Pablo La Roche

California State Polytechnic University Pomona

Topics in Advanced Architectural Design

• Cal Poly Pomona Neutral Carbon Prototypes Part 1: Southern California

• Low Cost Carbon Neutral Housing: Pomona & Tijuana

Fall Quarter 2007, 2008 Arch. 401+405 (UG / G)

There is no doubt now that humans are modifying climate (IPCC, 2007) and that buildings are responsible for a major portion of green house gas emissions that cause climate change. Furthermore, the U.S. population is projected to grow significantly over the coming decades, increasing the need for new buildings, including housing for this growing population. As architects we must learn how to reconcile the urgent need for new housing with the necessity to reduce our impact on climate change.

We must innovate in many areas while reducing carbon impact. However, architects have not been trained to reduce the carbon impact of buildings and do not know how to quantify their carbon emissions. Thus, to reduce building related anthropogenic warming, architecture students must learn how to design buildings with a reduced environmental impact and carbon emissions.

This studio addresses the need to improve carbon neutral design education while teaching them how to improve the quality of contemporary housing in an era of increased environmental concerns.

Fourth and fifth year students with Masters of Architecture I students participated in these studios and developed carbon neutral homes in two southern California climate zones: the inland desert and the temperate coast. In the first studio, emphasis was on developing strategies to reduce emissions due to operational energy and construction. In the Fall 08 studio, students included the analysis of emissions from water and waste. Transportation, which is related to building location, was also considered. Numbers are very imprecise but helps to create an initial picture of how building related carbon is being emitted. A flow chart diagram for a carbon neutral design process was developed to serve as a road map for a studio that took ten weeks to complete. During this period students had to analyze climate and geographical data, generate ideas, and evaluate them with different tools, such as carbon calculators, and tools such as Climate Consultant, Ecotect, HEED, Radiance, WinAir, and PV watts. Emphasis was on the generation and evaluation of environmental ideas, especially those that affected carbon emissions. Students continuously evaluated the carbon performance of their projects and had to demonstrate that their finalized idea performed as intended.

The first step in this CND process was to analyze census, climate, CO2 and population data to compare CO2 emissions in the different zip codes of the same climate zone. Students compared this data with the residential emissions and energy use so as to be able to implement and test appropriate design strategies. Analysis protocols were implemented to analyze concepts or design ideas: carbon climate analysis, origin of carbon emissions, solar site analysis, radiation impact on surfaces, air flow analysis, daylight analysis, heating and cooling loads, PV design and embodied energy calculations.

Students in this studio learned how to design innovative carbon neutral homes using different strategies and tools. They are now better prepared to design environmentally sensitive low carbon housing appropriate to this era of climate change. Work from all students in the studio was published in the zerocarbondesign.org website.

STUDIO PROFILE

Basic Description

10 week quarter course in the Fall of 2007 and 2008.
Undergraduate 4th and 5th year students and graduate MARCI
Freestanding "Topics Studio," individually taught. Students must take a certain number of these studios but have a choice depending on interests. 14 students in 2007 and 20 students in 2008. The students undertook individual projects, with hypothetical in 2007 and working with NGOs in 2008

Building Load Type

Small Climate Dominated. Some urban planning and analysis involved. I selected a small program so that the students could concentrate on sustainable issues.

Project Location

California Climate zones 6 coastal mild Mediterranean and climate zone 15 hot and dry in the Fall of 2007 and climate zone 6 mild Mediterranean and climate zone 9 hot and dry in the Fall of 2008.

In the Fall 08 studio I am specifically focusing on low cost sustainable housing working with Habitat for Humanity in Pomona and Corazon in Tijuana, Mexico.

SPECIAL FOCUS: SOFTWARE

Software and it is explained in the CND topics section. HEED, Ecotect, Radiance and WinAir are the main programs implemented.

ACKNOWLEDGEMENTS

This work has been sponsored in part by Energy Design Resources, which is funded by California utility customers and administered by Pacific Gas and Electric Company, Sacramento Municipal Utility District, San Diego Gas & Electric, Southern California Edison, and Southern California Gas under the auspices of the California Public Utilities Commission.

Studio Teaching Topic KEY

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

TEACHING TOPICS PROFILED

1. Carbon Neutral Design Process

Introduction to the design process that students will follow during the quarter and the tools that they will use to achieve low carbon buildings.

2. Analysis of Carbon Calculators

The objectives of this exercise are a) to understand the variables that affect carbon emissions in buildings; b) to learn how to quantify these emissions; c) to compare different carbon counting tools or methods available for each task.

3. Geographical Distribution of Carbon Emissions

Determine residential yearly CO2 emissions in zip codes located in different climate zones.

4. Residential Sources of Carbon Emissions in Different Climates

Energy modeling software is used to determine the energy consumption and CO2 emissions for the typical code compliant house in each climate zone.

5. Solar Site Analysis

Analyze climate to determine shading and radiation needs. Climate analysis of weather files can also help to determine when solar radiation is an asset or liability in outdoor spaces.

6. Radiation Impact on Surfaces

Using Ecotect select the option for solar access analysis under calculate and analyze the irradiation over the exterior surfaces of the building. Calculate radiation on building and site surfaces to determine solar impact and shading requirements.

7. Fenestration & Shading

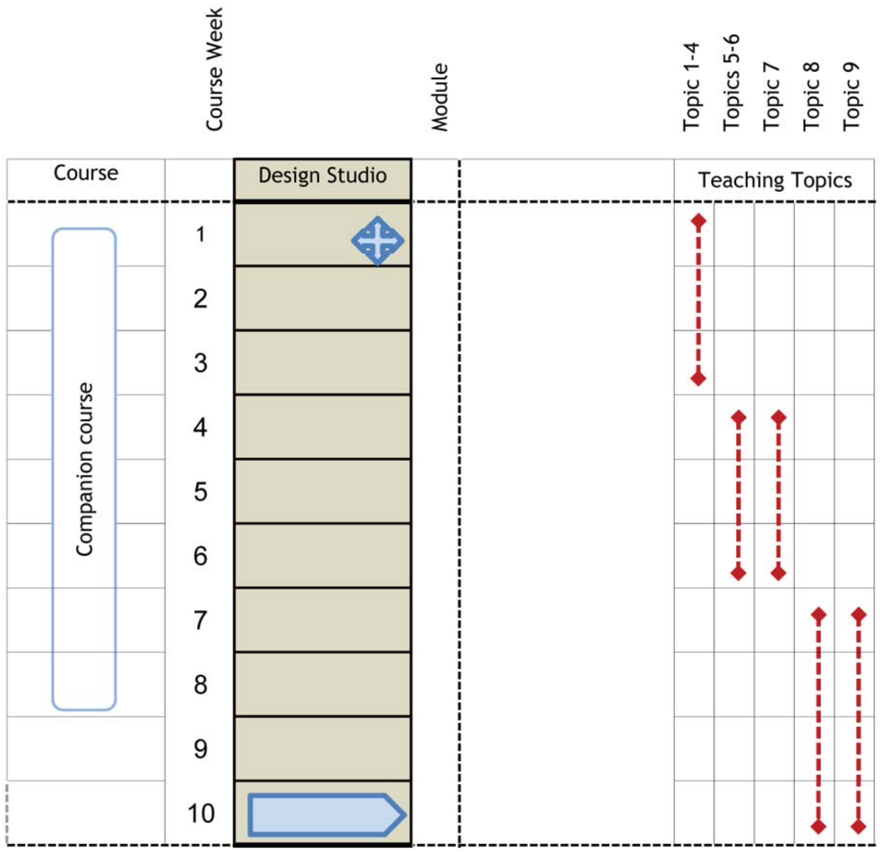
The objective is to design and optimize an integrated window and shading system to provide the necessary solar protection in the summer and solar radiation in the winter (if required) while providing daylight.

8. Daylight Analysis

Students must design the fenestrations to achieve the necessary illuminance levels while minimizing glare.

9. Air Flow Analysis

Using Ecotect and Win Air determine the pressures and direction of air movement through different areas of the house.



Philosophy of CND Studio Instruction

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

Humans are modifying climate and buildings are responsible for a major portion of green house gas emissions that cause climate change. To reduce building related anthropogenic warming architecture students must learn how to design buildings with a reduced environmental impact. This is especially important in the United States, responsible for 350 Gj of energy and 15 tons of carbon per capita, and the largest single energy consumer and generator of carbon in the world.

Educating architecture students takes many years, during which sustainability concepts have to be embedded in lecture and design courses, from introductory to advanced levels. The first step in this education process is to have these students understand that they must become stewards of the environment, and that for this to happen they must become ecologically literate. Ecological design in Orr's words is: "the careful meshing of human purposes with the larger patterns and flows of the natural world". This principle of stewardship is introduced in my first lecture as an expectation for the quarter. Students should understand that all of the sustainable strategies that they implement are framed by this principle.

In order to have a more thorough understanding of sustainable design concepts, the student should go into more depth in their resolution. As Ralph Knowles suggests "It is time to re-evaluate the studio custom in most schools of architecture, starting with small and simple projects and advancing to ever larger and more complex ones. Usually, as students become more capable, the projects become proportionally more comprehensive and difficult. The result is that students often become progressively more skilful at making diagrams of shape and layout, but not always with a deeper understanding of how the thing really works. What about delving progressively deeper instead of bigger, at least part of the time?" Students must have a thorough understanding of sustainability concepts and the tools to test them. Magic arrows disappear to become real "tested" representations of air movement and solar radiation. Knowledge to do this is acquired by combining lectures with hands on work.

