatic Design:

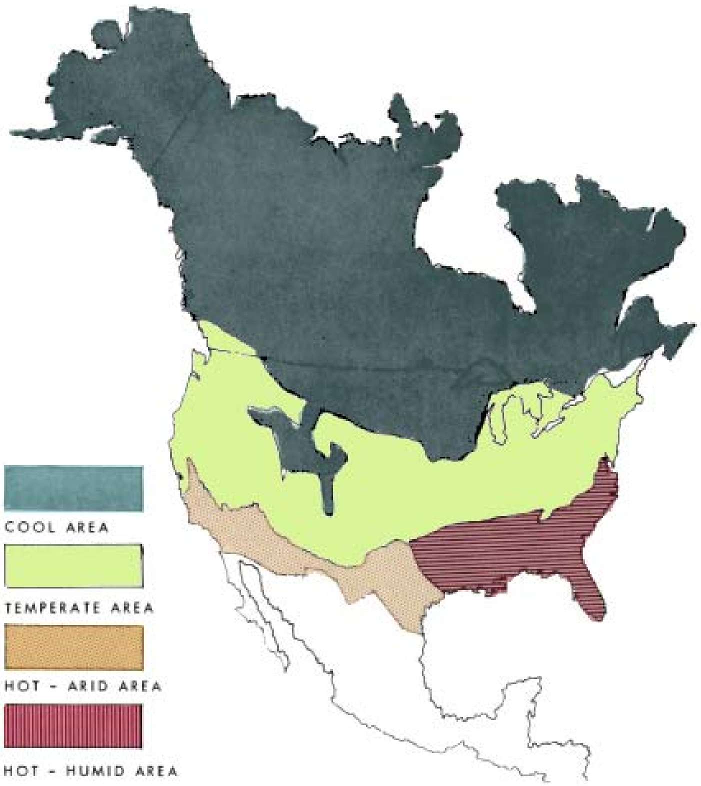
Design must first acknowledge regional, local and microclimate impacts on the building and site.

COLD

TEMPERATE

HOT-ARID

HOT-HUMID

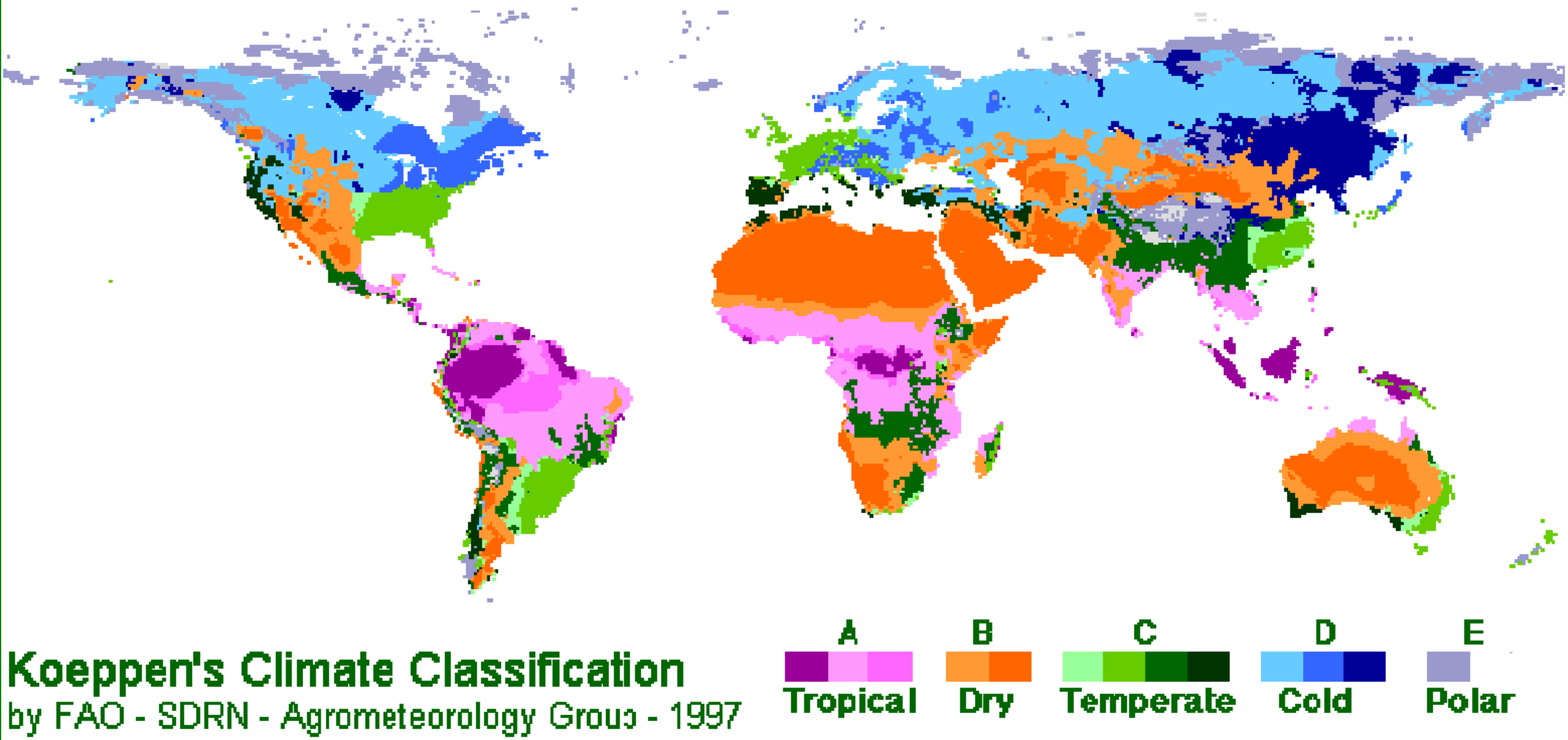


11. Regional climate zones of the North American continent.

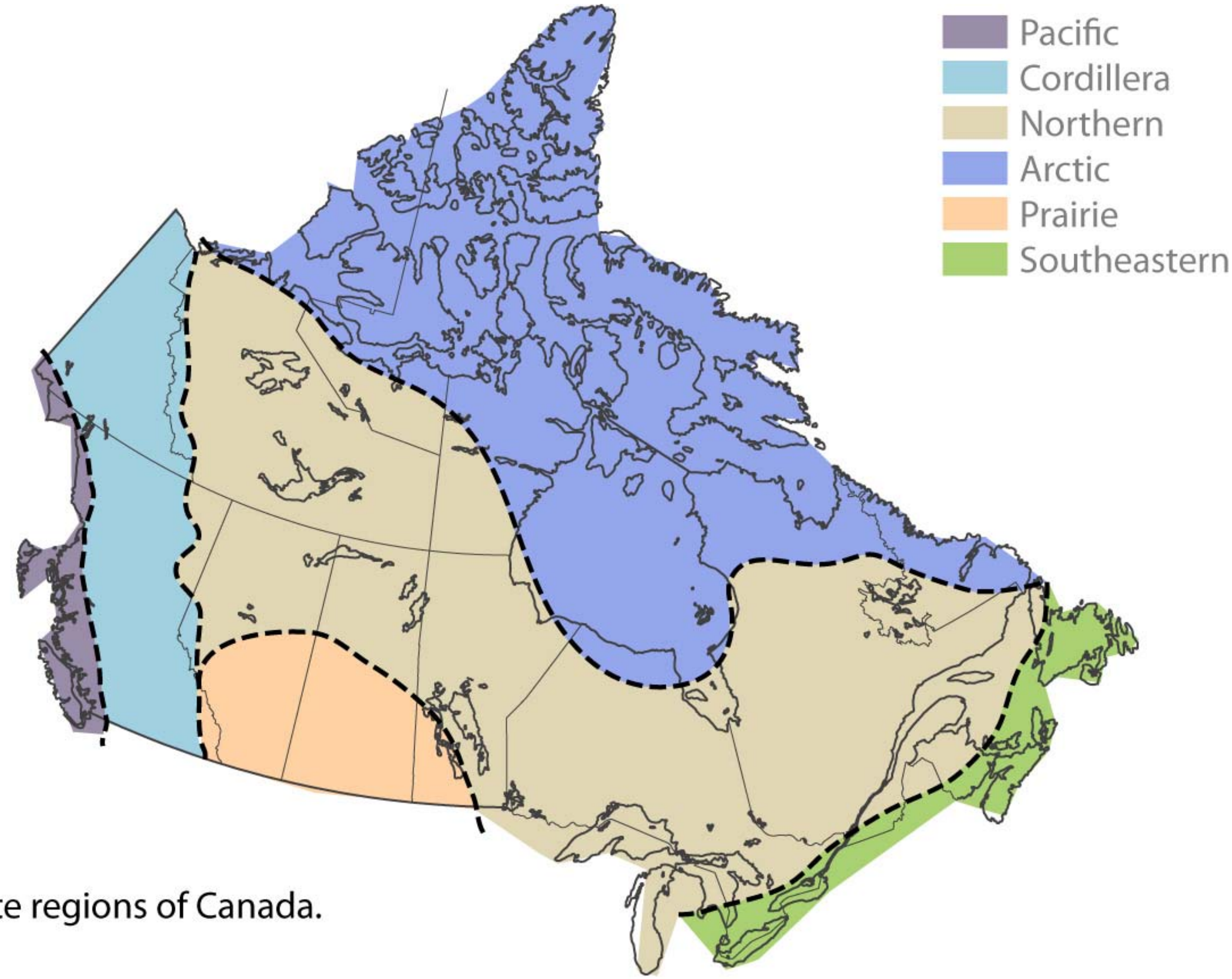
Image: 1963 “Design With Climate”, Victor Olgyay.

Global Bio-climatic Design:

Design must first acknowledge regional, local and microclimate impacts on the building and site.



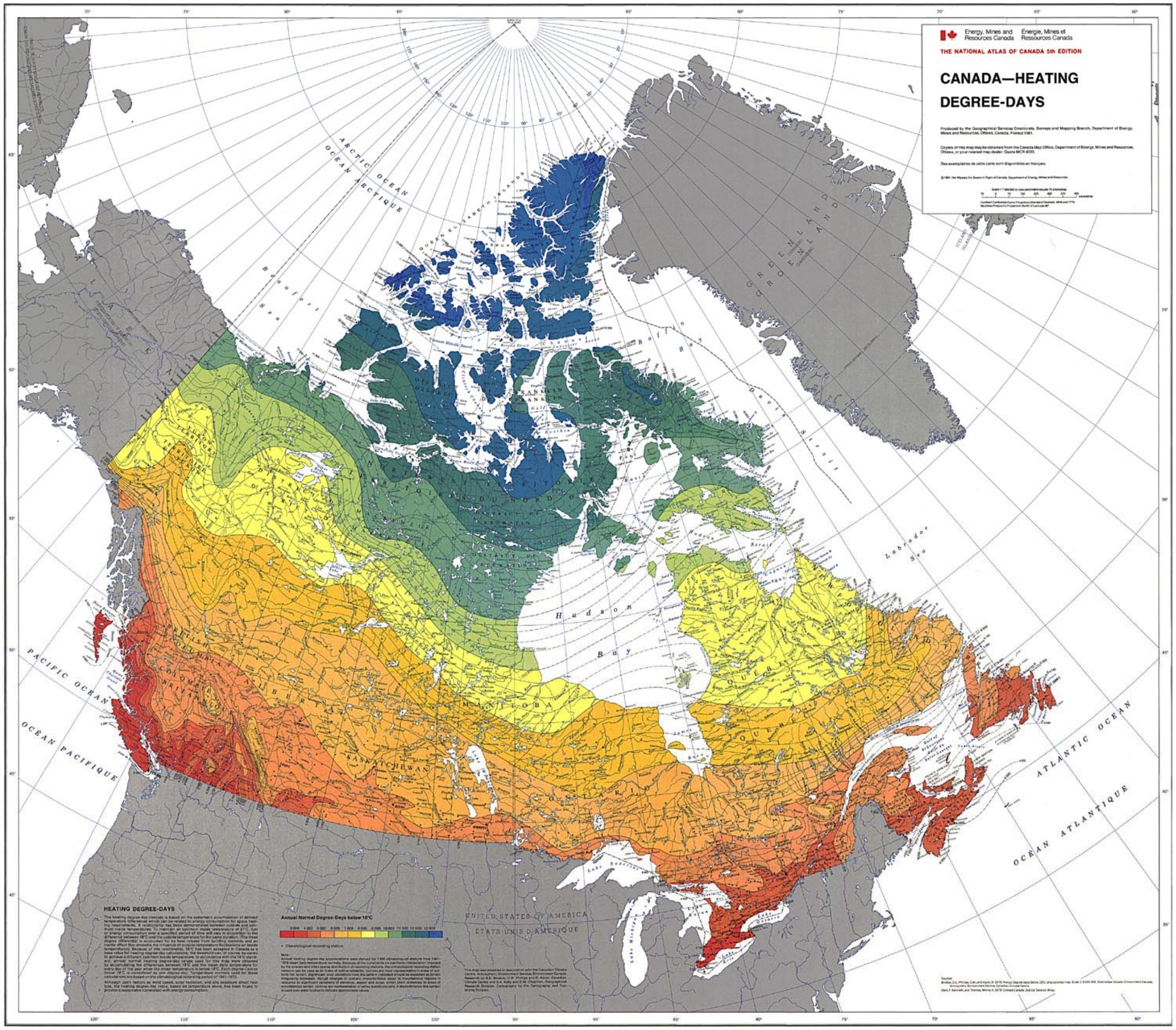
The climate regions of Canada



Climate regions of Canada.

Even within Canada, there exist variations in climate, enough to require very different envelope design practices and regulations. This mostly concerns insulation and water penetration, as well as humidity concerns.

Heating and Cooling Degree Days



This map shows the annual sum of heating degree days (an indicator of building heating needs). Data for period 1941 to 1970. **Determine if the climate is *heating* or *cooling* dominated** …this will set out your primary strategy.

The Goal is Reduction

CLIMATE AS THE STARTING POINT

FOR RETHINKING ARCHITECTURAL DESIGN

Bio-climatic Design: HOT-ARID

Where **very high summer temperatures** with great fluctuation predominate with **dry conditions** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

RULES:

- SOLAR AVOIDANCE: keep DIRECT SOLAR GAIN out of the building
- avoid daytime ventilation
- promote nighttime flushing with cool evening air
- achieve daylighting by reflectance and use of LIGHT non-heat absorbing colours
- create a cooler MICROCLIMATE by using light / lightweight materials
- respect the DIURNAL CYCLE
- use heavy mass for walls and DO NOT INSULATE

Traditional House in Egypt

Bio-climatic Design: HOT-HUMID

Where **warm to hot** stable conditions predominate with **high humidity** throughout the year. **Cooling degrees days greatly exceed heating degree days.**

RULES:

- **SOLAR AVOIDANCE** : large roofs with overhangs that shade walls and to allow windows open at all times
- **PROMOTE VENTILATION**
- **USE LIGHTWEIGHT MATERIALS** that do not hold heat and that will not promote condensation and dampness (mold/mildew)
- *eliminate basements and concrete*
- use STACK EFFECT to ventilate through high spaces
- use of COURTYARDS and semi-enclosed outside spaces
- use WATER FEATURES for cooling

House in Seaside, Florida

Bio-climatic Design: TEMPERATE

The summers are hot and humid, and the winters are cold. In much of the region the topography is generally flat, allowing cold winter winds to come in form the northwest and cool summer breezes to flow in from the southwest. **The four seasons are almost equally long.**

IslandWood Residence, Seattle, WA

RULES:

- BALANCE strategies between COLD and HOT-HUMID
- maximize flexibility in order to be able to modify the envelope for varying climatic conditions
- understand the natural benefits of SOLAR ANGLES that shade during the warm months and allow for heating during the cool months

Bio-climatic Design: COLD

Where **winter** is the dominant season and concerns for conserving heat predominate all other concerns. **Heating degree days greatly exceed cooling degree days**.

RULES:

- First **INSULATE**

- *exceed* CODE requirements (DOUBLE??)