Emphasis in the studio is on both development and evaluation of ideas. The student should be creative but also analytical, using sound theory, and with the knowledge to test and evaluate the concepts that are being generated. The performance of projects, or portions of projects should be evaluated with digital or analog tools.

Over the years digital tools have become faster and more user friendly, while students have also become progressively more computer savvy. Digital tools are generally used for analysis or modeling. Analysis tools help to understand specific topics such as energy, illumination, radiation and acoustics. Faster and more precise iterations using hourly data are now possible with digital analysis tools. Modeling tools are typically used to develop the design and analyze shading in the building. Analog tools are always pertinent because of the stronger haptic connection that is established between the physical model and the student. In my studio, students have also used analog tools to test physical models: class built wind tunnels to determine air flow, sun dials to evaluate shading and solar penetration, and illuminance meters to determine daylight levels.

Several exercises should be implemented, ranging in scale and dimension and which help the student to analyze different design alternatives at these scales. The exercises begin with analysis at a regional scale, then progress to an urban scale, continue with the site, the building skin and finally interior spaces. Examples of these exercises are: the analysis of the geographical distribution of carbon emissions, residential sources of carbon emissions in different climates, solar site analysis, radiation impact on surfaces, fenestration and shading design, daylight analysis and air flow analysis.

For the carbon neutral design process I emphasize understanding energy in buildings, which is the main "architectural factor" that can be modified in buildings to reduce their effect on climate change. Students learn how to design buildings that use low energy materials and operate with little energy. To operate with reduced energy the student must learn how to design passive solar buildings, that move energy between the building and available heat sinks to achieve indoor thermal comfort. Available heat sinks vary with climate and in most cases can help to dramatically reduce building related CO_2 emissions. Buildings that correctly express their environmental performance are also beautiful and better respond to nature's rhythms.

10 Critical Issues / 10 Common Mistakes

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

10 critical issues in THE teaching of Carbon Neutral Design

1. *Much of the information is not readily available. For example conversion factors for CO2 are not easy to find and vary by country, by region or even by hour of use..*
2. *There is no single method or tool to do all that is required to calculate carbon emissions from buildings. Specific methods and processes incorporating different tools or combinations of tools must be developed in class as required.*
3. *Imprecision of existing methods and tools.*
4. *Students have a hard time understanding units of carbon. They have learned how to understand space and calculate in three dimensions and now the must also visualize in another set of units.*
5. *There are many calculations and opportunities for error in a carbon neutral design process.*
6. *Students should be able to understand the relationship between carbon emissions and design strategies.*
7. *Students should be able to visualize the big picture and understand where the building fits in this picture.*
8. *Emphasis should be on both the creative and the analytical aspects of design. Students should be able to produce an exciting building high performance building.*
9. *Students have to understand the effect of buildings on climate change.*
10. *Many problems are developed in groups with many opportunities for error.*

10 student design mistakes that undermine the goal of Carbon Neutral Design

1. *Lack of knowledge of basic principles (U values, solar geometry, etc) which are prerequisites for appropriate use of energy modeling tools.*
2. *Lack of skills or knowledge to analyze the information (graphical and numerical) produced when using the tools.*
3. *Misunderstanding the relationship between energy and buildings and the movement of energy through the building fabric.*
4. *Production of tests or simulations that are executed to fulfill a course requirement but which the student does not use in the design process. Analysis should evaluate ideas and propose solutions as problems are discovered.*
5. *Lack of understanding of the whole picture. The effect of buildings on CO2 levels and climate change and what the student can do about it.*
6. *Not comparing CO2 emissions of studio projects with the reference case developed at the beginning of the studio.*
7. *Counting carbon twice or not counting carbon at all.*
8. *Misunderstanding units and the relationships between them.*

Supporting Material

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

Teaching Climate Responsive Design to Beginning Architecture Students
excerpt

(PDF) La Roche, Pablo. Presentation: Teaching Climate Responsive Design to Beginning Architecture Students. Teaching in Architecture Conference, Oxford 2008

COURSE MATERIALS

(PDF) La Roche. CND Course Materials Compilation

1. Syllabus. Fall 2007 ARC 401 + 405 Topics in Advanced Architectural Design

2. Syllabus. Fall 2008 ARC 401 + 405 Topics in Advanced Architectural Design

PAPERS

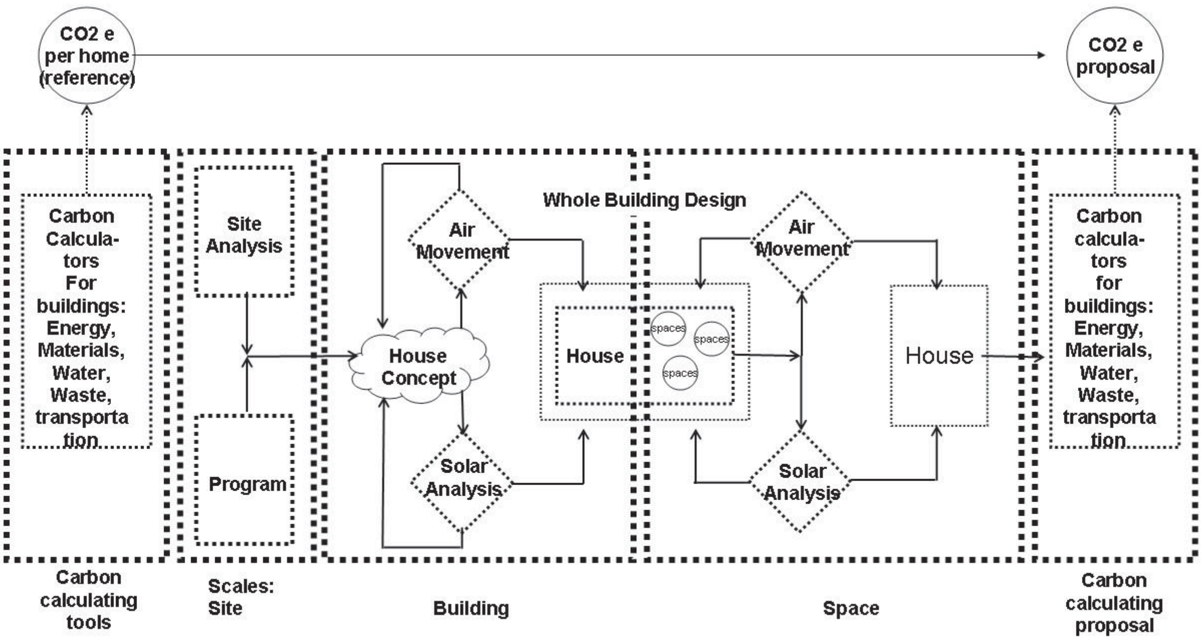
(PDF) La Roche, Pablo. *Teaching Climate Responsive Design to Beginning Architecture Students.* Teaching in Architecture Conference, Oxford 2008

(PDF) La Roche, Pablo. Presentation: *Teaching Climate Responsive Design to Beginning Architecture Students.* Teaching in Architecture Conference, Oxford 2008

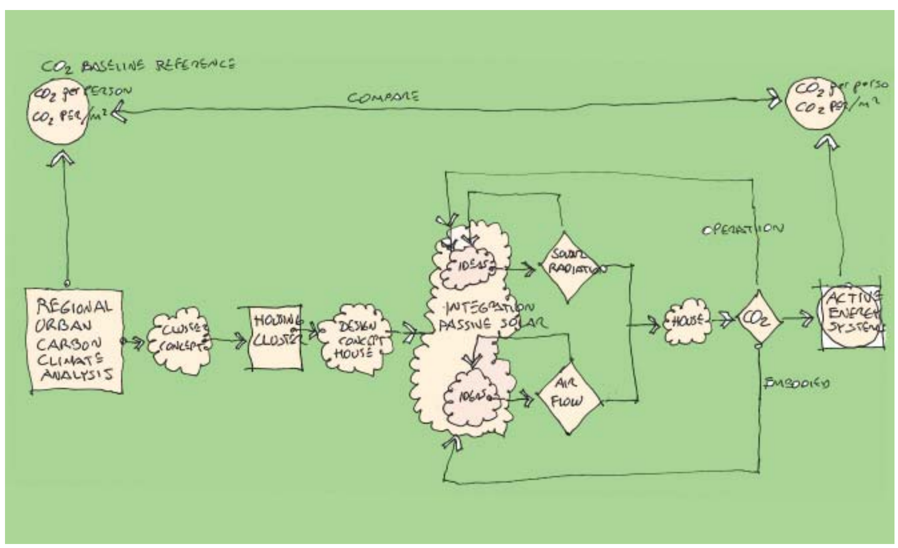
Carbon Neutral Design Process

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'



Fall 2008 Carbon Neutral Design Process



Fall 2007 Carbon Neutral Design Process

Design/ Performance Objective

Buildings are responsible for a large portion of green house gas emissions, accounting for about half of all green house gas emissions of anthropogenic origin. To reduce our impact on climate it is necessary to reduce these emissions and the first step in this process is to learn how to quantify carbon emissions in buildings.

Investigative Strategy

1.1. Carbon Neutral Design Process Diagram
Students are first introduced to the design process that they will follow during the quarter and the tools that they will use to achieve low carbon buildings.

The instructor develops a diagram that will serve as the roadmap for the student during the quarter. At the end of the quarter this diagram is used in www.zerocarbon.org as the outline that will organize student work in the different stages of this design process.

1.2. Counting carbon emissions from buildings
To determine the total building related carbon emissions students must calculate the emissions from the different areas in

Carbon Neutral Design Process (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

which buildings generate CO2 (in tonnes of CO2/year or Kgs of CO2/year). While in the 2007 studio only carbon emissions from operational energy were considered, in the 2008 studio more areas were considered: a) operational energy, which is used directly at the site (gas) or at the power plant (electricity) and includes heating, cooling, lighting and appliances; b) construction, by the fabrication or transportation of materials to the building and the construction processes; c) by using water, that must be provided to the building; d) by generating waste, that must be disposed from the building; e) by requiring transportation to and from the building. The sum of emissions from all of these is the total CO2 that is originated directly or indirectly by the building.

TC = TCO + TCT + TCW + TCWa + TCC

Operational energy	TCO
Transportation	TCT
Water	TCW
Waste	TCWa
Construction	TCC
Total Carbon	TC

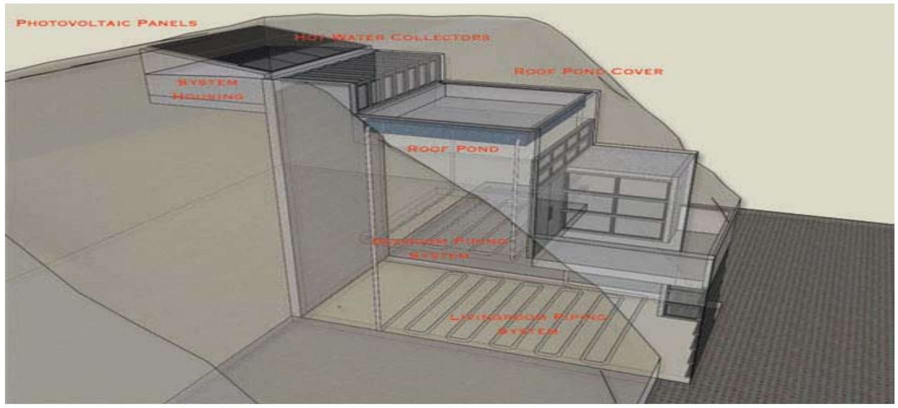
To calculate carbon in these areas several tools were used:

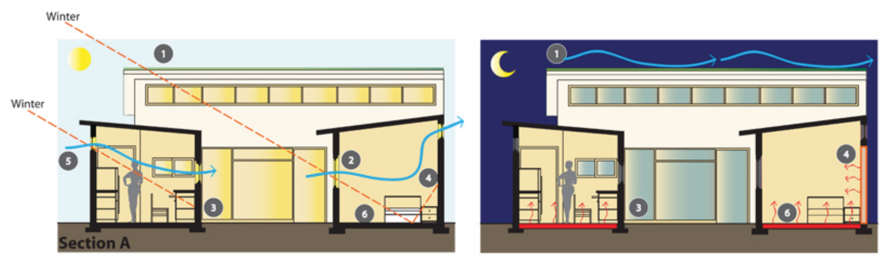
Operational Energy:
HEED:
http://mackintosh.aud.ucla.edu/heed/

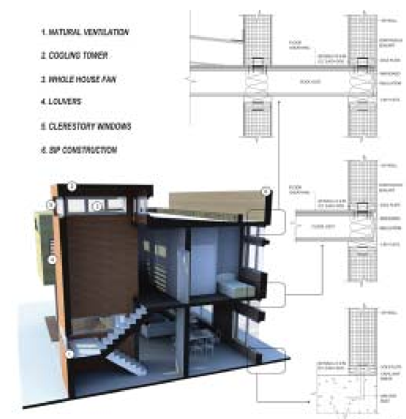
Construction:
Build Carbon Neutral:
http://buildcarbonneutral.org/
and
Athena Eco Calculator for Assemblies:
http://www.athenasmi.org/tools/ecoCalculator/index.html

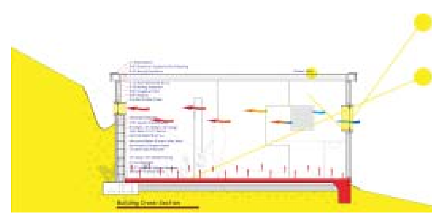
Water:
An emission factor of 0.82 kg of CO2 emitted per cubic meter of water provided to the building is used.

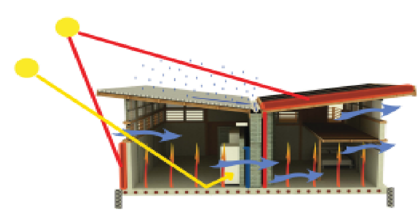
Waste:
EPA WARM Model:
http://epa.gov/climatechange/wycd/waste/calculators/Warm_home.html
or
EPA Personal Emissions Calculator:
http://www.epa.gov/climatechange/emissions/ind_calculator.html











Passive Strategies to reduce CO2 emissions from operational energy
Brandon Giuloti
Alexandra Hernandez, Aireen Batungbaka
David Castro
Luis A Torres and Lorenzo Medina
Don Bui and Megan Gorman

Transportation:
The Climate Trust CarbonCounter
http://www.carboncounter.org/
or
EPA Personal Emissions Calculator
http://www.epa.gov/climatechange/wycd/calculator/ind_calculator.html

A spreadsheet was prepared by the instructor and given to the students to include the results from the different

Carbon Neutral Design Process (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

areas and add them up. Some include formulas directly in the spreadsheet and it is expected that this spreadsheet will evolve into a webpage.

Design strategies should be linked to the areas in which buildings emit CO2 and implemented according to their potential to reduce building related CO2 emissions.

Evaluation Process

Data is generated using the different web based calculators and programs and added up using the spreadsheet. Several indicators are used to compare building performance.

Total carbon dioxide emissions (TC) are indicated as a total per building and a total per unit of area (Kgs CO2 /m2). This permits comparison between buildings of different sizes and between established reference values, permitting to classify them in emission classes according to how they perform (e.g. A, B, C, D etc)

Students also calculate the Energy Utilization Intensity (EUI) of the building. EUI is the total operational building energy use per year divided by the gross building floor area. It is measured in kWh/m2/yr (or kBTU/SF/year). In an existing building EUI could be determined from the metered area which does not have to match the building area. EUI can be used to calculate CO2 emissions due to operational energy, by multiplying energy use by the appropriate conversion factor.

The building enclosure glazing ratio (EGR) is the glazing area for the whole building per gross floor area (measured in SF/SFtotal or m2/m2 total). EGRorient is the bldg enclosure glazing ratio for each orientation and is the glazing area for each orientation per total gross floor area (SF/SFtotal or m2/m2 total). This variable is used to determine if a particular orientation is more favorable for glazing as a carbon reducing strategy.

Evaluative Criteria

Comparison of the values generated by the different tools based on analysis of values, precision, speed and ease of use.

DATA

Energy Utilization Intensity

	kWh/year	kWh/m²/year
Lighting/Appliances	1,833	16.9
Fuel for Appliances	1,943	17.4
TOTAL	3,827	31.7

Skin Dominance Factor (SF/SF)

130%

Enclosure Glazing Ratio (SF/SF Total)

26.7%

per Orientation: South 20.4%, North 4.4%, West 2.0%, East 0%

Construction Cost (US $)

$89,900

Site Renewable Energy Utilization

	kWh/year	kWh/m²/year	year offset	Kg CO_2/m²
Solar Hot Water	6,982	57.8	4,315.0	
Photovoltaics	2,870	23.8	1,774.0	
TOTAL	9,853	81.6		
Carbon Offset			6,089	49.9

Carbon Dioxide Emissions

	Kg CO_2/year	KgCO_2/meter²
Operational		
Lighting/Appliances	1,152	
Fuel for Appliances	357	
Water	180	
Waste	889	
Construction(1/50th)	853	
TOTAL	3,443	28.5
Transportation	3,462	
TOTAL	6,906	57.2

To Calculate the Carbon Footprint of the Building — Surface of the Building in Square Meters: 138

1. Operational Energy:
HEED http://mackintosh.aud.ucla.edu/heed/
In the BEPS screen in HEED look for the total electricity consumed annually in kWHr and the total fuel consumed annualy in Therms
multiply electricity by 0.6118 kgs/kWHr — BEPS ELECTRICITY: 1298 KWhr — CO2 Electricity: 794.1164
multiply gas by 5.43 kgs/Therm — BEPS GAS: 66.37 THERMS — GAS Co2: 360.3891
Total Operational Energy CO2: 1154.505

2. Construction:
Build Cart http://buildcarbonneutral.org/
or
Athena Eco Calculator for Assemblies http://www.athenasmi.org/tools/ecoCalculator/index.html
Total Construction Energy CO2: 580

3. Water:
An emission factor of 0.82 kg of CO2 emitted per cubic meter of water provided to the building is used. Department of Environment Food and Rural Affairs & Best Foot Forward.
Total Water CO2: 17

4. Waste:
EPA WARM Model or
http://epa.gov/climatechange/wycd/waste/calculators/Warm_home.html
EPA Personal Emissions Calculator http://www.epa.gov/climatechange/emissions/ind_calculator.html
Total Waste CO2: 1081

5. Transportation:
The Clima http://www.carboncounter.org/
or
EPA Personal Emissions Calculator
Total Transportation CO2: 0

Total CO2 with Transportation: 2832.505
Total CO2 without Transport: 2832.505

Energy Generated on Site
Renewable On SiteElectricity: 0
CO2 sequestered on site: 0

Total CO2 Emissions: 2832.51
CO2 emissions/m2: 20.52543

Cautions- Possible Confusions

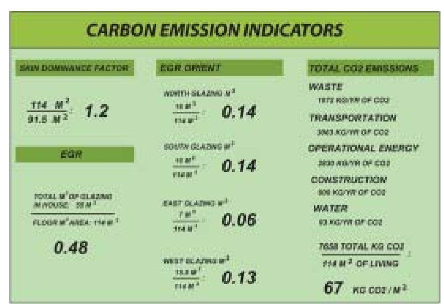
Many calculations and possibilities for error. Some of these tools are very imprecise and many multiplying factors are still not available, imprecise or variable.