- minimize infiltration (build tight to reduce air changes)

- Then **INSOLATE**

- ORIENT AND SITE THE BUILDING PROPERLY FOR THE SUN

- maximize south facing windows for easier control

- fenestrate for **DIRECT GAIN**

- apply **THERMAL MASS** inside the building envelope to store the FREE SOLAR HEAT

- create a sheltered MICROCLIMATE to make it LESS cold

YMCA Environmental Learning Centre, Paradise Lake, Ontario

Reduce, Renew, Offset

And, a *paradigm shift* from the recycling 3Rs…

Reduce - build less, protect natural ecosystems, build smarter, build efficiently

Renew - use renewable energy, restore native ecosystems, replenish natural building materials, use recycled and recyclable materials

Offset - compensate for the carbon you can't eliminate, focus on local offset projects

Net impact reduction of the project!

source: www.buildcarbonneutral.org

The Importance of Impact Reduction:

If the **impact** of the building is NOT reduced, it may be *impossible* to reduce the CO_2 to zero. Because:

Site and location matter.

- **Design for bio-regional site and climate**
- **Orientation for passive heating, cooling and daylighting**
- Brownfield or conserved ecosystem?
- Urban, suburban or rural?
- Ability to restore or regenerate ecosystems
- All determine *potential* for carbon sequestration on site

7 Impacts source: www.buildcarbonneutral.org

The buildings at IslandWood are located with a “solar meadow” to their south to take advantage of solar heating and daylighting.

Disturbance is impact.

- Protect existing soil and vegetation
- Design foundations to minimize impact
- Minimize moving of soil
- Disturbance changes existing ecosystems, natural habitats and changes water flow and absorption
- Disturbed soil releases carbon
- Disturbance can kill trees, lowering site potential for carbon reduction
- Look at the potential for reusing materials on site

Difficult foundations for a treed, sloped site for the Grand House Student Cooperative in Cambridge, Ontario, Canada

Natural ecosystems sequester carbon.

- Carbon is naturally stored below ground and is released when soil is disturbed
- Proper treatment of the landscape can keep this carbon in place *(sequestration)*
- Proper treatment of the landscape can be designed to store/accumulate/sequester more carbon over time
- Verify landscape design type with your *eco-region* – use of indigenous plant material requires less maintenance/water – healthy plants absorb more CO_2
- Possible to use the natural ecosystems on your site to assist in lowering the carbon footprint of your project

The natural site is preserved at IslandWood, Bainbridge Island.

Smaller is better.

- ***Simple!***…**less** building results in **less** embodied carbon; i.e. **less** carbon from materials used in the project, **less** requirements for heating, cooling and electricity….

- Re-examine the building program to see what is *really* required

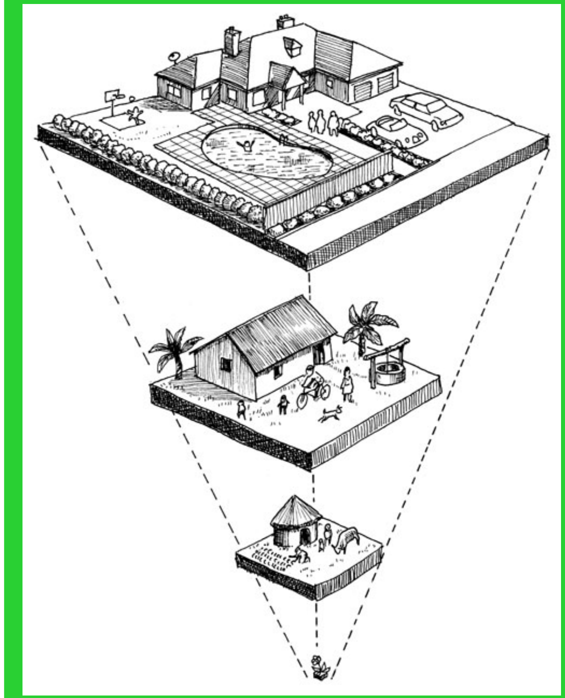
- How is the space to be used?

- Can the program benefit from more inventive double uses of spaces?

- Can you take advantage of outdoor or more seasonally used spaces?

- **How much building do you *really need?***

- **Inference of LIFESTYLE changes**



Calculating your "ecological footprint"

… can naturally extend to an understanding of your "carbon footprint"

Source: http://www.cycleoflife.ca/kids/education.htm

Buildings can help to sequester carbon.

- The materials that you choose can help to reduce your carbon footprint.
- Wood from certified renewable sources, wood harvested from your property, or wood salvaged from demolition and saved from the landfill can often be considered net carbon sinks.
- Planting new trees can help to compensate for the carbon released during essential material transport
- Incorporating *green roofs* and *living walls* can assist in carbon sequestration

Green roof at White Rock Operations Center, White Rock, B.C.

Green roof at Vancouver Public Library

Material choice matters.

- Material choice can reduce your building's *embodied* carbon footprint.
- Where did the material come from?
- Is it local?
- Did it require a lot of energy to extract it or to get it to your building?
- Can it be replaced at the source?
- Was it recycled or have significant post consumer recycled content?
- Can it be recycled or reused *easily;* i.e. with minimal additional energy?
- Is the material durable or will it need to be replaced *(lifecycle analysis)?*

Note: many of these concerns are similar to what you might already be looking at in LEED™

Foster's GLA – may claim to be high performance, but it uses many high energy materials.

Green on the Grand, Canada's first C-2000 building chose to import special windows from a distance rather than employ shading devices to control solar gain and glare.

Reuse to reduce impact.

- Reuse of a building, part of a building or elements reduces the carbon impact by avoidance of using new materials.
- Make the changes necessary to improve the operational carbon footprint of an old building, before building new.
- Is there an existing building or Brownfield site that suits your needs?
- Can you adapt a building or site with minimal change?
- Design for disassembly (Dfd) and eventual reuse to offset future carbon use

The School of Architecture at Waterloo is a reused factory on a remediated Brownfield site.

All of the wood cladding at the YMCA Environmental Learning Center, Paradise Lake, Ontario was salvaged from the demolition of an existing building.

Towards Zero Energy \ Zero Carbon:

LEED™ Gold

IslandWood

Early ZED

BEDZed

case studies

Jubilee Wharf

ZED

Aldo Leopold Legacy Center

Carbon Neutral

Zero Energy Design

The ZEDfactory Philosophy…

Key to the necessary paradigm shift required to go ZED, is a re-visioning of priorities for design.

"Architects and engineers say that reaching a zero-energy goal necessarily requires a much more integrated design process than is typical for a conventional building."

Current, unsustainable UK consumption

Image credit: ZEDfactory

BedZED:
Beddington Zero Energy Development

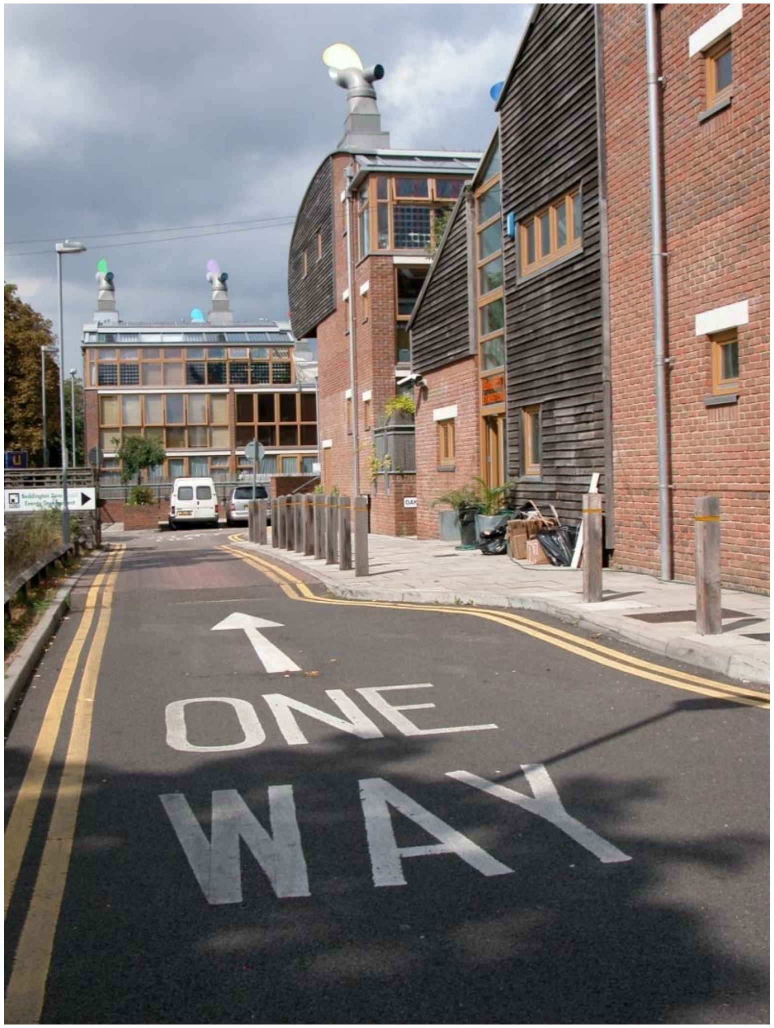
BedZED, Hackbridge, England, was created as a partnership with the BioRegional Development Group, the Peabody Trust, Bill Dunster Architects, Arup, and Gardiner and Theobald. The 82 houses, 17 apartments, and 1,405 m² of workspace were built between 2000-02. An example of early ZED design.

Climate: temperate, inland

BedZED:
Beddington Zero Energy Development

*Starts with **basic** sustainable principles of design:*

- ORIENTATION
- very high environmental standards
- high thermal insulation levels
- triple glazed windows
- sunlight / daylighting
- solar energy (direct gain + PV)
- reduction of energy consumption
- natural ventilation
- waste water recycling
- strong emphasis on roof gardens
- built from natural, recycled, or reclaimed materials
- reduction in parking – pedestrian oriented
- re-allocation of site/use distribution for community's best interests



BedZED: Then goes for Zero Energy….
Density and General Site Strategies

#1.

The development uses a higher density than typical.

#2.

This separates parking from housing.

#3.

And consolidates significant green space.

BedZED:
Alternative Parking/Car Strategies

#1.

Designed to encourage alternatives to car use.

#2.

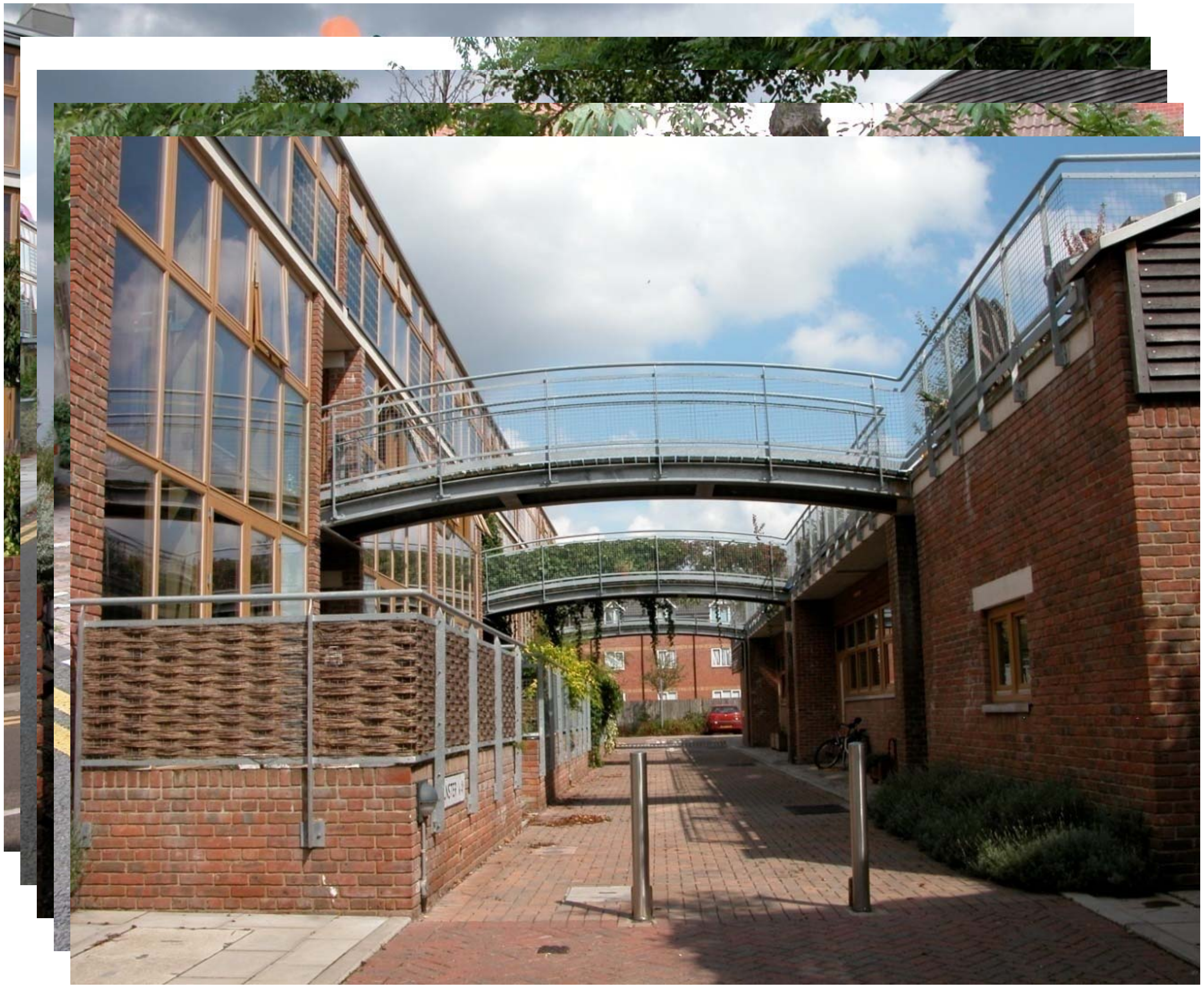
A green transport plan promotes walking, cycling, and use of public transport.

#3.

A car pool for residents has been established. BedZED's target is a 50% reduction in fossil-fuel consumption by private car use over the next 10 years compared with a conventional development.

#4.

A "pedestrian first" policy with good lighting, drop curbs for prams (strollers) and wheelchairs, and a road layout that keeps vehicles to walking speed.



BedZED:
Landscape and Vegetation

#1.

Green space divided into large communal spaces + personal gardens/terraces.

#2.

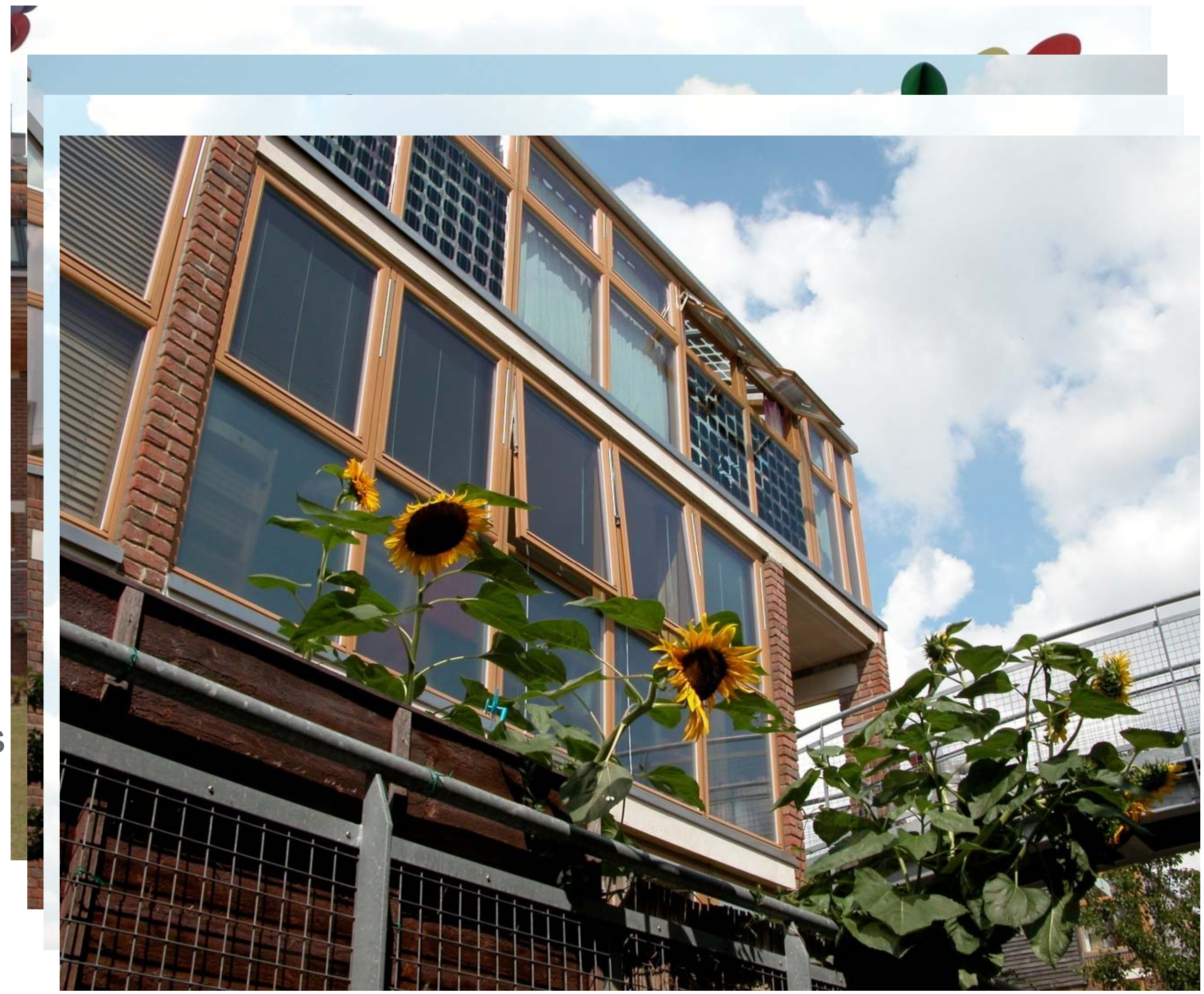
Green space at grade assists in lowering overall overheating in summer.