Duration of Exercise

One week.

Degree of Difficulty

Difficult



Charles Campanella and Serge Meyer
Don Bui and Megan Gorman
David Castro Luis Torres

Carbon Neutral Design Process (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2008 graduate/undergraduate elective 'Topics Studio'

References

egrid 2006 version 2.1 April 2007

Solar Cities: The fundamental documents S. Roaf and R. Gupta. (2006)

Nadav Malin. Counting Carbon: Understanding Carbon Footprints of Buildings, Environmental Building News, July 1, 2008.

Department of Environment Food and Rural Affairs UK.

J. Paul Padgett, Anne C. Steinemann, James H. Clarke, Michael P. Vandenbergh, A comparison of carbon calculators, Environmental Impact Assessment Review 28 (2008) 106–115

Michael Utzinger, Aldo Leopold Legacy Center, LEED Submissions for Energy, Renewable Energy, Green Power and Carbon Neutral Operation Provided to SBSE by project Environmental Consultant Michael Utzinger (2007).

Alison G Kwok / Walter Grondzik. The Green Studio Handbook. Environmental Strategies for Schematic Design. Architectural Press. 2007.

Sue Roaf, Manuel Fuentes, Stephanie Thomas, Ecohouse, Third Edition, 2007.

LEED-NC Version 2.1 Rating System http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf

Norbert Lechner (2001) Heating, Cooling, Lighting Design Methods for Architects, Wiley

John T. Lyle, Regenerative Design for Sustainable Development (1994), p 105-140

Plea Note 6, Keeping Cool: Principles to Avoid Overheating in Buildings. La Roche, P., Quirós, C., Bravo, G., Machado, M., Gonzalez G., (2001). Kangaroo Valley, Australia: Passive Low Energy Architecture Association & Research Consulting and Communications, 60 p.

Mechanical and Electrical Equipment for buildings, 10th edition, by Stein, Reynolds, Kwok and Gronzik published by Wiley, 2006.

Givoni B. Climate Considerations in Building and urban Design. 1998 Van Nostrand Reinhold. 464 p.

Givoni B.Passive and Low Energy Cooling of Buildings. 1995 Van Nostrand Reinhold. 262 p.

Barnett, Dianna Lopez with William Browning. A primer on Sustainable Building, Rocky Mountain Institute Green Development Services, Snowmass, CO 1995.

Climate Design, by Donald Watson, and Kenneth Lab, published by John Wiley & Sons.

European Passive Solar Handbook. Basic Principles and Concepts for Passive Solar Architecture. Commission for the European Communities. Directorate General for Science, Research and Development. Edited by P Achard and R Gicquel (1987).

Introduction to Architectural Science: The Basis of Sustainable Design, Steven Szokolay, Elsevier 2004.

Tools and Websites

HEED:
http://mackintosh.aud.ucla.edu/heed/

Build Carbon Neutral:
http://buildcarbonneutral.org/

Athena Eco Calculator for Assemblies:
http://www.athenasmi.org/tools/ecoCalculator/index.html

EPA WARM Model:
http://epa.gov/climatechange/wycd/waste/calculators/Warm_home.html

EPA Personal Emissions Calculator:
http://www.epa.gov/climatechange/emissions/ind_calculator.html

The Climate Trust CarbonCounter
http://www.carboncounter.org/

EPA Personal Emissions Calculator
http://www.epa.gov/climatechange/wycd/calculator/ind_calculator.html

www.zerocarbondesign.org

Analysis of Carbon Calculators

Pablo La Roche
California Polytechnic State University

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

	A	Name of Tool	Tool Developer		Operational Energ	Public Transport	Private Transport	Water	Construction of Building	Waste	Output (lbs)	(kilograms)	Suggestions for Carbon Reductions	Estimated Time Needed	Rating Scale	Additional Review	Additional Info Giv
7		Home Energy Saver	Environmental Energy Technologies Division of Lawrence Berkeley Nat'l Library	Pomona (Small)	7,394 kwh 664 Therms						12,438 lb.CO2	5,654	Prgrmble Thermostat	5 min.	5	Must provide info to get results. Usage of other software needed.	Suggested: Provides House/Upgrades/ Savings
8		(H.E.S.)		Tijuana (Small)	6,141 kwh 508 Therms						9,823 lb. CO2	4465	Replace light bulbs	5 min.	5		
9				Pomona (Large)	8,362 kwh 777 Therms						14,371 lb.CO2	6,532	Replace lrg appliances	5 min.	5		
10				Tijuana (Large)	6,786 kwh 578 Therms						11,049 lb.CO2	5,022	Replace windows	5 min.	5		
11	1.)	Electric Power Pollution	Infinite Power Texas State Energy Conservation Office	Pomona (Small)	3099 Kw/hr		455 gallons of Gas 2727 lbs Carbon 4 lbs carbon/mile			lbs CO2	5352 lbs CO2	2,432	See Screen Shot	2 min.	4	Not sure if other information is applicable. Setting info not asked.	Determines amount of Carbon Dioxide is produced
12				Tijuana (Small)	2469 Kw/hr					18260 lbs CO2	4980 lbs CO2	2,263	See Screen Shot	2 min.	4		
13				Pomona (Large)	4954 Kw/hr					24644 lbs CO2	6721 lbs CO2	3,055	See Screen Shot	2 min.	4		
14				Tijuana (Large)	3803 Kw/hr					21930 lbs CO2	5981 lbs CO2	2,718	See Screen Shot	2 min.	4		
15	2.)	Energy Star	U.S. Environmental Protection Agency	Pomona (Small)	10,351 kWhr						14,108 lbs CO2	6,413		1 min.		Only asks for: bill payment, usage of energy, etc. Needs software assistance for supporting data.	Suggests: Actions to take Provides: Heating/Cooling Degree Days
16				Tijuana (Small)	8,244 kWhr						11,236 lbs CO2	5,108		1 min.			
17				Pomona (Large)	16,541 kWhr						27,061lbsCO2	12,300		1 min.			
18				Tijuana (Large)	12,698 kWhr						20,774lbsCO2	9,443		1 min.			
19	3.)	Home Energy Use Calculator	SECi, Santee	Pomona (Small)												Considers many appliances and usage. Results not found.	
20				Tijuana (Small)													
21				Pomona (Large)													
22				Tijuana (Large)													
23	4.)	BEF Carbon Calculator	GreenTag USA	Pomona (Small)	3099 kWhr 286 Therms		455 gal 8902 lb.				15989 lbs.	7,268	None. Equivalents	5 min.	3	Promotes user to buy offset. Provides required rate to become climate neutral.	Categories: Eletricity, Heating, Vehicle, Air Travel, Emission Results Provides: calculations in lbs.
24				Tijuana (Small)	2469 kWhr 277 Therms						15124 lbs.	6,875	None. Equivalents	5 min.	3		
25				Pomona (Large)	4954 kWhr 395 Therms						19505 lbs.	8,866	None. Equivalents	5 min.	3		
26				Tijuana (Large)	3803 kWhr 361Therms						17718 lbs.	8,054	None. Equivalents	5 min.	3		
27	5.)	Carbon Counter	r.org	Pomona (Small)	3099 kWhr 286Therms			5.55 Tons CO2/yr			15989 lbs.	7,268		2 min.	2		
				Tijuana	2469 kWhr			5.55 Tons									

Sheet1 Sheet2 Sheet3

Ready

Example of Student Spreadsheet
Alexandra Hernandez, Aireen Batungbaka

Design/Performance Objective

Climate change is caused by an increase in the concentration of green house gas emissions due to human activities. Since buildings need energy to operate and be habitable, and this energy usually comes from power plants that generate CO2, buildings are responsible for a large portion of green house gas emissions. However, even though operation accounts for a major portion of building related greenhouse gas emissions it is not the only one.

The objectives of this exercise are a) to understand the variables that affect carbon emissions in buildings; b) to learn how to quantify these emissions; c) to compare different carbon counting tools or methods available for each task.

Investigative Strategy

There are several types of carbon calculating tools: a) carbon footprint calculators which are available online to determine personal carbon emissions b) carbon estimators which are also available online for estimations of carbon emissions of buildings c) carbon calculators which are available for purchase that work with BIM systems for a more accurate analysis. In this studio, students focused on the first type of tools and some energy modeling programs.

Two single family dwellings were created as reference homes for later comparison with the student generated projects. Both of them were energy code compliant: a 1408 sq ft one-story house and a 2304 sq ft (gross building floor area) two-story house which was slightly smaller than the 2005 US avg. The houses had the following characteristics: the one story house was 32 by 44 ft and the two story house was 48 by 24 ft. Both were oriented east-west. Envelope to Glazing Ratio was 20% of the building distributed evenly in all elevations. U value of window in the coastal zone was 0.67 and inland was 0.55. SHGC = 0.40. The roof insulation was R30 with a radiant barrier in climate zone 9, and R30 in climate zone 7. If there was an option for water heater students used a gas storage water heater with a EF = 0.575.

Carbon emissions were determined for these houses in the two studio sites: climate zone 9 which includes Pasadena and Pomona with Hot and Dry Summers, and climate zone 7 which includes San Diego and Tijuana with a mild coastal climate (eg. Figs 2, 3). Carbon calculators were run for each of these homes and each team organized results in tables similar to Fig. 1. These tables included screen images of the tool (input and results page) and a short description of any assumptions made and comments on the tool. All tools were analyzed by at least two teams.

The values generated by the different tools were compared by the whole class to determine relationships and possible patterns (Fig. 4). Comparison was based on values that were generated by the tools, precision, speed, and ease of use.

At the end of the exercise a matrix was generated that included all of the tools that were analyzed and the areas in which they could be used.

Evaluation Process

Data produced by all the students was compared in a master spreadsheet (Fig. 4) to determine relationships and atypical values.

Evaluative Criteria

Evaluation of student work was based on completing assigned tasks.

Cautions- Possible Confusions

There are many calculations involved in the process and possibilities for error.

It is difficult to compare the carbon calculators if most of the underlying calculations are not transparent.

Duration of Exercise

One week.

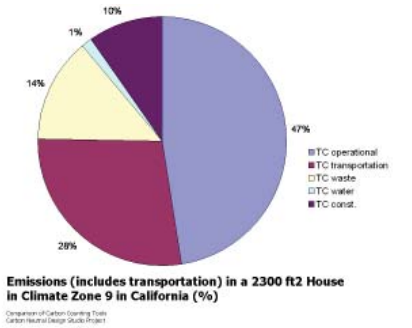
Degree of Difficulty

Difficult

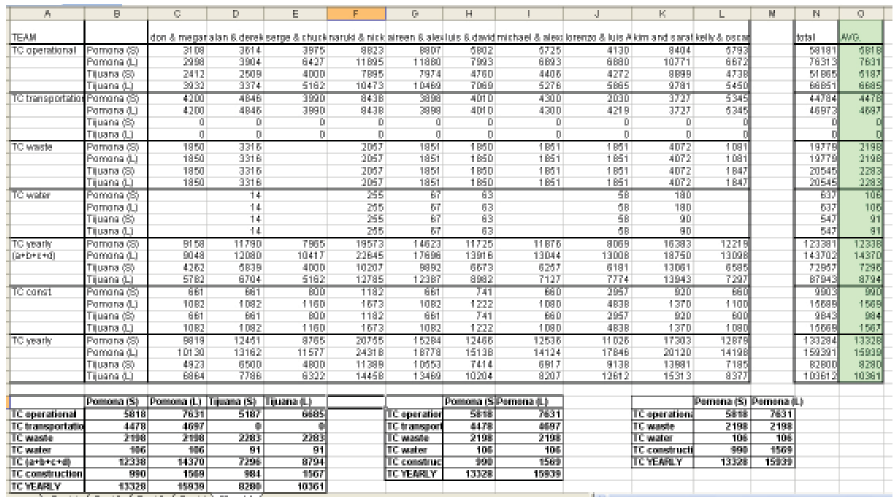
Analysis of Carbon Calculators (cont.)

Pablo La Roche
California Polytechnic State University

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'



Distribution of emissions in one of the reference houses

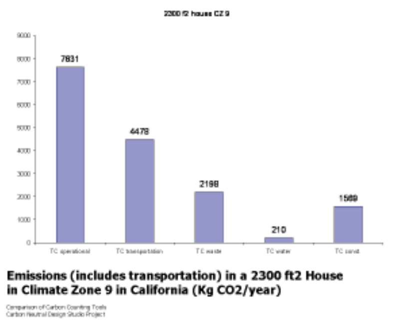


A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
TEAM		don & megar	alan & derek	serge & chuck	naruki & nick	aireen & alex	luis & david	michael & alex	lorenzo & luis A	kim and sarah	kelly & oscar		total	AVG.
TC operational	Pomona (S)	3108	3614	3975	8823	8807	5802	5725	4130	8404	5793		58181	5818
	Pomona (L)	2998	3904	6427	11895	11880	7993	6893	6880	10771	6672		76313	7631
	Tijuana (S)	2412	2509	4000	7895	7974	4760	4406	4272	8899	4738		51865	5187
	Tijuana (L)	3932	3374	5162	10473	10469	7069	5276	5885	9781	5450		66851	6685
TC transportation	Pomona (S)	4200	4846	3990	8438	3898	4010	4300	2030	3727	5345		44784	4478
	Pomona (L)	4200	4846	3990	8438	3898	4010	4300	4219	3727	5345		46973	4697
	Tijuana (S)	0	0	0	0	0	0	0	0	0	0		0	0
	Tijuana (L)	0	0	0	0	0	0	0	0	0	0		0	0
TC waste	Pomona (S)	1850	3316		2067	1851	1850	1851	1851	4072	1081		19779	2198
	Pomona (L)	1850	3316		2067	1851	1850	1851	1851	4072	1081		19779	2198
	Tijuana (S)	1850	3316		2067	1851	1850	1851	1851	4072	1847		20545	2283
	Tijuana (L)	1850	3316		2067	1851	1850	1851	1851	4072	1847		20545	2283
TC water	Pomona (S)		14		255	67	63		58	180			637	106
	Pomona (L)		14		255	67	63		58	180			637	106
	Tijuana (S)		14		255	67	63		58	90			547	91
	Tijuana (L)		14		255	67	63		58	90			547	91
TC yearly (a+b+c+d)	Pomona (S)	9158	11790	7965	19573	14623	11725	11876	8069	16383	12219		123381	12338
	Pomona (L)	9048	12080	10417	22645	17696	13916	13044	13008	18750	13098		143702	14370
	Tijuana (S)	4262	5839	4000	10207	9892	6673	6257	6181	13061	6585		72957	7296
	Tijuana (L)	5782	6704	5162	12785	12387	8982	7127	7774	13943	7297		87943	8794
TC const	Pomona (S)	661	661	800	1182	661	741	660	2957	920	660		9903	990
	Pomona (L)	1082	1082	1160	1673	1082	1222	1080	4838	1370	1100		15689	1569
	Tijuana (S)	661	661	800	1182	661	741	660	2957	920	600		9843	984
	Tijuana (L)	1082	1082	1160	1673	1082	1222	1080	4838	1370	1080		15669	1567
TC yearly	Pomona (S)	9819	12451	8765	20755	15284	12466	12536	11026	17303	12879		133284	13328
	Pomona (L)	10130	13162	11577	24318	18778	15138	14124	17846	20120	14198		159391	15939
	Tijuana (S)	4923	6500	4800	11389	10553	7414	6917	9138	13981	7185		82800	8280
	Tijuana (L)	6864	7786	6322	14458	13469	10204	8207	12612	15313	8377		103612	10361

	Pomona (S)	Pomona (L)	Tijuana (S)	Tijuana (L)
TC operational	5818	7631	5187	6685
TC transportatio	4478	4697	0	0
TC waste	2198	2198	2283	2283
TC water	106	106	91	91
TC (a+b+c+d)	12338	14370	7296	8794
TC construction	990	1569	984	1567
TC YEARLY	13328	15939	8280	10361

	Pomona (S	Pomona (L)
TC operatior	5818	7631
TC transport	4478	4697
TC waste	2198	2198
TC water	106	106
TC construc	990	1569
TC YEARLY	13328	15939

	Pomona (S)	Pomona (L)
TC operationa	5818	7631
TC waste	2198	2198
TC water	106	106
TC constructi	990	1569
TC YEARLY	13328	15939



Emissions in one of the reference houses

	Operational: Total Only	lights	fans	A/C	Equip/Appl	water heate	el: Applianc	Furnace	Transportation: private	public	Water	Waste	Constructi
Athena: EcoCalculator for Assemblies													*
Be Green Now									*				
Best Foot Forward	*												
Bonneville Environmental Foundation	*												
Build Carbon Neutral Construction Calculator													*
California Carbon Calculator	*												
Carbon Counter.org													
Carbon Footprint													
center for alternative technologies	*												
City of Fair Oaks, CA Water Use Calculator											*		
City of Tampa, Florida Water Use Calculator											*		
Carbon Fund	*												
Ecotect	*			*				*					
Electric Power Pollution Caculator													
Energy Star Target Finder	*												
EPA Waste Reduction Model WARM												*	*
Equest													
HEED		*	*	*	*	*	*	*					
Home Energy Use Calculator													
Home Energy Saver Calculator	*	*		*	*	*	*	*					
and Revit Models	*												
Inconvenient Truth													
Live Neutral													
National Grid													
Safeclimate	*								*				
Stopglobalwarming.org													
The Climate Trust: Personal Calculator	*								*				
Calculator									*				
Yahoo Green Calculator	*												
Water Conservation Calculator											*		
World Wildlife Foundatin: Footprint Calculator													
Zerofootprint: Earthhour	*												
Zerofootprint: Unilever Go Blue											*		
											*		

Comparison of Carbon Calculators

Sarah Buck, Alan Thong, Serge Mayer, Lorenzo Medina, Derek Rungsea, Luis Torres, Luis A. Torres, Alexandra Hernandez, Aireen Batungbakal, Nicholas Klank, Naruki Nagata, Chuck Campanella, Kim Black, Megan Gorman, Kelly Saguini, Don Bui, Oscar Cobos, Michael Scott, Alexa Parks

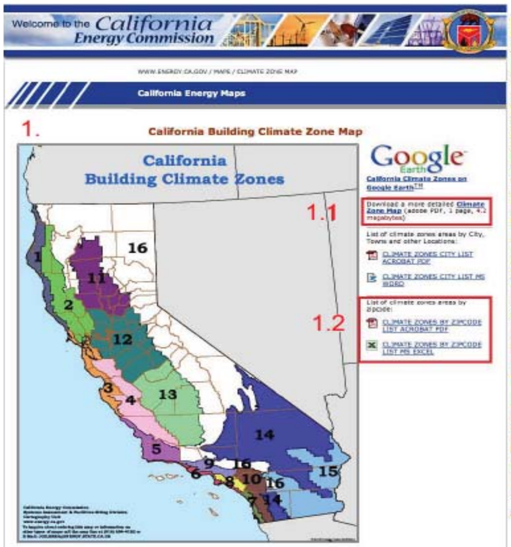
References

The leap to zero carbon, defining the first steps to carbon neutral design, Terri Meyer Boake, SBSE Retreat, UK, 2008.
Ed Mazria (2003), Turning down the Global Thermostat, Metropolis Magazine Oct 2003 p 103-107
Plea Note 6, Keeping Cool: Principles to Avoid Overheating in Buildings. La Roche, P., Quirós, C., Bravo, G., Machado, M., Gonzalez G., (2001). Kangaroo Valley, Australia: Passive Low Energy Architecture Association & Research Consulting and Communications, 60 p.