#3.

Green space at the roof level is private, and also incorporates seedum roofs.

#4.

Vegetable and edible crops are encouraged.



BedZED:
Passive Solar Strategies

#1.

Uses passive solar techniques to maximize heat gain for cool months

#2.

Houses are arranged in south facing terraces to maximize direct solar gain

#3.

Glass is maximized on south face (minimized on north side to prevent losses).

BedZED:
Passive Cooling Strategies

#1.

Each terrace is backed by north facing offices, which reduces the tendency to overheat and the need for air conditioning.

#2.

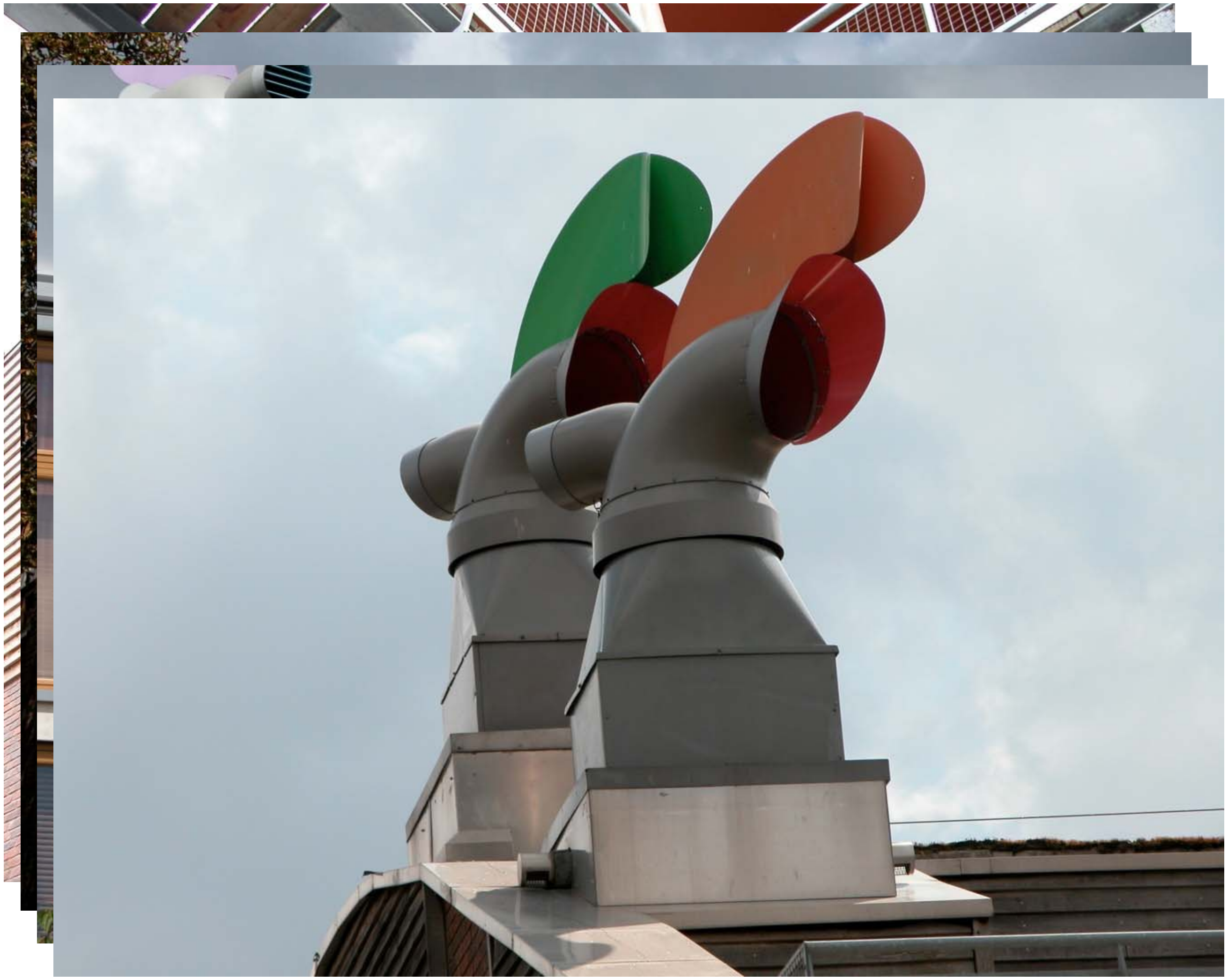
Large quantities of operable windows encourage natural ventilation.

#3.

PV is used to shade windows.

#4.

Wind cowls direct ventilation flow.



No A/C is provided.

BedZED:
Non-fossil fuel heating for space and water

Once needs have been reduced passively…

#1.

A centralized heat and power plant (CHP) provides hot water, which is distributed around the site via a district heating system of super-insulated pipes.

#2.

The CHP plant at BedZED is powered by off-cuts from tree surgery waste that would otherwise go to landfill.

The target was for zero fossil fuel use.

BedZED:
Material choices

#1.

Embodied energy (a measure of the energy required to manufacture a product) was key in choosing materials.

#2.

They were sourced within a 35-mile radius of the site when possible, reducing transportation energy.

#3.

Recycled materials and high recycled content were key.

75 year minimum target design life.

BedZED:
Generation of on Site Electricity

#1.

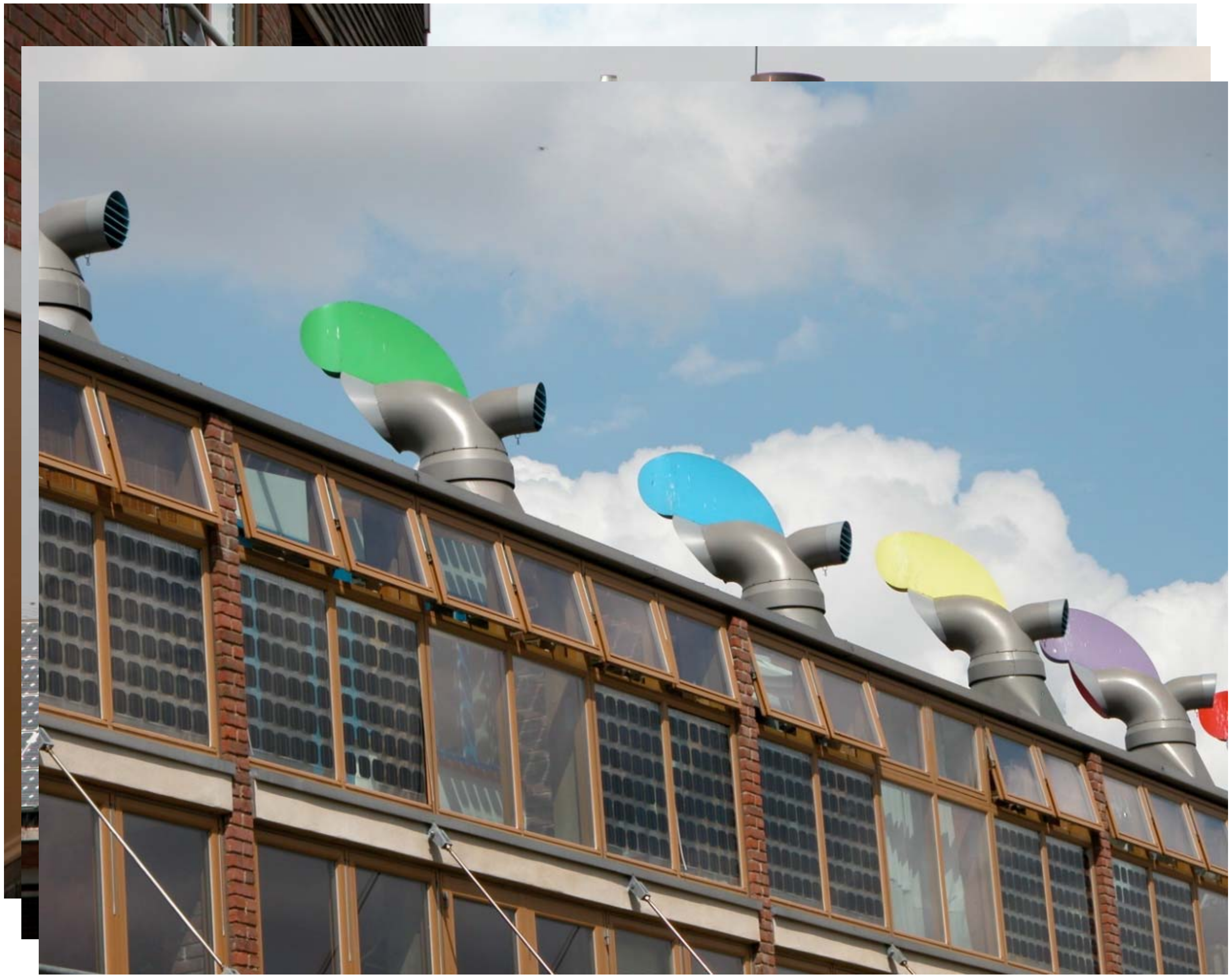
It was felt to be more efficient to generate electricity with the CHP facility.

#2.

PV panels were targeted at fueling electric vehicles.

#3.

PV was installed over 777m2 and was also used for shading.



Excess electricity is sold back to the grid.

BedZED:
Water Systems

Water use is carefully planned…

#1.

Rainwater is collected and used for irrigation and toilet flushing.

#2.

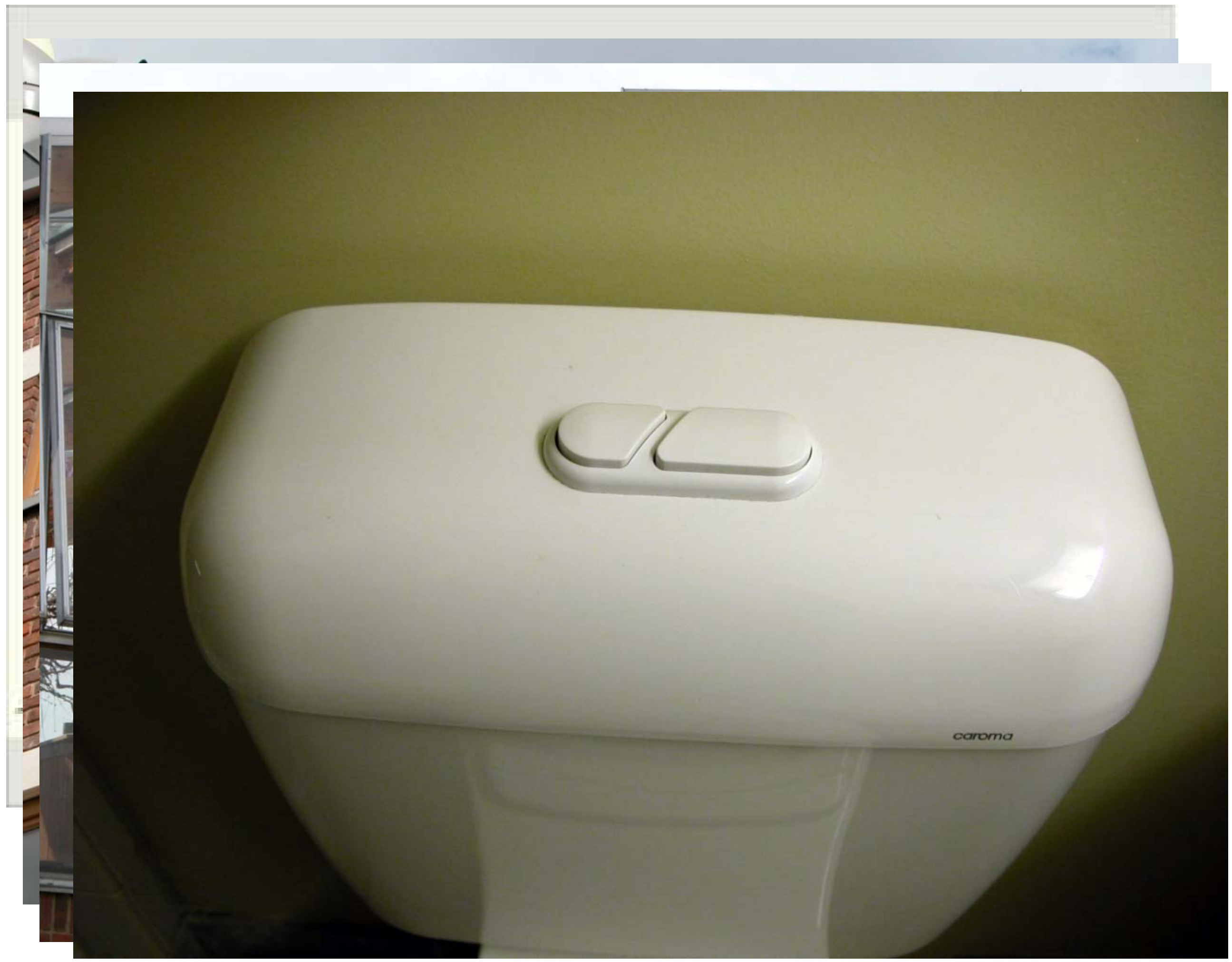
Black water is treated on site and cycled into the irrigation system.

#3.

Dual flush toilets reduce water consumption.

#4.

Shaped bathtubs reduce water requirement.



The target was to cut normal household use by 33%.

BedZED:
Waste Recycling

#1.

Waste recycling collection depots are located throughout the community.

#2.

Kitchens are outfitted with built in recycling storage.

#3.

On site composting.

The target was to reduce landfill waste by 66%.

BedZED:

Integrated Design Process

KEY WORKING CONCEPT:

Such a complex design with delicately inter-layered, synergistic systemic requirements mandates use of the ***Integrated Design Process*** from the early concept stages of development.

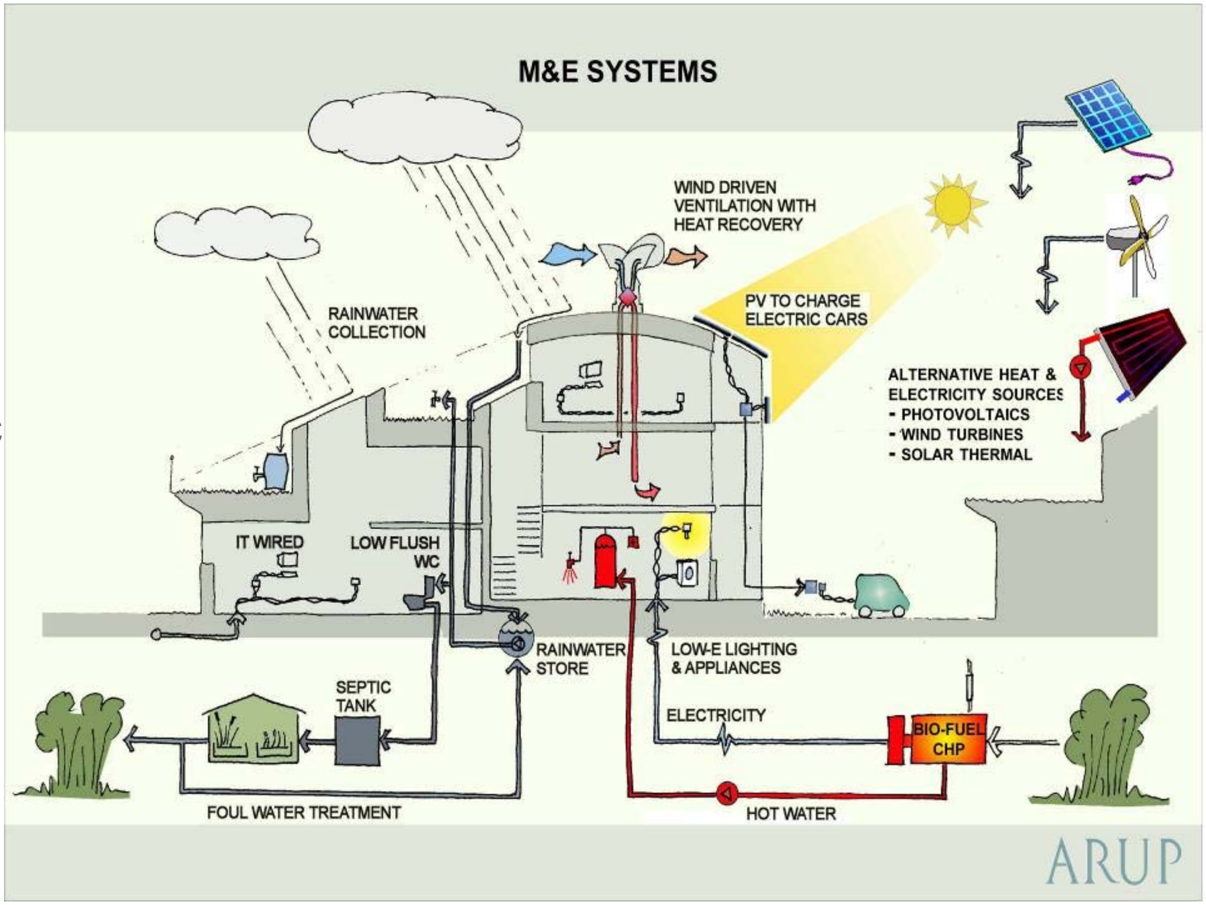


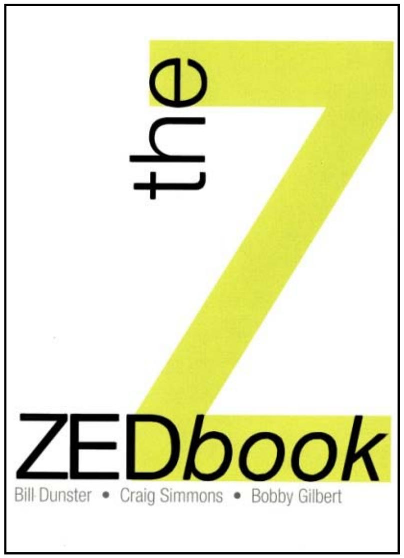
Image credit: ARUP and Dunster

Zero emission design requires strict adherence to a philosophy of conservation and cooperation.

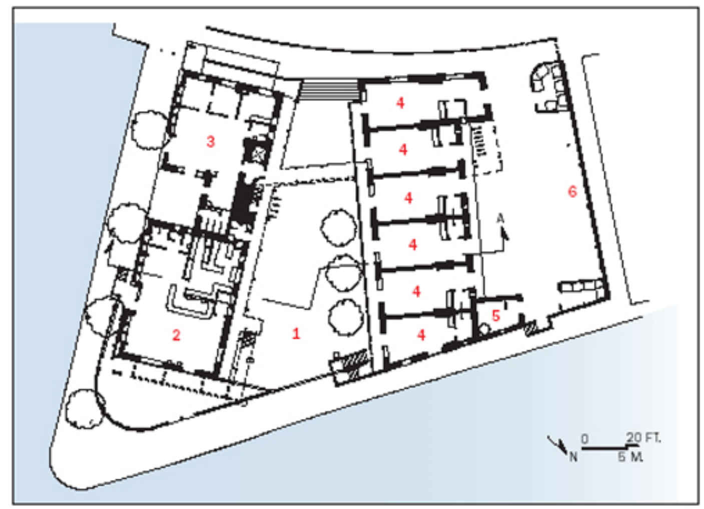
The ZEDfactory Philosophy…

Post BEDZed, ZEDfactory has set a list of priorities that are now incorporated into most designs:

- ✓ First consider the site, climate, solar angles
- ✓ Use brownfields
- ✓ Maximize density, while keeping green amenity space
- ✓ Keep a loose fit to allow for change, adaptation over time
- ✓ Design out the need to travel
- ✓ Minimize thermal and electrical requirements as it is easier to save electricity than to generate it
- ✓ Make an energy efficient envelope
- ✓ Use efficient appliances
- ✓ Use passive solar energy for heat and sun for daylighting
- ✓ Use natural ventilation
- ✓ Use wind cowls to assist natural ventilation
- ✓ Generate maximum renewable energy *from within the site boundaries*
- ✓ Incorporate wind turbines and PV
- ✓ Allow for upgrade paths if not all systems can be installed
- ✓ Use reclaimed or local materials



Jubilee Wharf: ZEDfactory



GROUND FLOOR PLAN

1 Courtyard
2 Cafe
3 Community hall
4 Workshop
5 Boiler room
6 Parking

Architect: ZEDfactory
Location: Jubliee Wharf, Penryn, Cornwall
Client: Robotmother Ltd
Description: Mixed use with residential, workshops and nursery
Start / Completion: October 2004 - September 2006
Climate: temperate, coastal

Jubilee Wharf:
Integrated Design Process

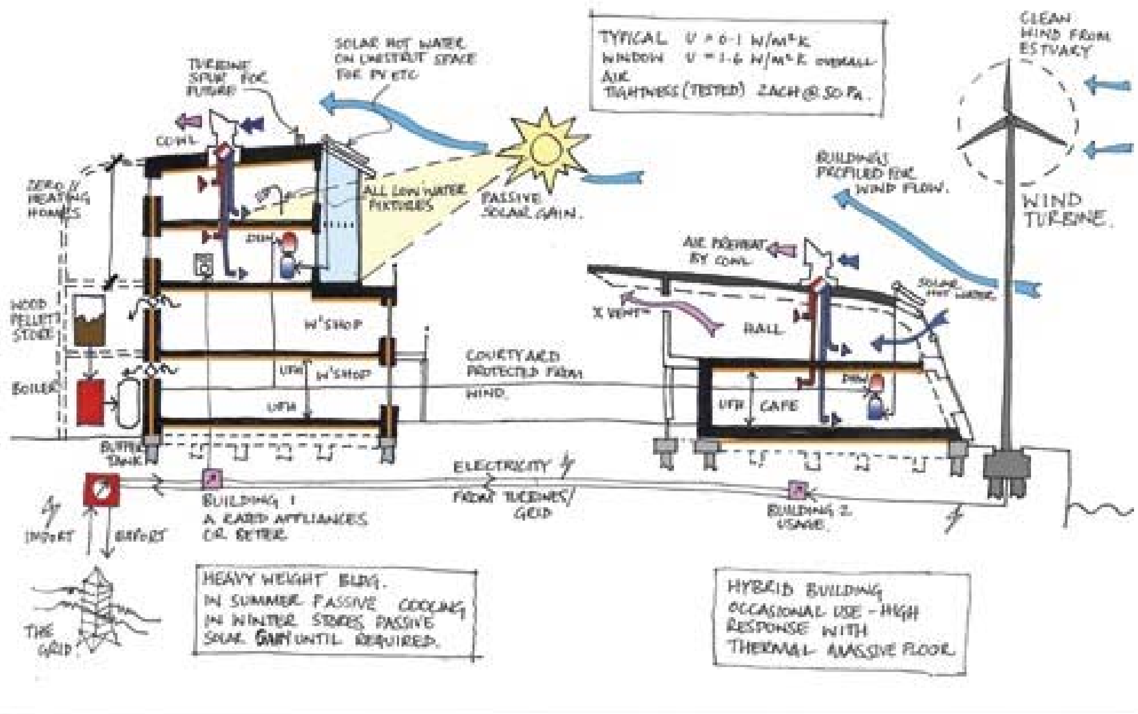


Image credit: ZEDfactory

The project begins with an integrated design approach that takes all of the key ZED concepts into account – from the beginning, starting with the sun, wind and climate.

The IDP diagram provides the basis for decisions throughout the project. It reveals how the building has been zoned by use – intensive residential use on the left, and occasional use on the right. This makes better use of the systems and site.

Jubilee Wharf:

Key Strategies List | Site and Community

Brownfield Site –
The site was previously occupied by a coalyard.

Community creation & revitalization - a hub for craft makers, quality childcare onsite, health & fitness classes, café for socializing.

Pedestrian and public transit oriented - good public transport links, located in central Penryn for easy pedestrian access.

Jubilee Wharf:
Key Strategies List | Envelope

Super Insulation –
300mm insulation reduces energy consumption to less than half a conventional building. This level of efficiency is necessary to reduce consumption and make fossil fuel avoidance possible.

Thermal Mass –
The interior surfaces are made from concrete block, concrete and plaster so that heat is stored efficiently.

Air Tightness –
The interior surfaces are parged with plaster, making sure to seal all cracks between joining materials.

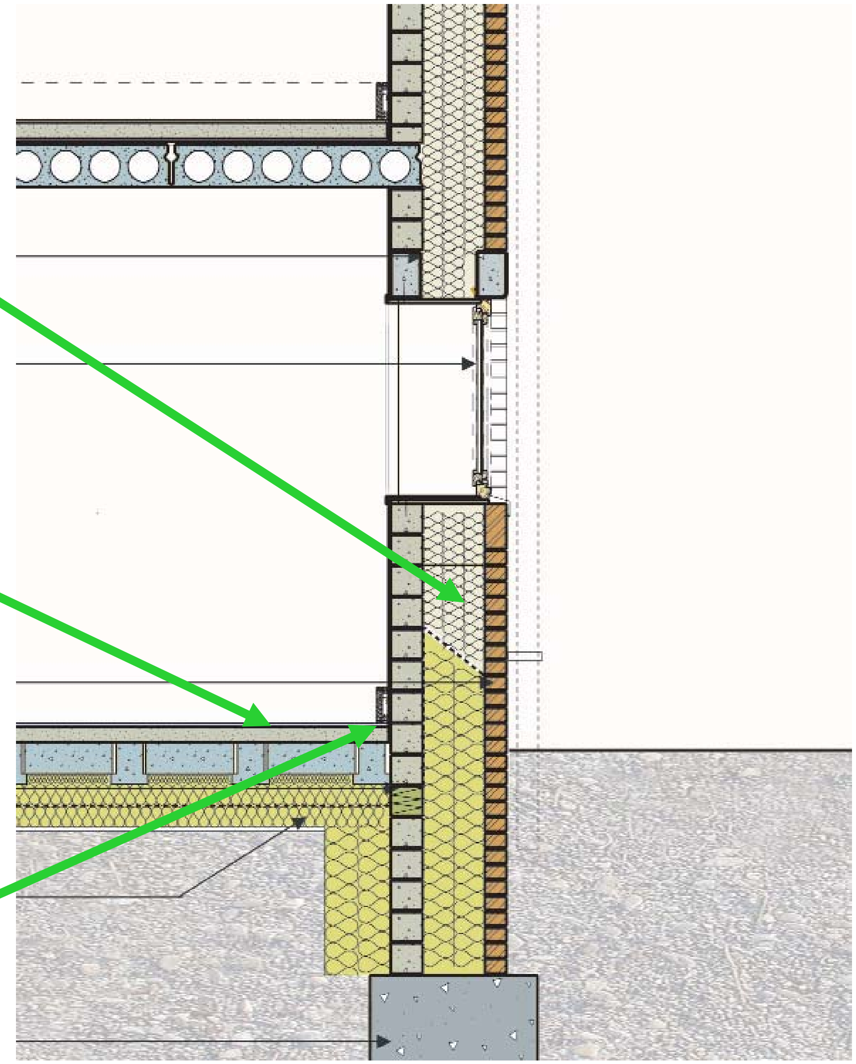


Image credit: ZEDfactory

Jubilee Wharf:

Key Strategies List | Reclaimed Materials

Using local & reclaimed materials - old floorboards, granite, Cornish cedar cladding and larch soffits, and some unused windows from BedZed

For example:
The ceiling of the Yoga space is made of reclaimed floorboards from a Victorian house. The boards have not been changed but simply treated and cut to length.

Image credit: ZEDfactory

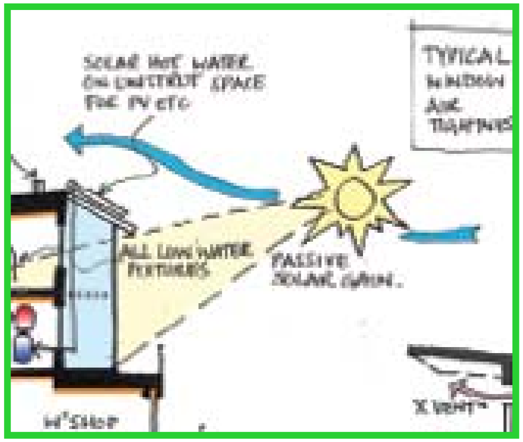
Jubilee Wharf:
Key Strategies List | Healthy Materials

Healthy materials - low VOC paints, low formaldehyde floor coverings, natural fibers & surfaces, PVC only where unavoidable – with emphasis on creating a healthy environment.

Jubilee Wharf:
Key Strategies List | Energy and Systems

Passive solar heating –
The sun space faces south and is used as a buffer space. In cold months the thermal mass heats up. In hot months the space can be closed off to keep the interior cool. It also shades the interior space.

Daylighting –
Window placement makes use of natural light.



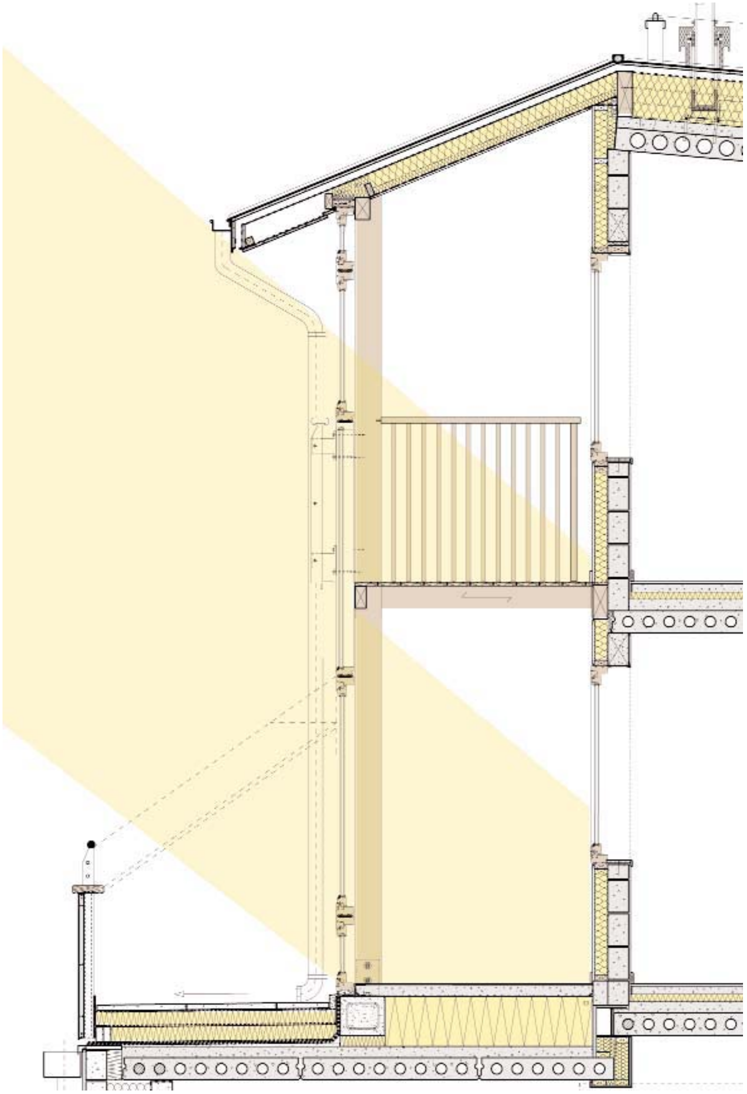


Image credits: ZEDfactory

Jubilee Wharf:

Key Strategies List | Energy and Systems

Natural ventilation –
Wind cowls ventilate without the need for electric fans.