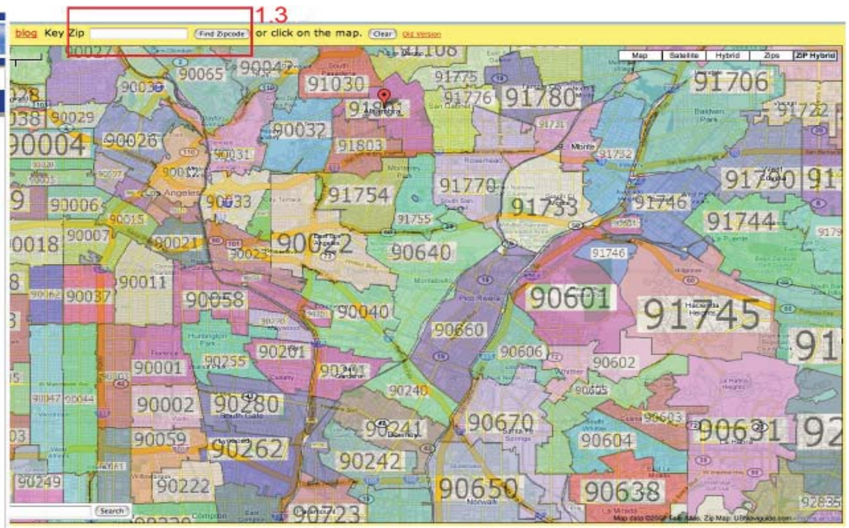
Geographical Distribution of Carbon Emissions

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007 graduate/undergraduate elective 'Topics Studio'



California Climate Zones



Zip Codes

City Name	Zip Code	Population	House Holds	Land Area [Kilometer]	Land Area [Square Meters]	Population /Kilometer²	Energy Use/Year [$]	CO_2 Produced per Household Annually [lbs]	CO_2 Proc per Hou Ann [kg]
Indio	92201								
Indio	92203								
Palm Desert	92210								
Palm Desert	92211								
Banning	92220								
Blythe	92225								
Brawley	92227								
Cabazon	92230								
Calexico	92231								
Calipatria	92233								
Cathedral City	92234								
Coachella	92236								
Desert Hot Springs	92240								
Desert Hot Springs	92241								
El Centro	92243								
Heber	92249								
Holtville	92250								
Imperial	92251								
La Quinta	92253								
Mecca	92254								
Niland	92257								
Palm Desert	92260								
Palm Springs	92262								

1.3

Census Data

Carbon Emission Analysis

Students that worked in this exercise and are responsible for all the images: Serge Mayer, Ryan Cook, Marcos Garcia, John Duong, Ryan Hansanuwat, Nick Pieroti, John Gayomail, Greg Ladjimi, Brandon Gulloti, Garrett Van Leeuwen.

Design/Performance Objective

Students are not used to visualizing amounts of CO2. It is important that they learn to think and visualize in units of carbon just as they can think in units of length, width and space. This exercise will help the student to visualize CO2 emissions per units of dwellings.

The students had to determine residential yearly CO2 emissions in zip codes located in different climate zones. This exercise will help students achieve an understanding of the relationship between carbon emissions, climate and population density.

Investigative Strategy

The students work in teams to analyze CO2 emissions in several climate zones using a method developed in class. The method begins by determining the extent of the climate zones and the zip codes located in each zone. Energy use and CO2 emissions for a typical home in each zone are determined and maps are generated with this information. The next exercise compares this information with potential CO2 reducing strategies.

1. Climate Zones and Zip Codes

1.1. The students define the boundaries of the climate zones and determine the zip codes in each climate zone. For this project California Climate zones were used, so the limits and the zip codes inside the zone were previously defined.

1.2. Determine which zip codes are in the climate zone under study.

1.3. Gather census data from website http://www.census.gov./geo/www/gazetteer/places2k.html

1.4. Use the following information from the census files. This is organized in a spreadsheet in the following columns:

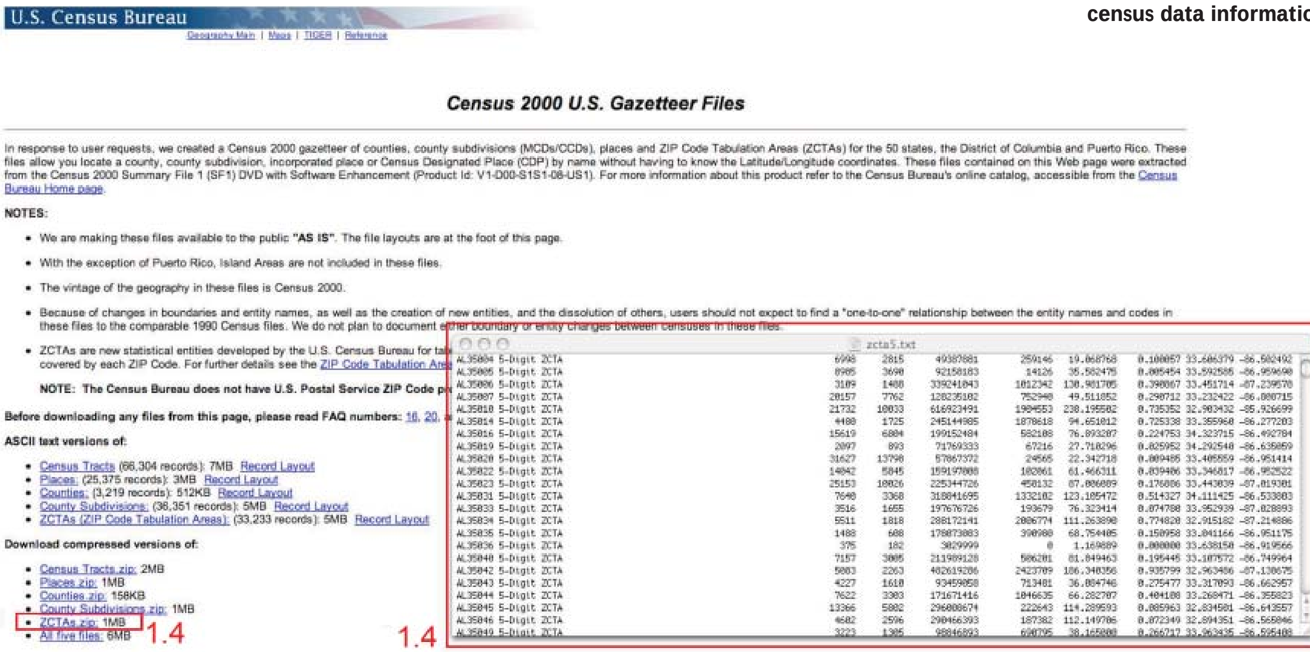
- •City name [A]
- •Zip code [B]
- •Population [C]
- •Households [D]
- •Land area (square miles) [E]
- •Land area (square meters) [F]

Geographical Distribution of Carbon Emissions (cont.)

Pablo La Roche
California Polytechnic State University

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

census data information



Home Energy Saver windows

2. Determine Residential Energy use and CO2 emissions per Zip Code
Determine energy and CO2 emissions for a reference house in each zip code in the climate zone.

Then multiply CO2 and energy per dwelling by the number of units in each zip code. Several energy modeling programs can be used to determine energy and emissions. Home Energy Saver has been used in this exercise and the calculation is done in the following form (numbers correspond with numbers in figures):

2.1. Go to Home Energy Saver Site: http://hes.lbl.gov

2.2. Enter zip code

2.3. Set cooling to "central air"
- Save answer
- Calculate

2.4. Select link "more details..."
Columns
- Energy use/money per year [G]
- Price per KwHr [H]

Geographical Distribution of Carbon Emissions (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

2.5. The estimated CO_2 emissions for the house are indicated in the website.

3. Determine CO2 emissions in the zip code. Select the CO_2 per household obtained in 2.5 for each zip code and multiply by the number of households per zip code.

- •CO2 (kg) per household annually [I]
- •CO2 (kg) per household annually [J]
- •CO2 (kg) per zip code annually [K]
  G x C = H
- •CO2 (kg) / m2 annually [L]
  H/D
- •Lbs/ft2 of CO2 annually [M]
  (H x 2.2)/(D x 10.7636)
- •Lbs of CO2 per person [N]
  (H x 2.2)/B

4. Generate Maps with this Information. Emphasis is on creating maps that help to understand the relationships between emissions and population density and emissions with surface areas. GIS would help create these maps (Figs 4,5,6) but they can also be drawn by hand (as these have been).