Being passive it uses no electricity.

This displacement ventilation provides fresh air at low level and extracts air at the high level when the temperature of the air in the room has risen.

The cowl turns to face the wind drawing fresh air in via a heat exchanger which warms the incoming air with the outgoing air.

The heat exchanger is 70 - 80% efficient and minimizes heat loss from the building while providing a constant supply of fresh air.

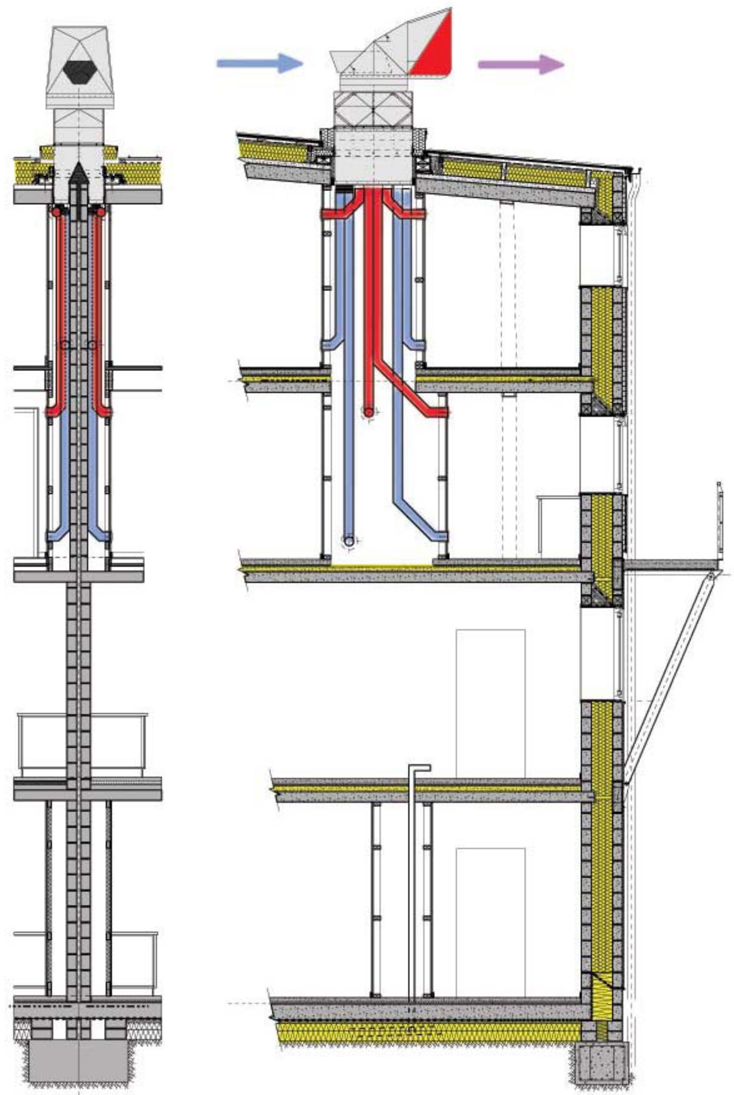


Image credit: ZEDfactory

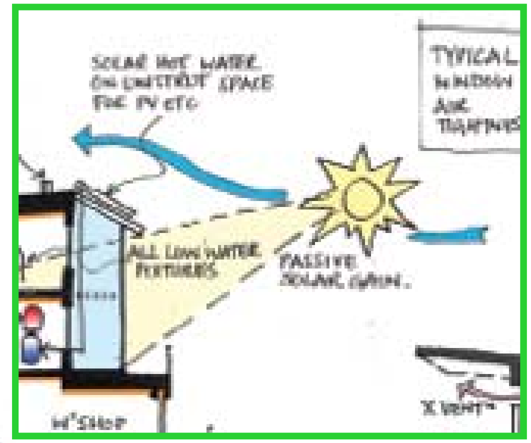
Jubilee Wharf:
Key Strategies List | Energy and Systems

Solar panels –
The project uses evacuated tubes for water heating – one panel per residence.

Photovoltaics –

Photovoltaic cells were not included in the original budget but provisions have been made for them to be fitted later.

Reduced water consumption –
Low flush toilets, aerated taps, grade “A” consumption appliances.



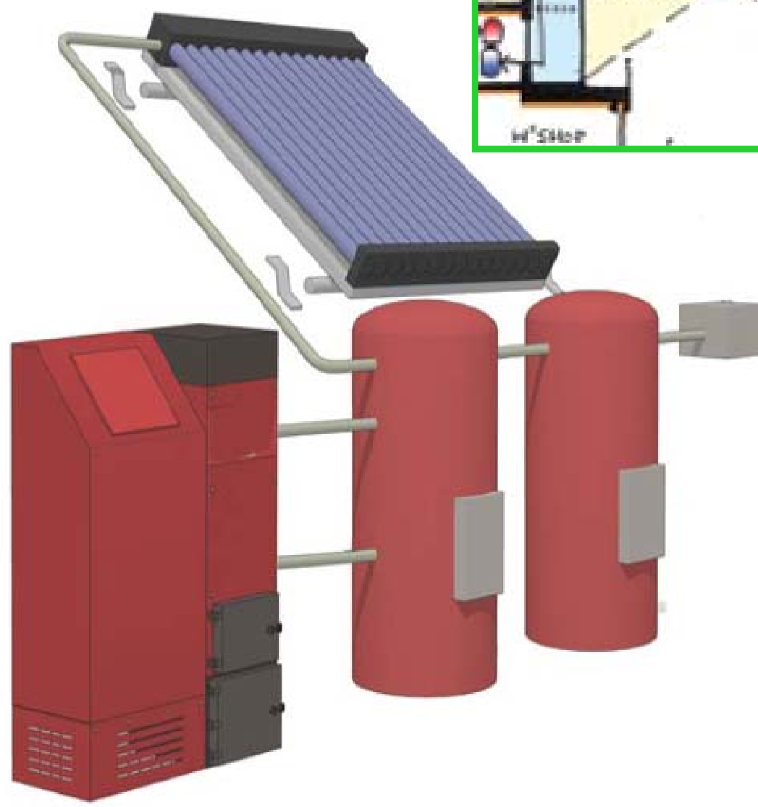


Image credits: ZEDfactory

Jubilee Wharf:

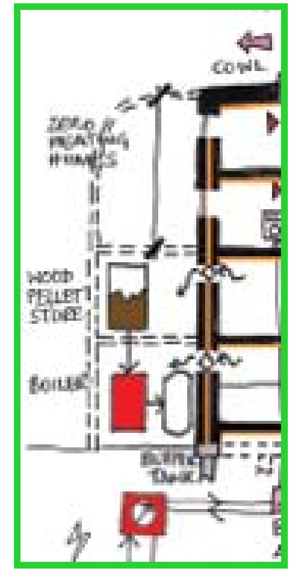
Key Strategies List | Energy and Systems

Biomass heating –

Under floor heating and hot water from a 75kW wood pellet boiler.

Onsite micro generation –

4 x 6kW Proven wind turbines provide most of the electricity – giving back to the grid or drawing from as required.



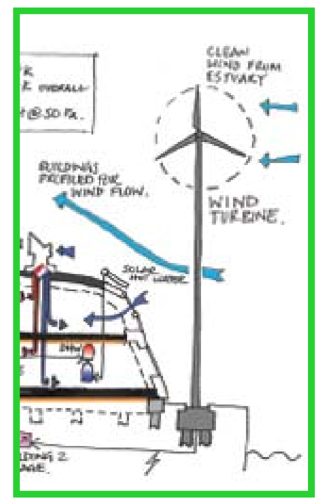


Image credits: ZEDfactory

Carbon Neutral – Operating Energy

Aldo Leopold Legacy Center

Baraboo, Wisconsin

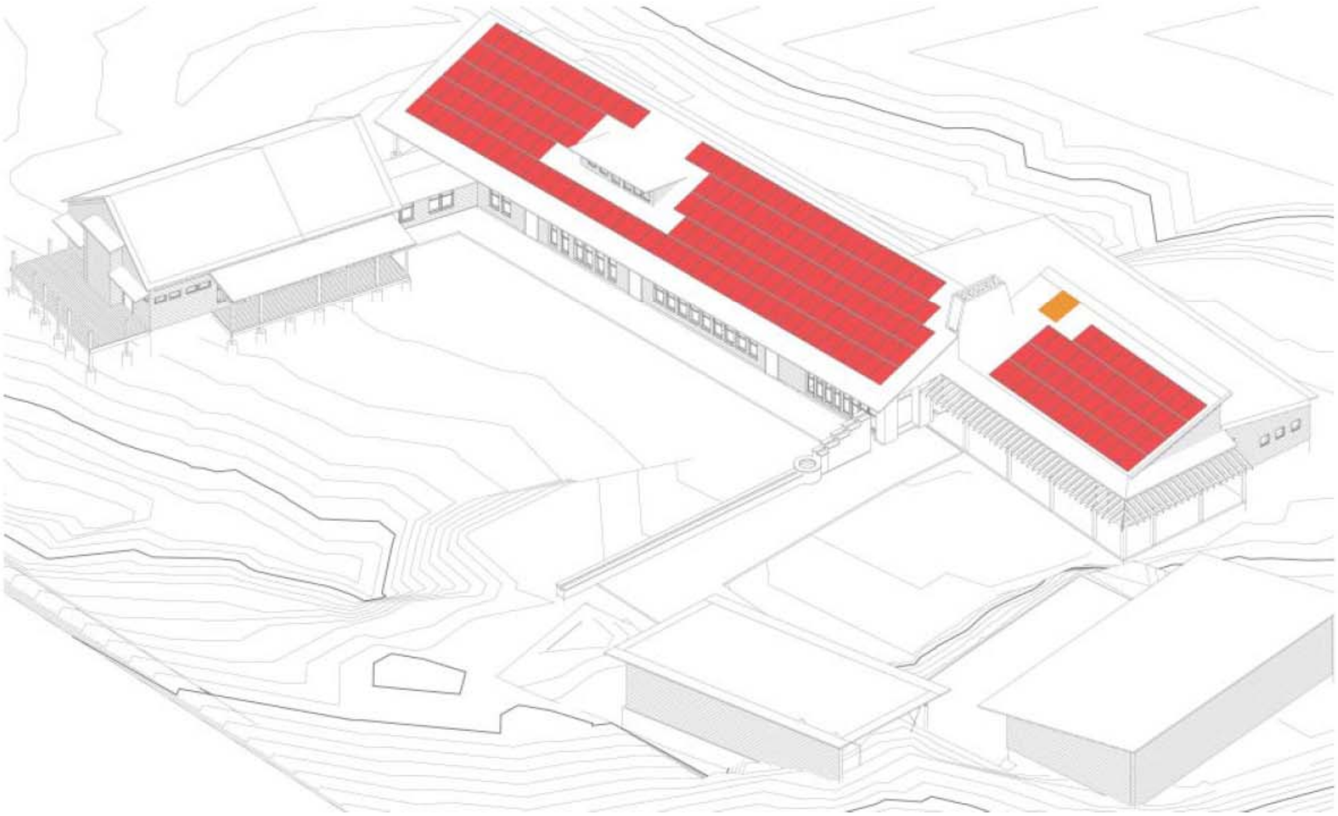
The Kubala Washatko Architects
LEED^{TM} Platinum 2007

Technical information from Prof. Michael Utzinger, University of Wisconsin-Milwaukee

Leopold Approach to Carbon Neutral Design

- Design a Net Zero (Operating Energy) Building
- Apply Carbon Balance to Building Operation (Ignore Carbon Emissions due to Construction)
- Include Carbon Sequestration in Forests Managed by Aldo Leopold Foundation
- Design to LEED™ Platinum (as well)
- with 2 unique starting points…

#1 - Net Zero Energy Design



SOLAR PV DENSITY
(conditioned s.f.)
4.66 Watt / SF

SOLAR THERMAL DENSITY
(conditioned s.f.)
.012 SF / SF

Renewables + Site Generation

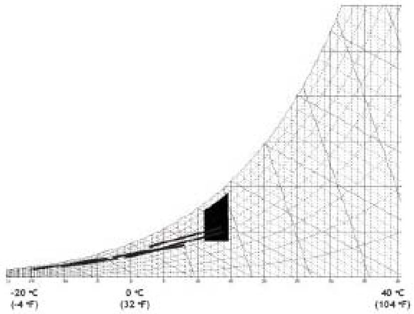
A $US250,000 PV array was included at the outset of the project budget and the building was designed to operate within the amount of electricity that this would generate.

#2 - Site Harvested Lumber:

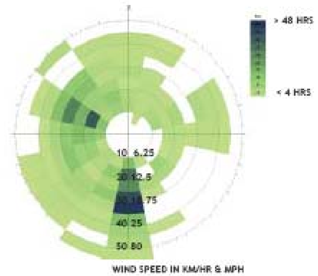
Embodied Carbon in Building Materials

The building was designed around the size and quantity of lumber that could be sustainably harvested from the Leopold Forest.

Climate Analysis



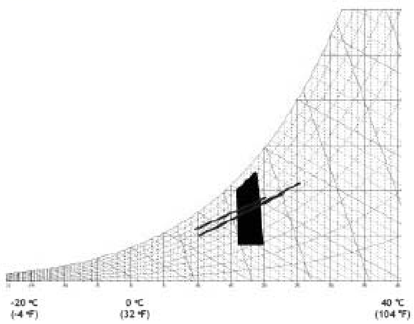
HEATING SEASON: OCT. - APR.



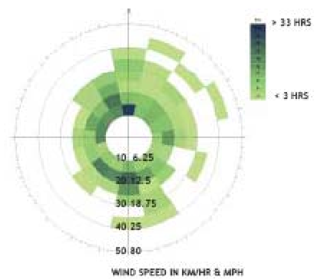
HEATING SEASON MONTH: JANUARY

Climate Narrative
Source: NOAA Weather Data Files

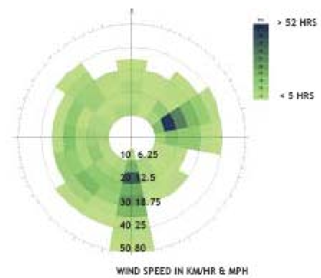
The climate is typical of the continental interior of North America with a large annual temperature range and with frequent short period temperature changes. The range of extreme temperatures is from about 43 to -40 degrees Celsius (110 to -40 degrees Fahrenheit). Winter temperatures (December-February) average near -7 °C (20 °F) and the summer average (June-August) is around 20 °C (in the upper 60s °F). Daily temperatures average below 0 °C (32 °F) about 120 days and above 4 °C (40 °F) for about 210 days of the year.



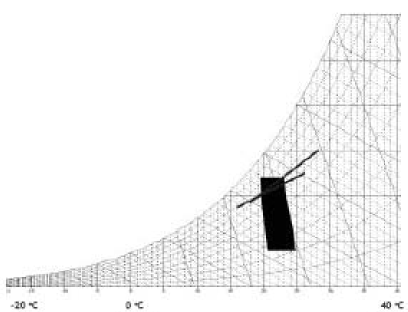
SWING SEASONS: MAY - JUN., SEP.