Residential CO2 in kg/m2 per year
Residential CO2 in kg/person per year
Population per square kilometer

Kg of CO_2 per Meter^2 Yearly. Climate Zone 6

Population per sq/km. Climate Zone 6

Kg of CO_2 per Person. Climate Zone 6

Evaluation Process

Class discussions and presentations of the maps and the information to the other teams.

Evaluative Criteria

Students must find relationships between CO2 emissions, population density and climate. Some relationships such as density and CO2 are easy to understand, but they are sometimes affected by land use. The next project addresses the origin (residential) of these emissions.

Cautions- Possible Confusions

Calculations should be checked several times because there are many opportunities for errors in this process.

Duration of Exercise

One Week

Degree of Difficulty

Difficult

References:

http://www.energy.ca.gov/maps/building_climate_zones.html http://hes.lbl.gov
http://www.census.gov./geo/www/gazetteer/places2k.html
http://mackintosh.aud.ucla.edu/heed/
http://www2.aud.ucla.edu/energy-design-tools/

Residential Sources of Carbon Emissions in Different Climates

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007 graduate/undergraduate elective 'Topics Studio'

Design/Performance Objective

Determine origins of energy use and CO2 emissions for a representative 1500 ft2 code compliant house. This house will represent a typical energy code compliant house, and the calculation is done in two climate zones. This house will be used as the base case for comparison with student projects developed during the studio. This assignment will help the student gain a better understanding of the relationship between the sources of carbon emissions in homes, local climate and energy use in that specific climate. Emphasis is on emissions from operational energy. Transportation to and from the building, providing water to the building, disposing of waste from the building and construction of the building are not analyzed in this base case in 2007. They are analyzed in another exercise in 2008.

Investigative Strategy

Energy modeling software is used to determine the energy consumption and CO2 emissions for the typical code compliant house in each climate zone. In this exercise two climate zones were selected, only one of which is presented here.

1. Energy Consumption and CO2 emissions in the reference house.

1.1. Energy modeling of the reference house with Home Energy Designer as indicated in the previous technique "geographical distribution of carbon emissions" and HEED. Both of these permit to determine the total energy consumption and their origins. In HEED this is done using the energy costs screen (Fig 1). This screen presents the results in units of energy and carbon emissions for air conditioning, fans and blowers, lights, equipment and appliances, electric heat or pumps, water heater, appliance fuel and furnace fuel.

1.2. Use Home Energy Saver to determine total energy consumption and their origin in the different zip codes. This is done using the results screen: heating, cooling, hot water, lighting, major appliances, miscellaneous.

1.3. Determine combinations of climate zones and zip codes with similar energy use

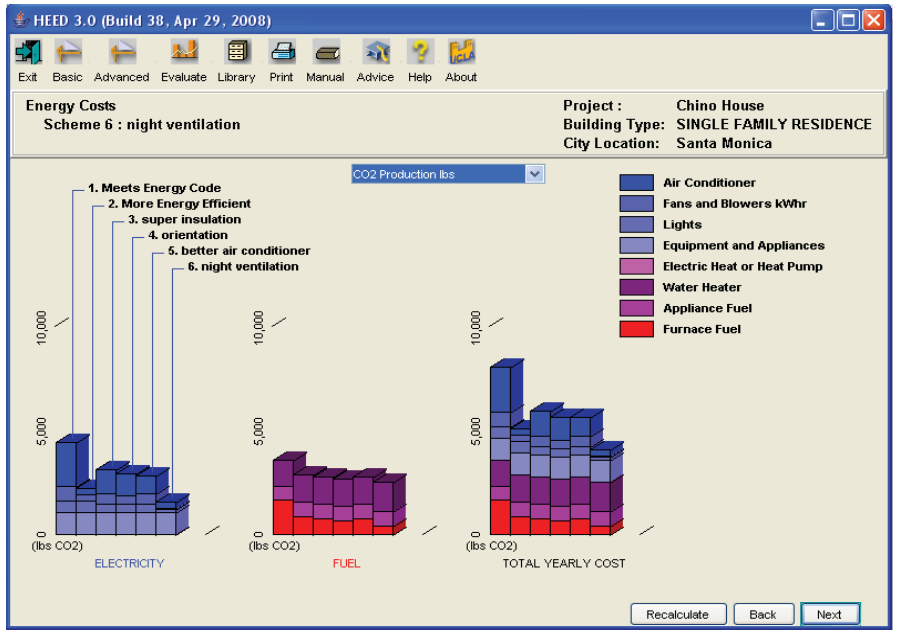


Fig 1: Origin of Residential Energy Use

Toward Zero Energy Building

Attribute	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6
Passive Hours (no heat or cool)...%	55.09	90.51	70.94	70.09	70.94	92.45
Total Floor Area .... sq.ft.	1400.00	1400.00	1384.00	1384.00	1384.00	1384.00
Total Fuel consumed..... kBTU/sf	24.78	19.03	18.45	17.81	18.45	16.33
Total Electricity consumed kWhr/sf	3.55	1.76	2.56	2.40	2.30	1.27
Electricity Equivalent...in kBTU/sf	12.11	6.02	8.73	8.19	7.85	4.33
Site Energy Use Total......kBTU/sf	36.89	25.05	27.18	26.00	26.30	20.66
Site Energy Use. ....% of Scheme 1	100.00	67.91	72.85	69.68	70.48	55.36
CO2 Carbon Dioxide...........lbs/sf.	5.75	3.64	4.30	4.08	4.07	2.97
CO2..................% of Scheme 1	100.00	63.43	73.94	70.16	70.00	51.04

OK

Fig 2. : Carbon Emissions of Reference Building

Carbon Emission Analysis

Students: Serge Mayer, Ryan Cook, Marcos Garcia, John Duong, Ryan Hansanuwat

Residential Sources of Carbon Emissions in Different Climates (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007 graduate/undergraduate elective 'Topics Studio'

patterns (Fig. 3). This will permit them to be compared with climate design strategies that would reduce the building's carbon footprint.

2.Climate Analysis
2.1. Use Climate Consultant or the Weather Tool to determine design strategies that could be incorporated in the design of the house to reduce energy use and CO2 emissions. Traditionally climate analysis is done before any type of modeling is done. In this case it was done after the energy analysis to determine strategies that could reduce the emissions factors from the different sources detected in 1.

2.2. Rank the potential impact and performance of these strategies. This can be graphed for the heating and cooling seasons separately (Fig 5, 6). The strategies can be organized in tables that indicate potential CO2 reductions after implementing them (Fig 7).

Evaluation Process

Class discussions and presentations of the maps and the information to the other teams. Students must find relationships between CO2 emissions, the origin of these emissions in the buildings, and climate in which these buildings are located.

Evaluative Criteria

Students should be able to select and rank the strategies.

Cautions- Possible Confusions

Calculations should be checked several times. There are many opportunities for errors in this process.

Duration of Exercise

One Week

Degree of Difficulty

Medium

References

Title 24 maps:
http://www.energy.ca.gov/maps/building_climate_zones.html http://hes.lbl.gov

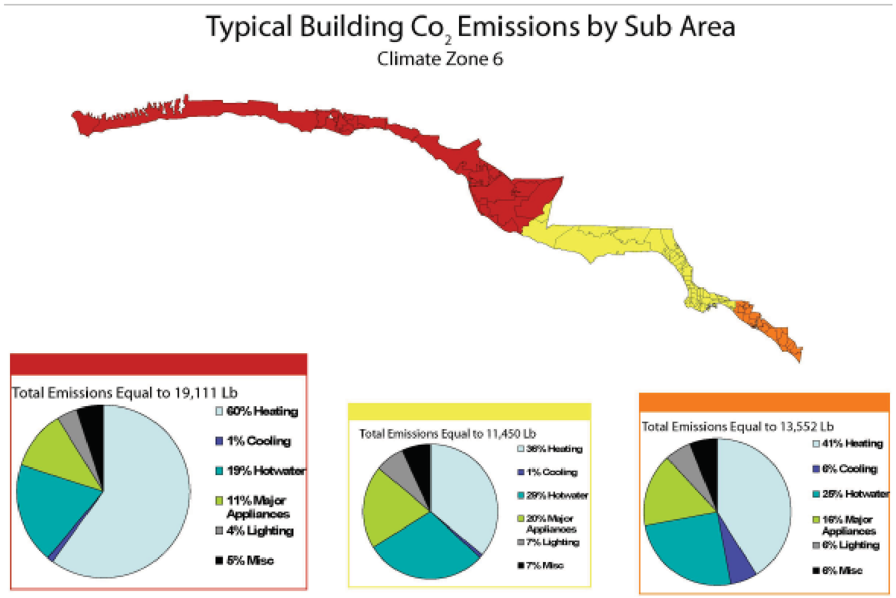


Fig 3: Residential Energy use in one Climate Zone

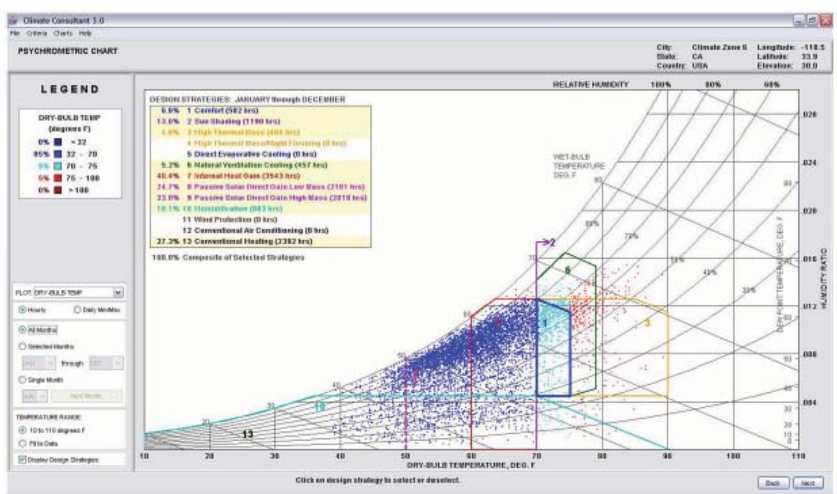


Fig 4: Climate Analysis

Carbon Emission Analysis
Students

Serge Mayer, Ryan Cook, Marcos Garcia, John Duong, Ryan Hansanuwat

Residential Sources of Carbon Emissions in Different Climates (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