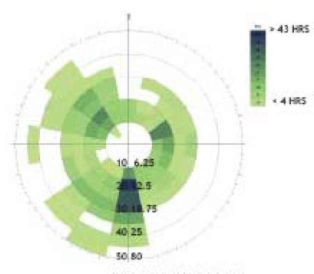
SWING MONTH: SEPTEMBER



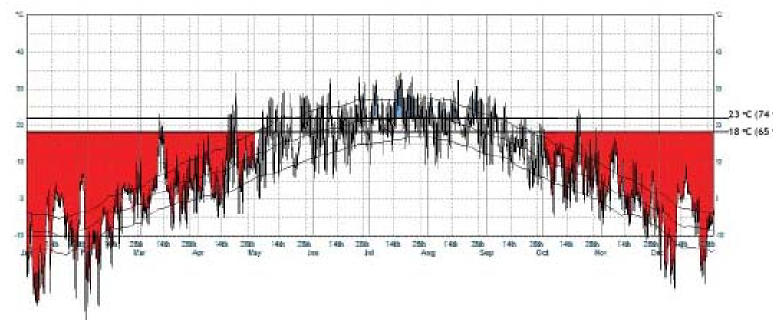
SWING MONTH: MAY



COOLING SEASON: JUL. - AUG.



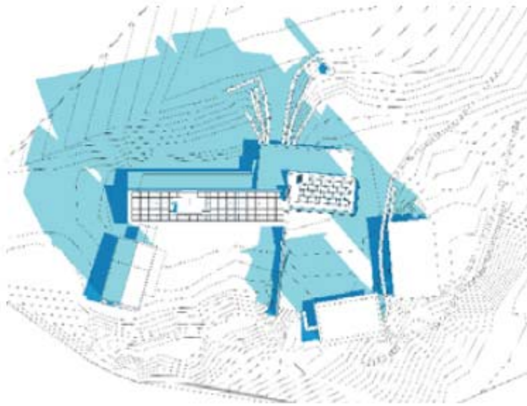
COOLING SEASON MONTH: JULY



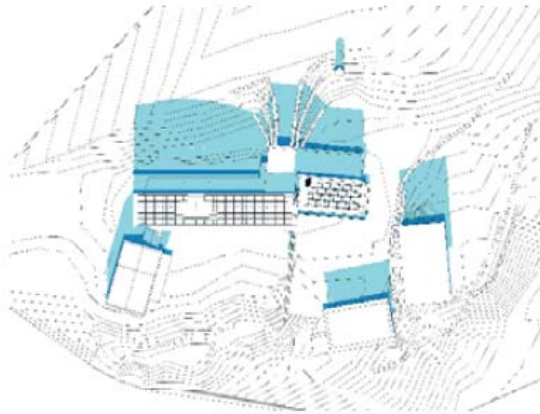
DAILY TEMPERATURE

Heating Degree Days (HDD): 7,643
Cooling Degree Days (CDD): 139

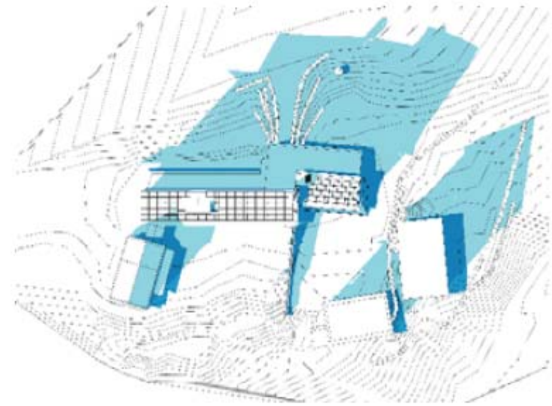
Site Analysis



9:00 am



Noon

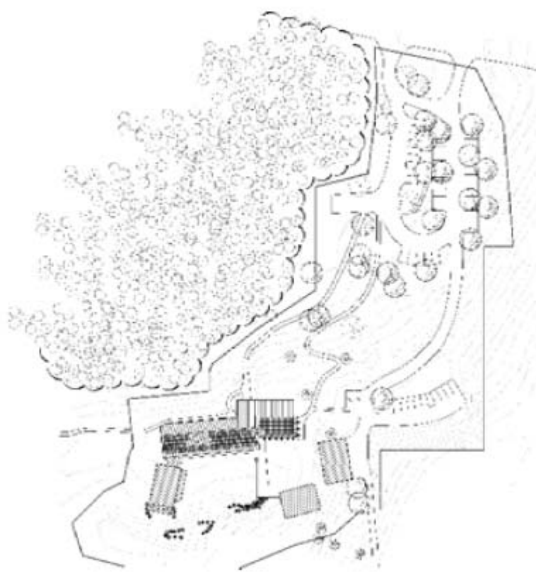


3:00 pm

Site Shading Study

June 21
December 21

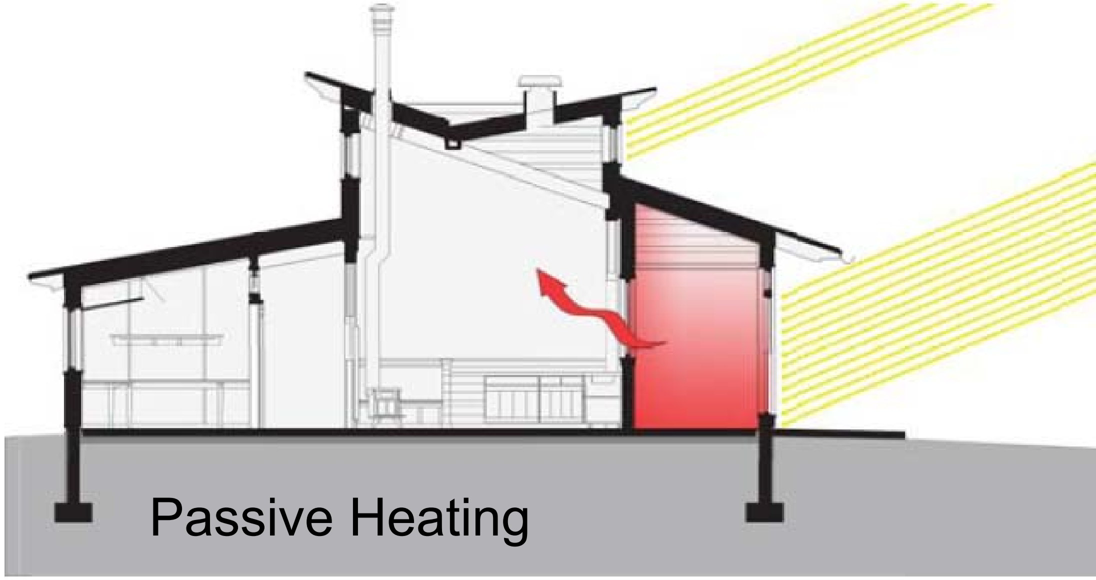
Ariel Image from South
Source: ____________

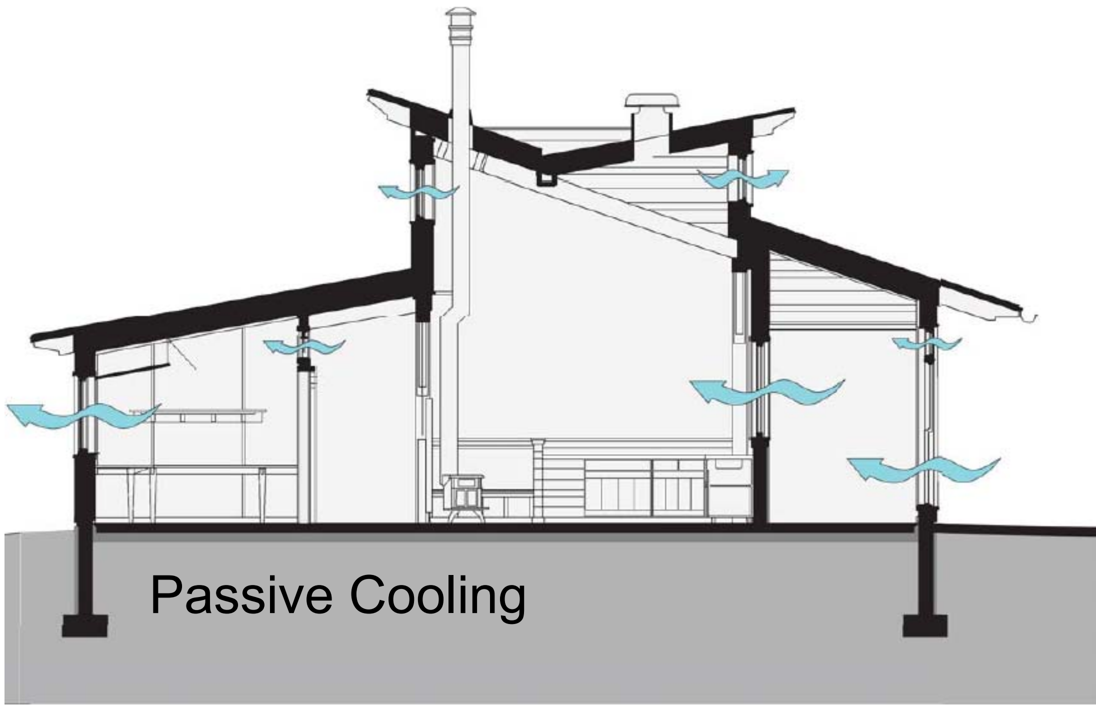


N

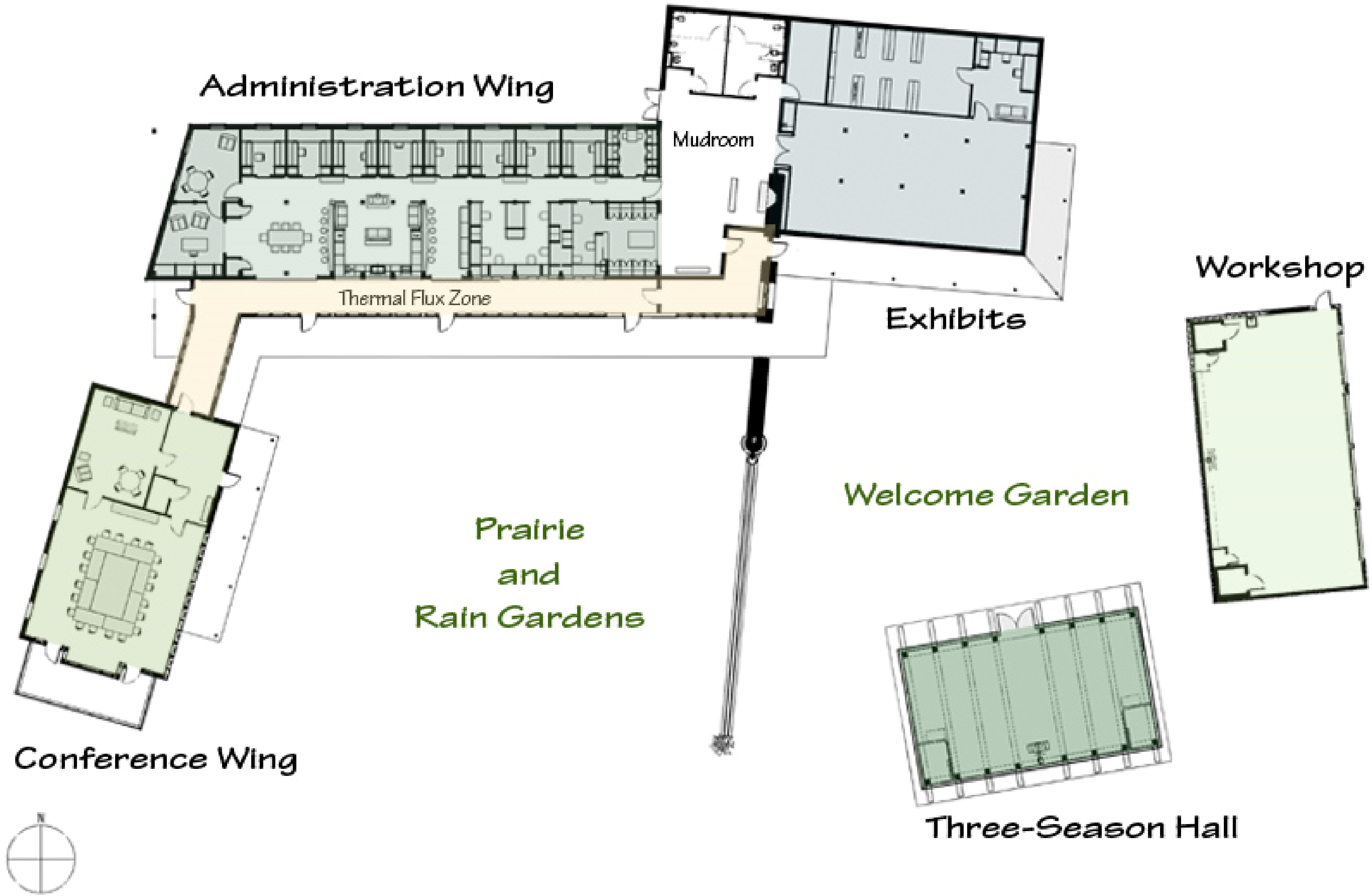
Architectural Design Strategies

- Start with bioclimatic design
- Program Thermal Zones
- All perimeter zones (no interior zones – skin load dominated building)
- Daylight all occupied zones
- Natural ventilation in all occupied zones
- Double code insulation levels
- Passive solar heating
- Shade windows during summer





Thermal Zones ~ Perimeter Zones

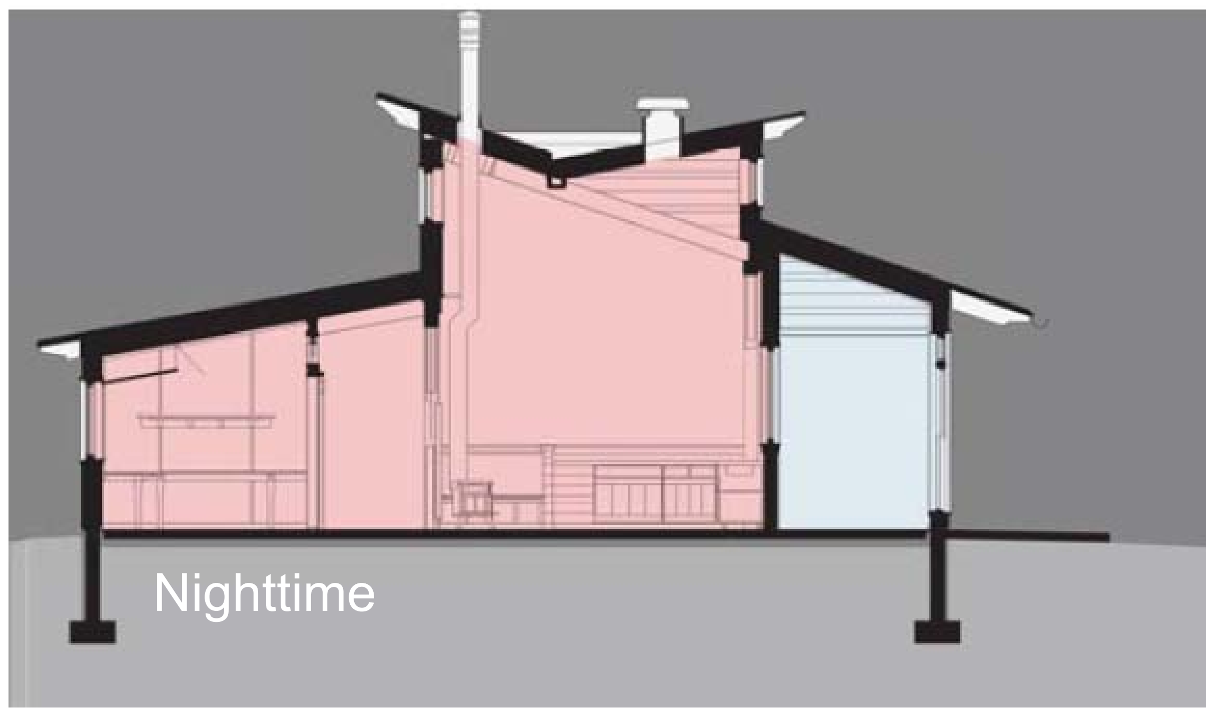


Keep the buildings thin to allow for maximum daylight and use of solar for passive heating.

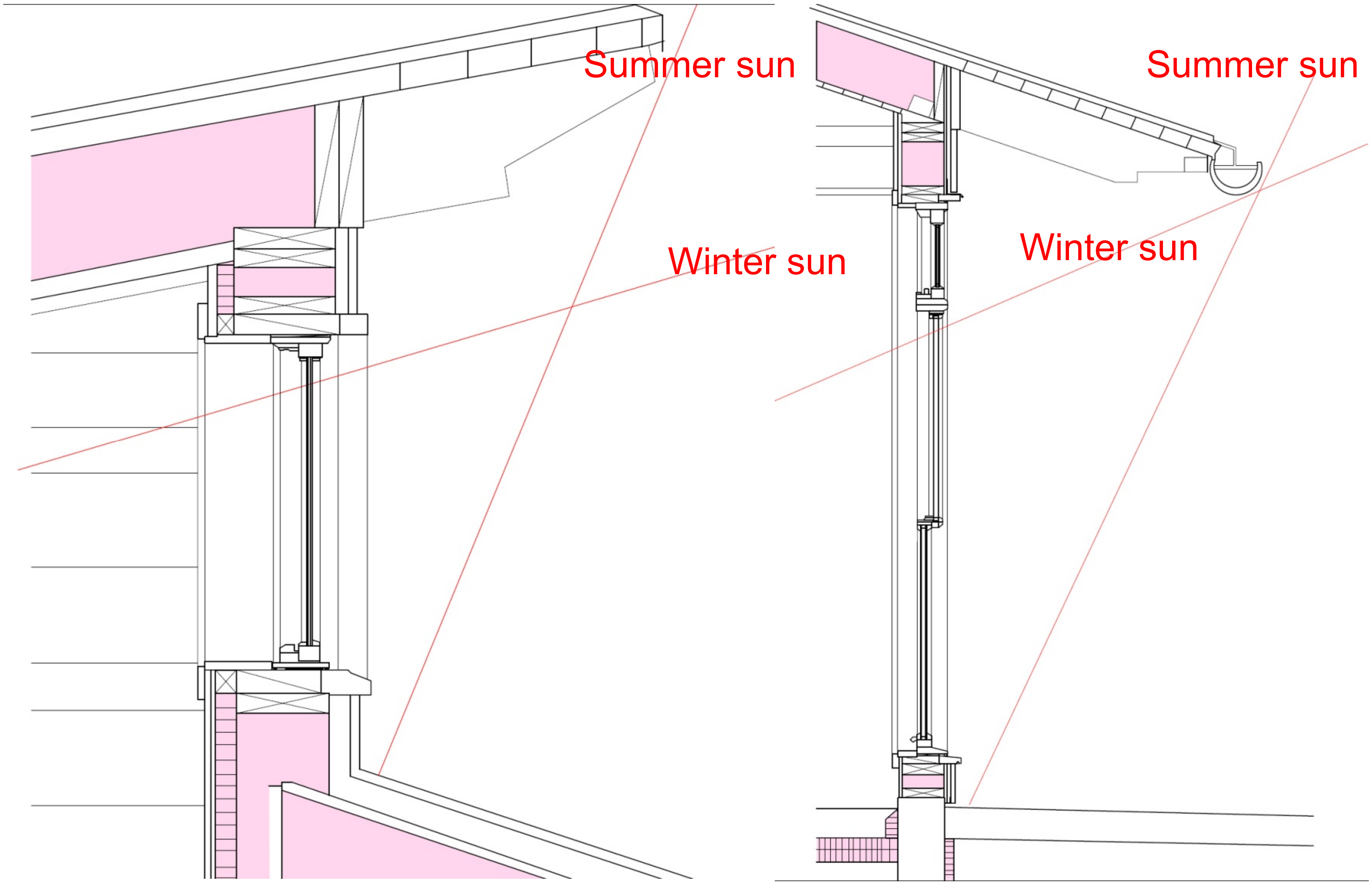
Passive Solar Heating

- The concrete floor in the hall is used with direct gain to store heat
- Large doors are opened to allow transfer to occupied spaces

Daytime



Passive Cooling: Shade Windows During Summer



Basic first tier principle of HEAT AVOIDANCE.

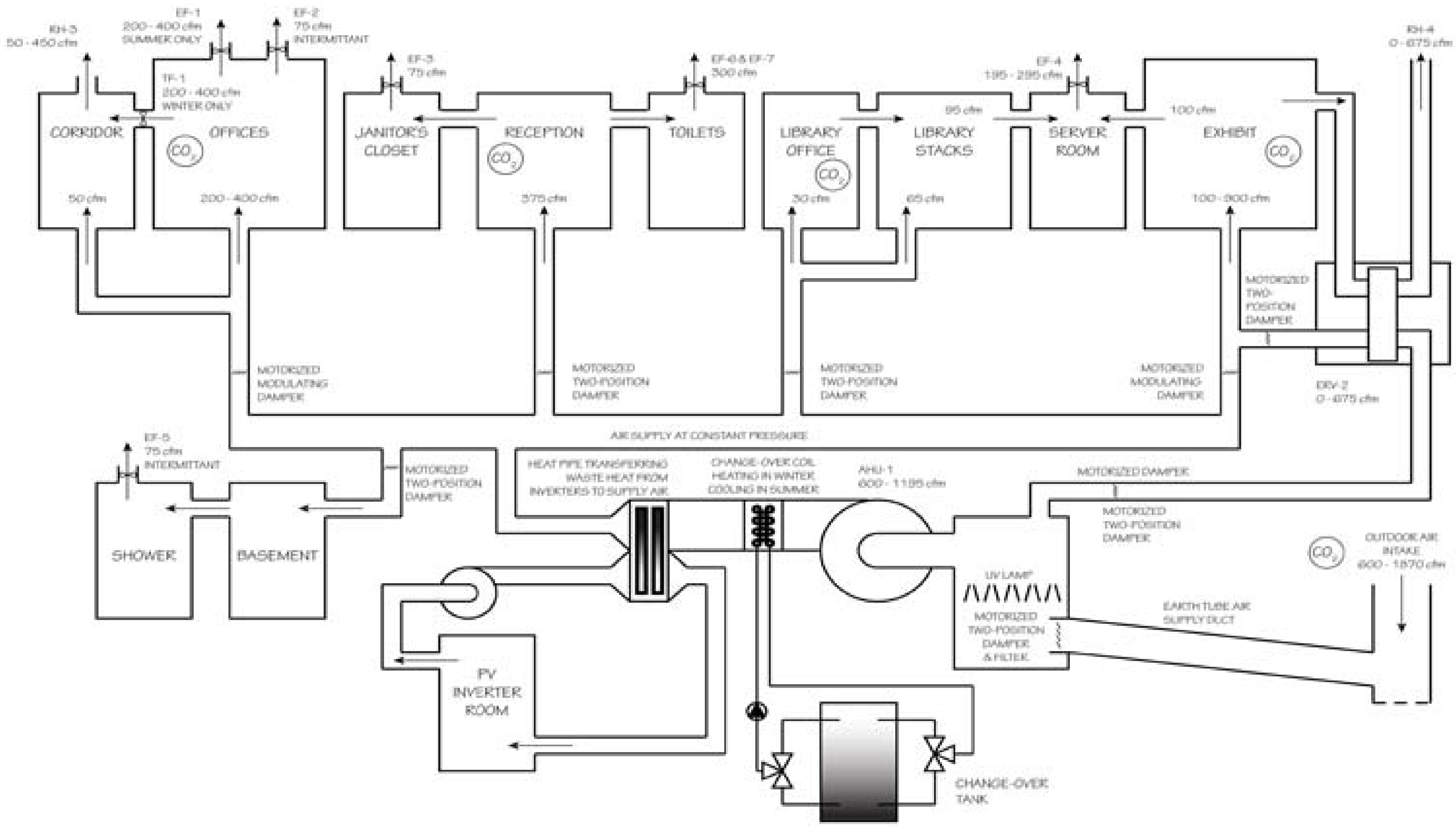
Natural Ventilation

- Natural ventilation strategy based on NO A/C provision for the building
- Operable windows
- Flow through strategy
- Insect screens to keep out pests

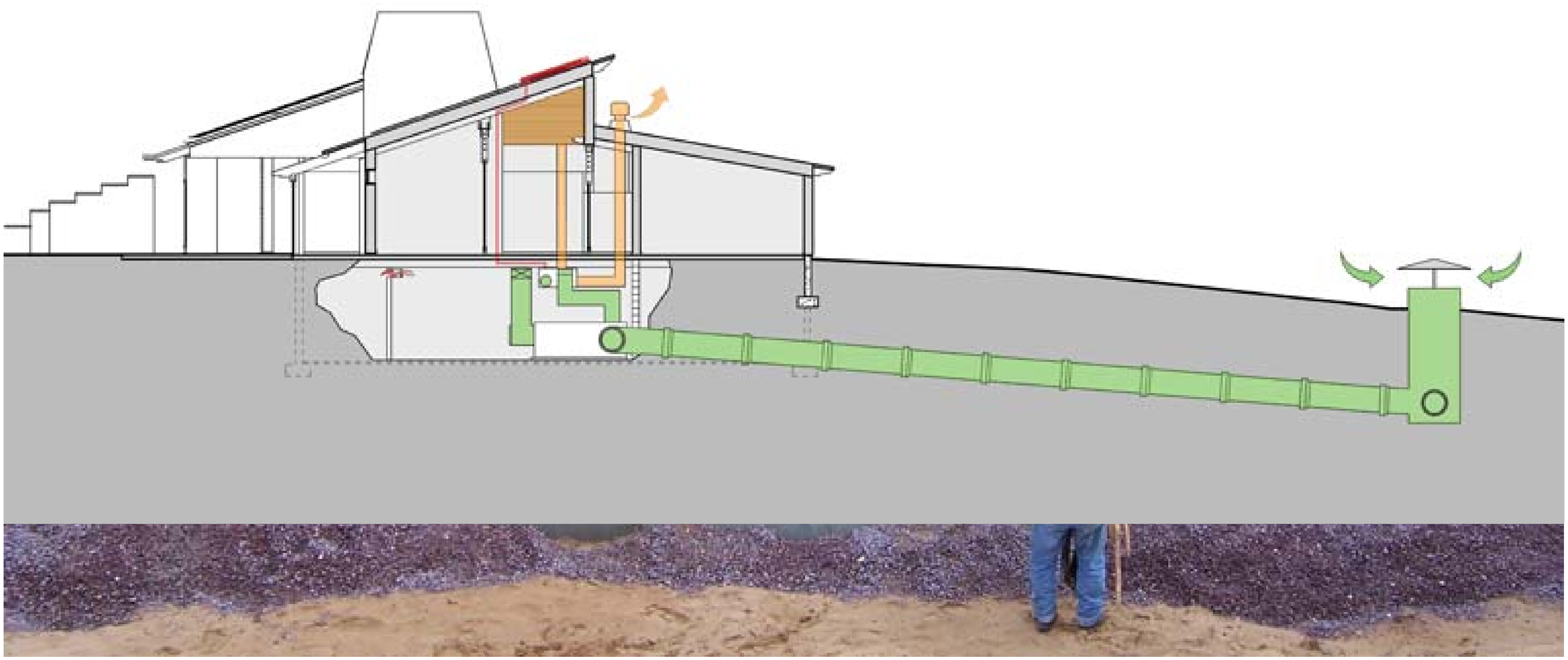
HVAC Strategies

- Ventilate only to Occupant outdoor air requirements (2/3 ACH)
- 100% Outdoor air (no recirculation)
- Earth tube air pretreatment
- Demand Control Ventilation (600 to 2,500 cfm)
- Separate ventilation from heating and cooling
- Radiant floor slabs for heating and cooling
- Use ground as heat source & sink (ground source heat pumps)
- Storage tank as thermal capacitor between heat pumps & load
- Seasonal change-over system
- Solar heated service hot water

Ventilation System



Earth Duct for Air Pretreatment



Installation of large earth ducts to preheat and precool the air.

Radiant Heating and Cooling

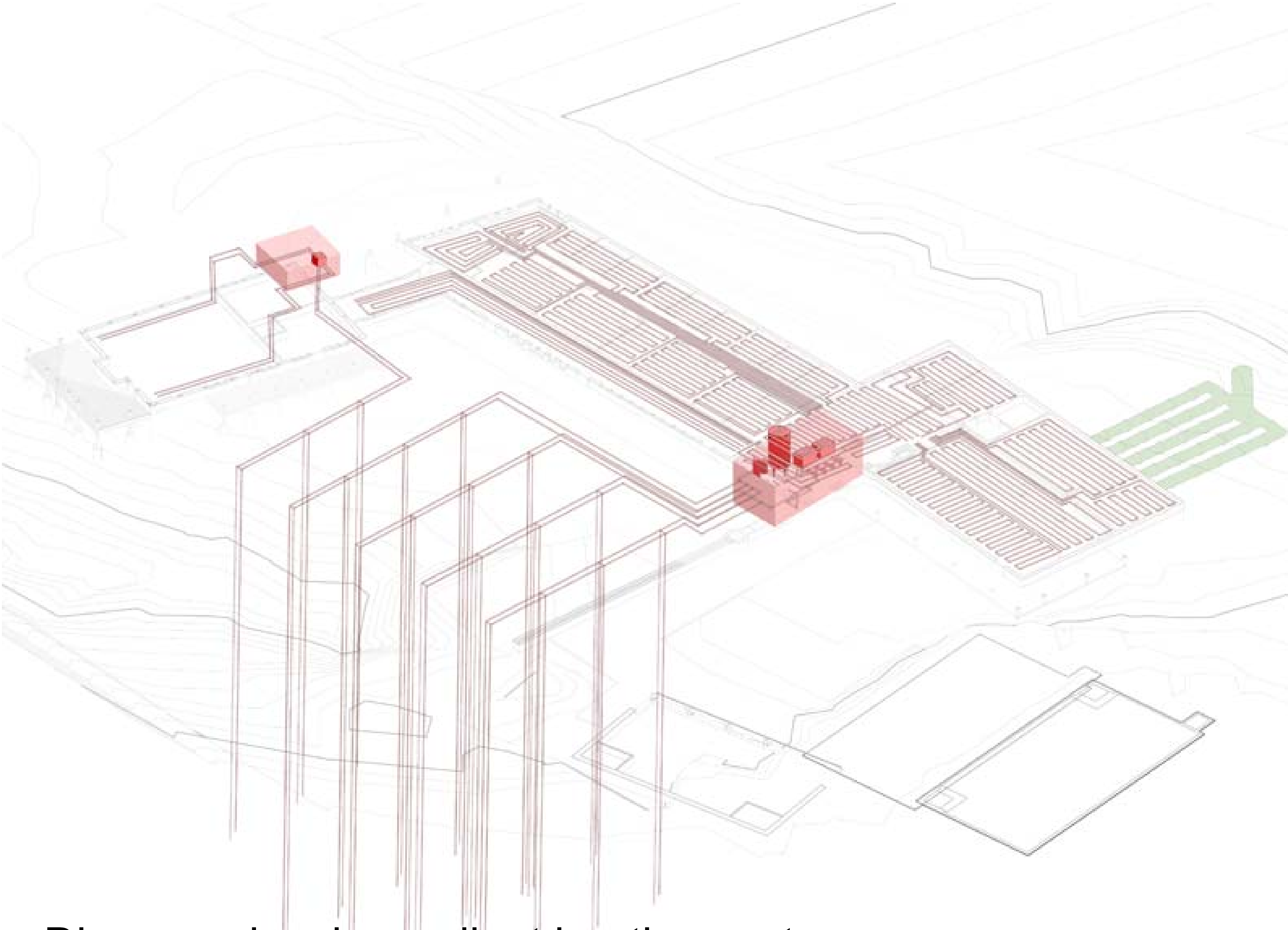
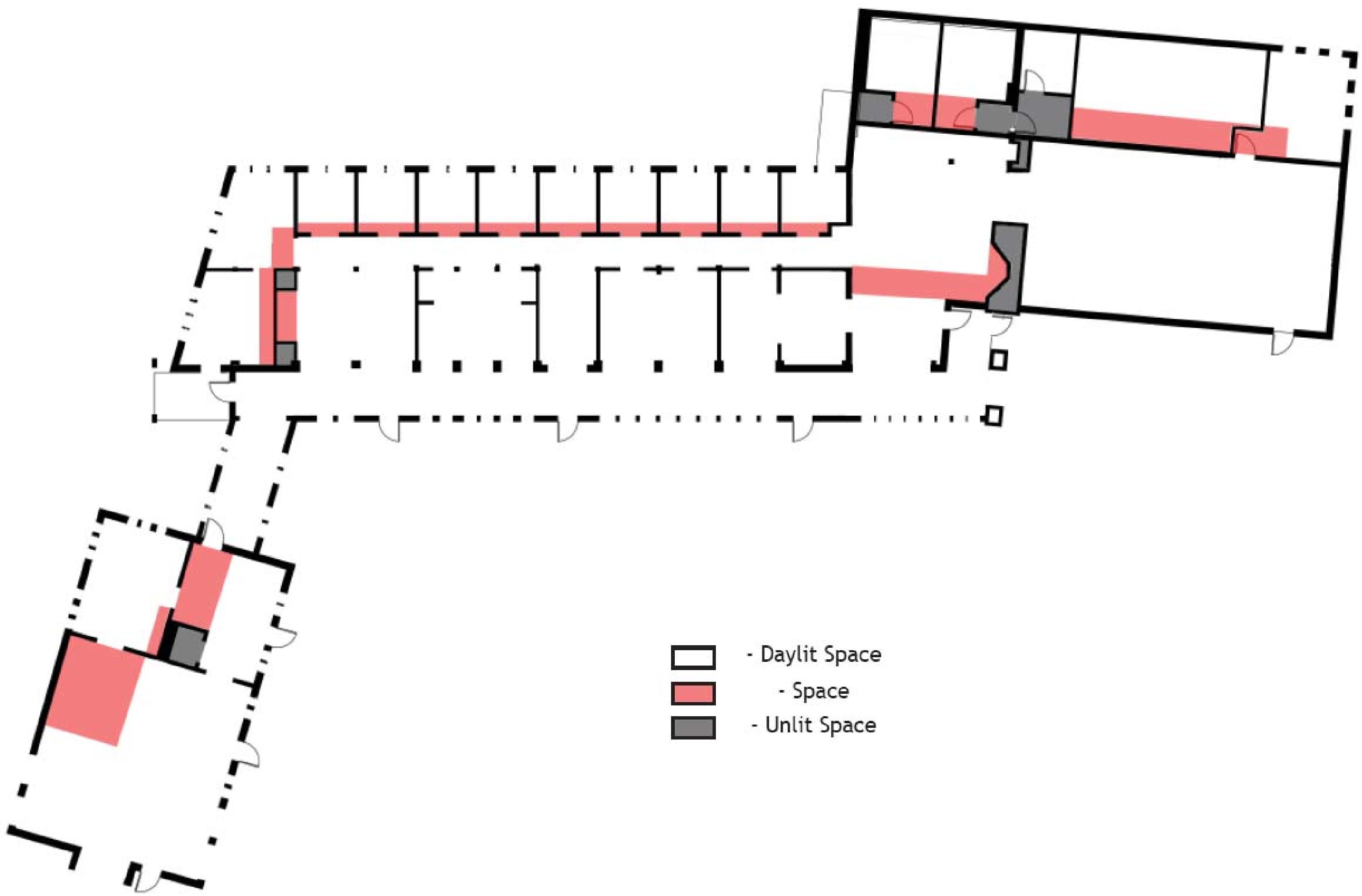


Diagram showing radiant heating system.

Ground Source Heat Pumps

Super insulate hot water runs to minimize heat losses.

Daylight All Occupied Zones



Electric lights are only ON when there is insufficient daylight.

Three Season Hall

A large room designed NOT to be used in the winter when the weather is too severe to allow heating by a combination of passive + fireplace

Forest Management & Sustainable Harvest

Before Harvest

After Harvest

The Carbon Neutral Design Project Web Site

The Carbon Neutral Design Project

- Curriculum materials project
- Society of Building Science Educators
  www.sbse.org
- Funded by the American Institute of Architects
- Web site dedicated to
  - explaining carbon neutral design
  - examination of building case studies
  - exploration of carbon calculation tools/software
  - exposition of teaching materials at the University level

THE AMERICAN INSTITUTE OF ARCHITECTS

CND Project - BETA SITE - under development

- Project Introduction
- What is Carbon Neutral Design?
- Carbon Neutral Design Process
- Carbon Neutral Design Strategies
- Carbon Calculation Protocols
- Carbon Calculation Tools
- Carbon Neutral Case Studies
- Carbon Neutral Teaching
- Resources
- Links

sbse CARBON NEUTRAL DESIGN CURRICULUM MATERIALS PROJECT CND

The Society of Building Science Educators www.sbse.org

The Carbon Neutral Design Project:

http://www.tboake.com/carbon-aia/index.html

The Aldo Leopold Legacy Center, Baribou, Wisconsin:
the first Carbon Neutral Building in the United States, in addition to being awarded LEED® Platinum
Members of the CND Project enjoy a site tour in November 2008

The Carbon Neutral Curriculum Materials Project is a joint research effort between members of the Society of Building Science Educators (**www.sbse.org**), the American Institute of Architects (**www.aia.org**), and a private donor, the purpose of which is to provide practitioners, faculty and students with the means to meet the 2030 Challenge (**www.architecture2030.org**)- that is, to be able to design and construct buildings to a state of carbon neutrality by the year 2030.

Please use the links at the left to find out more about designing buildings to a state of carbon neutrality.

IMPORTANT: THIS SITE IS A WORK IN PROGRESS - COMPLETION SCHEDULED FOR APRIL 2009

this page last updated Friday, 13-Mar-2009 8:46 AM

THE AMERICAN INSTITUTE OF ARCHITECTS

CND Project - BETA SITE - under development

- Project Introduction
- What is Carbon Neutral Design?
- Carbon Neutral Design Process
- Carbon Neutral Design Strategies
- Carbon Calculation Protocols
- **Carbon Calculation Tools**
- **Survey of Tools**
  - > Energy Modeling Software
  - > Daylighting / Lighting Software
  - > 3-D Modeling Software
  - > Building Information Modeling Software
  - > LCA Tools
  - > Rating Systems
  - > Sun Angle Calculators
  - > Carbon Calculators
  - > Climate Data Sources
  - > Physical Modeling Tools
  - > Top 10 Web Sites List
- Tools More
- Carbon Neutral Case Studies
- Carbon Neutral Teaching
- Resources
- Links

The Carbon Neutral Design Project:

Carbon Calculation Tools:

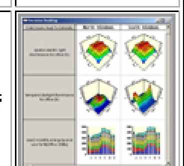
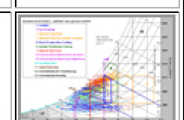
Survey of Available Tools

Note #1: Where professors associated with the Carbon Neutral Design Project have used the software in their coursework, their comments will be located below the software description and a link to their assignment hot linked to their name in the right hand column.

Note #2: It will be noted if the product is available as a FREE DOWNLOAD, ONLINE TOOL or purchased product. For pricing for products for purchase please visit the associated website.

Note #3: The required OS will be noted. Most of the Energy Programs are PC based only. For Mac users, it is recommended to run the programs using a PC simulator such as Bootcamp, Parallels or Virtual PC.

Note #4: Where possible, screenshots will be provided so that you can get an idea of the nature of the interface. These will be located in the right hand column. Click on the thumbnail for a larger version of the image.

Energy Modeling Software		Click on the Image for a Screenshot!
Software Name	**Description / URL / Comments**	**Professors / Projects**
A Course in Climate Responsive Building Design	http://www.aud.ucla.edu/energy-design-tools/ FREE DOWNLOAD *(software mostly PC)* The software and problems sets have been provided by Professor Emeritus Murray Milne to assist designers in understanding Climate Responsive Building Design. Scroll towards the bottom of the above linked page for more information, and to access the course materials.	
Building Design Advisor	http://gaia.lbl.gov/BDA/ *(PC only)* A powerful buildings design tool that will unify various specialized tools previously developed at LBNL makes it easy to compare design alternatives and includes multimedia resources such as a case-study library.	
Climate Consultant 4	http://www.aud.ucla.edu/energy-design-tools/ FREE DOWNLOAD *(PC only)* This program graphically displays climate data in either metric or imperial units in dozens of ways useful to architects including monthly bar charts, timetable charts, and psychrometric charts, sun shading charts, and sun dial charts. 3-D plots show temperatures, humidity, radiation, and sky cover. The "Wind Wheel" graphics shows velocity	

Remaining "Wicked Problems"

#1 – Building Size and Shape

- Most carbon neutral or ZED buildings to date are small
- No ZED buildings at a large scale to examine or emulate
- Buildings must be designed with a thin plan to allow for daylighting
- Tall buildings will have limited roof area for the installation of PV arrays
- Solar potential of wall areas needs to be studied

#2 - Location

- Most current ZED buildings have been constructed in rural areas
- Rural areas have a higher potential for solar harvesting, wind harvesting, installation of renewables, fresh air, carbon sequestration through use of the property/green space
- Urban areas will have severe issues with overshadowing and other limits on the installation of renewables
- Urban areas have limited site area

#3 – Natural Ventilation

- A key way to reduce the energy required to power a building is via the elimination of A/C
- Not all buildings can tolerate the resulting humidity or fluctuations in interior environment that can result from no A/C
- Urban environments can be too “dirty” for natural ventilation
- Urban environments can be too noisy for natural ventilation

#4 – Severe climates

- Severe climates will require more energy to heat and cool buildings
- Northern climates have limited solar potential for both daylighting and passive heating
- Hot-humid climates may require additional energy to bring interior environments to a state of reasonable comfort

#5 – Fee structures

- The bottom line in reduction is to consider building less
- Fees are normally based as a percentage of construction cost
- Disincentive to reduce scope of building as it reduces income
- Need to find a way to link fees to energy savings
- Need to have additional fees to properly engineer the synchronized systems of carbon neutral buildings

Smaller is better

- ***Simple!***…**less** building results in **less** embodied carbon; i.e. **less** carbon from materials used in the project, **less** requirements for heating, cooling and electricity….

- Re-examine the building program to see what is *really* required

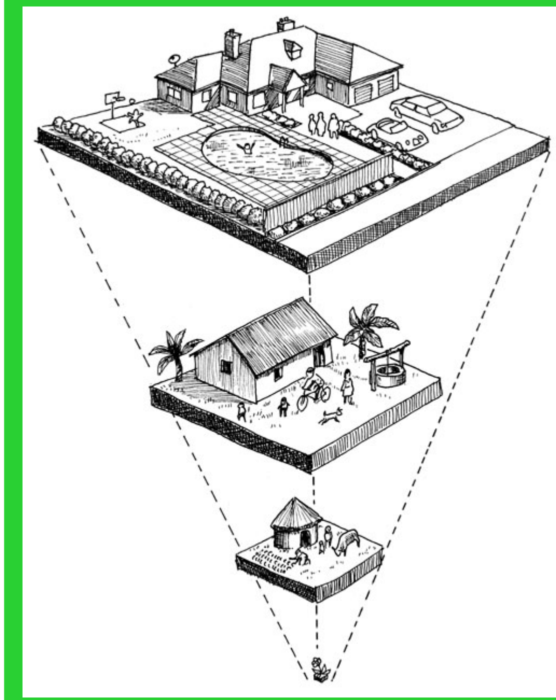
- How is the space to be used?

- Can the program benefit from more inventive double uses of spaces?

- Can you take advantage of outdoor or more seasonally used spaces?

- **How much building do you *really need?***

-INFERENCE OF LIFESTYLE CHANGES!



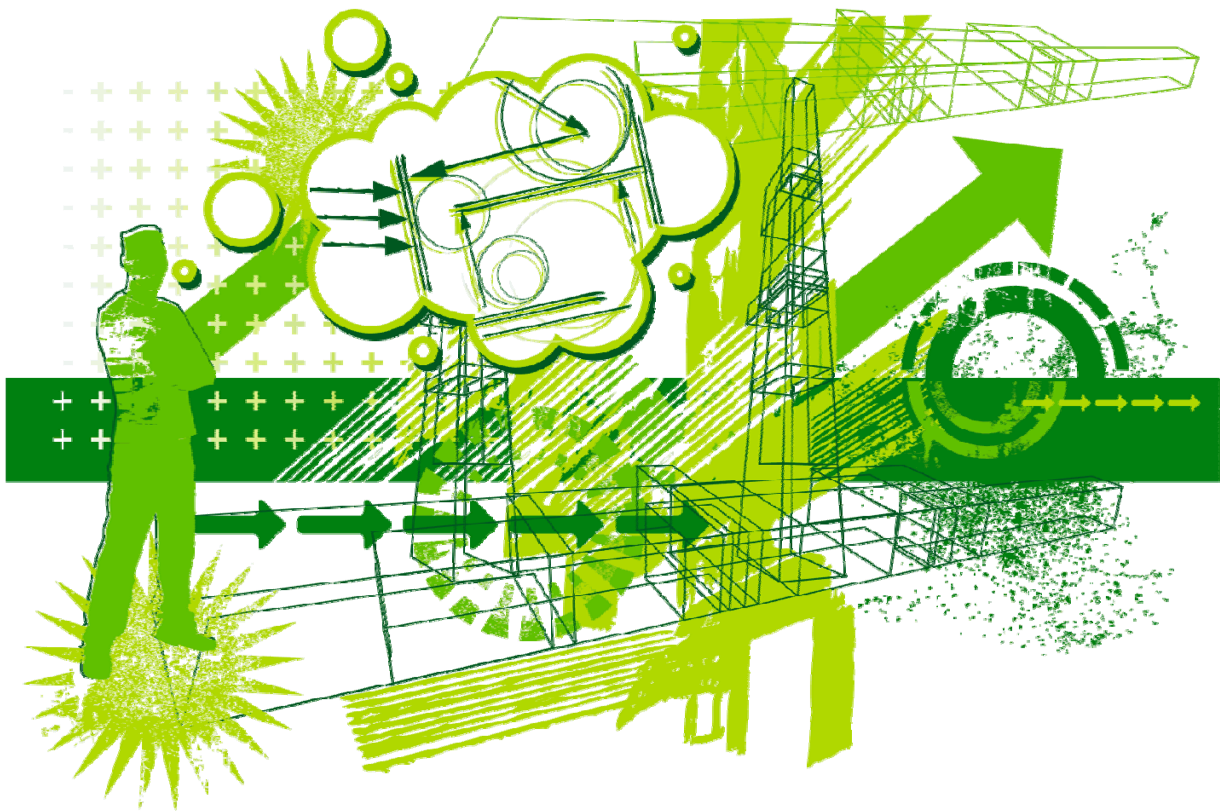
Calculating your "ecological footprint"

… can naturally extend to an understanding of your "carbon footprint"

Source: http://www.cycleoflife.ca/kids/education.htm

#6 – Integrated Design

Carbon Neutral cannot be done without the highest level of early and continued cooperation amongst the client, architect and engineers



http://www.greenhome.org/policy/makers/how_p.html

Summary:

What IS the **difference** between a Sustainable Building and a Carbon Neutral Building?

- Sustainable building does not equal Carbon Neutral Building
- Sustainable building prefers renewable materials
- Carbon Neutral Building looks for Carbon emission impacts in materials use
- Sustainable building seeks to reduce energy consumption for its heating and cooling systems
- Carbon Neutral building looks for Zero Net Energy in its heating and cooling systems

Summary:

What ARE the KEY STRATEGIES needed to design to a state of CARBON NEUTRALITY?

#1 - **Reduce loads/demand first** (passive design, daylighting, shading, orientation, etc.)

#2 - **Meet loads efficiently and effectively** (energy efficient lighting, high-efficiency MEP equipment, controls, etc.)

#3 - **Use on-site generation/renewables to meet energy needs** (doing the above steps *before* will result in the need for much smaller renewable energy systems, making carbon neutrality achievable.)

Summary:

What are the ARCHITECTURAL IMPLICATIONS of designing to Zero Carbon?

- increased impact of plan and section design in achieving reduced energy requirements
- increased importance of building orientation, siting and treatment of site both during and after construction
- greater need for integrated design process and coordination with consultants from outset of project
- narrower scope of "acceptable" materials
- more energy efficient "systems"
- more highly glazed (daylighting) and insulated buildings

Summary:

What is the POTENTIAL of designing a building to a state of Carbon Neutrality?

- Ability to effect a reduction in CO_2 emissions
- Ability to increase the likelihood of creating a regenerative or restorative building
- Ability to exceed LEED™ design levels
- Ability to create a building that is superior in its durability
- Ability to deliver a building that is extremely low in its energy related operating costs and life cycle costs
- Ability to create a “conscience free” building