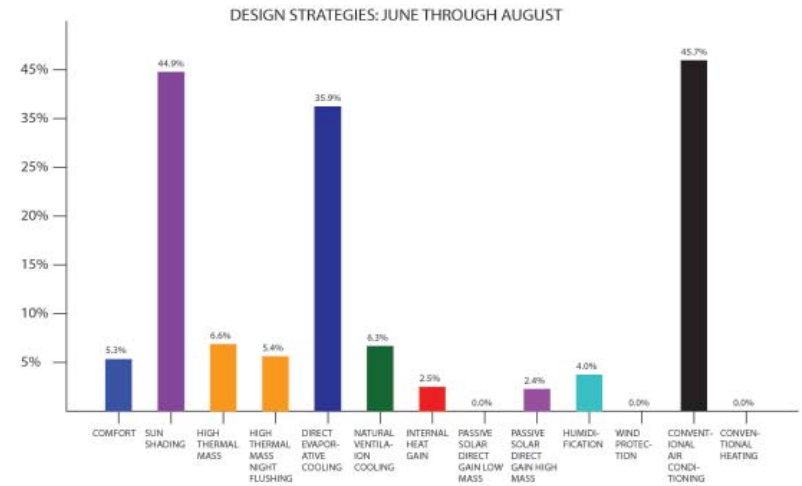
gazetteer/places2k.html

HEED:
http://mackintosh.aud.ucla.edu/heed/
Climate Consultant:
http://www2.aud.ucla.edu/energy-design-tools/

P. Torcellini, S Pless, M Deru, D Crawley. Zero Energy Buildings: A Critical Look at the Definition. ACEE, Summer Study, Pacific Grove CA (2006).

A Green Vitruvius. Principles and Practice of Sustainable Architectural Design. European Commission, Directorate General XVII For Energy (2001).

Plea Note 6, Keeping Cool: Principles to Avoid Overheating in Buildings. La Roche, P., Quirós, C., Bravo, G., Machado, M., Gonzalez G., (2001). Kangaroo Valley, Australia: Passive Low Energy Architecture Association & Research Consulting and Communications, 60 p.



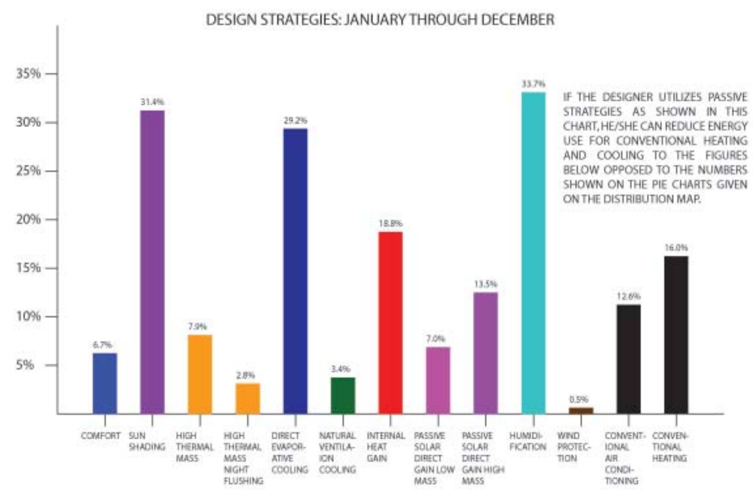


Fig 5 & 6: Seasonal Design Strategies. Climate Zone 6

Northern Sub-Zone

	Average Household 8686		Potential Reductions		New co2 emissions per year
	% of co2 emissions	kg of co2	% of co2 reduction w/ proposed strategies	Reduction in kg of co2	
Heating	60%	5212	64%	3335	1876
Cooling	1%	87	0%		87
Hot Water	19%	1650	85%	1403	248
Major Appliances	11%	955	0%		955
Lighting	4%	347	75%	261	87
Misc	5%	434	0%		434
Totals		8686		4999	3687
			Percentage of CO2 reduced		58%

Central Sub-Zone

	Average Household 5205		Potential Reductions		New co2 emissions per year
	% of co2 emissions	kg of co2	% of co2 reduction w/ proposed strategies	Reduction in kg of co2	
Heating	36%	1874	64%	1199	675
Cooling	1%	52	0%		52
Hot Water	29%	1509	85%	1283	226
Major Appliances	20%	1041	0%		1041
Lighting	7%	364	75%	273	91
Misc	7%	364	0%		364
Totals		5205		2756	2449
			Percentage of CO2 reduced		53%

Southern Sub-Zone

	Average Household 6160		Potential Reductions		New co2 emissions per year
	% of co2 emissions	kg of co2	% of co2 reduction w/ proposed strategies	Reduction in kg of co2	
Heating	41%	2526	64%	1616	909
Cooling	6%	370	0%		370
Hot Water	25%	1540	85%	1309	231
Major Appliances	16%	986	0%		986
Lighting	6%	370	75%	277	92
Misc	6%	370	0%		370
Totals		6160		3203	2957
			Percentage of CO2 reduced		52%

Fig 7: Design Strategies for different sub-zones. Climate Zone 6
Serge Mayer, Ryan Cook, Marcos Garcia, John Duong, Ryan Hansanuwat

Solar Site Analysis

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007 graduate/undergraduate elective 'Topics Studio'

Design/Performance Objective

Building shading on outdoor spaces has an important effect in the perception of the space and its use. If it is intended for winter use and it is shaded by a neighboring building it will probably be dark, cold and unused. Nor will it be used if it is intended for hot weather use and it is unshaded. This technique permits to calculate the effect of building shading on exterior spaces to determine if they spaces can be used as proposed during the summer or winter. The method can also be used to determine performance of PV systems or solar windows for passive and active heating. Adjustments in building massing can then be proposed to improve shading or solar access.

Investigative Strategy

1.1. Shade in site. Analyze climate to determine shading and radiation needs. Climate analysis of weather files indicates required design strategies to achieve thermal comfort in indoor spaces (Fig. 1) but can also help to determine when solar radiation is an asset or liability in outdoor spaces. The sun shading chart in Climate Consultant combines solar geometry with outdoor temperature in one diagram making it more useful.

1.2. Determine the placement of the analysis points using a grid or strategically located points (Fig 3).

1.3. Select the points option in Ecotect's 3d editor. Place these points in the desired positions.

1.4. Select Sun Path Diagram Tool under "Calculate" in Ecotect and place the cursor in the points. Ecotect draws the perimeter of the building mass in the sun path diagram permitting to determine their shading effect during the whole year.

2. Orientation of buildings.
2.1. Radiation of surfaces is calculated using Ecotect to determine best building orientations. A visual analysis is done but total irradiation per surfaces can also be calculated to determine the most efficient surface .

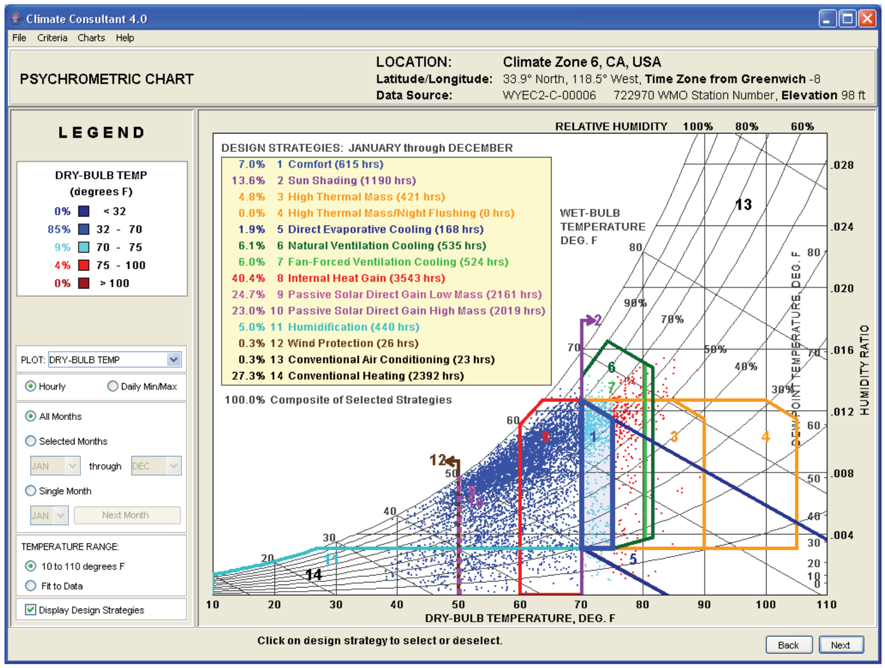


Fig 1: Climate Analysis

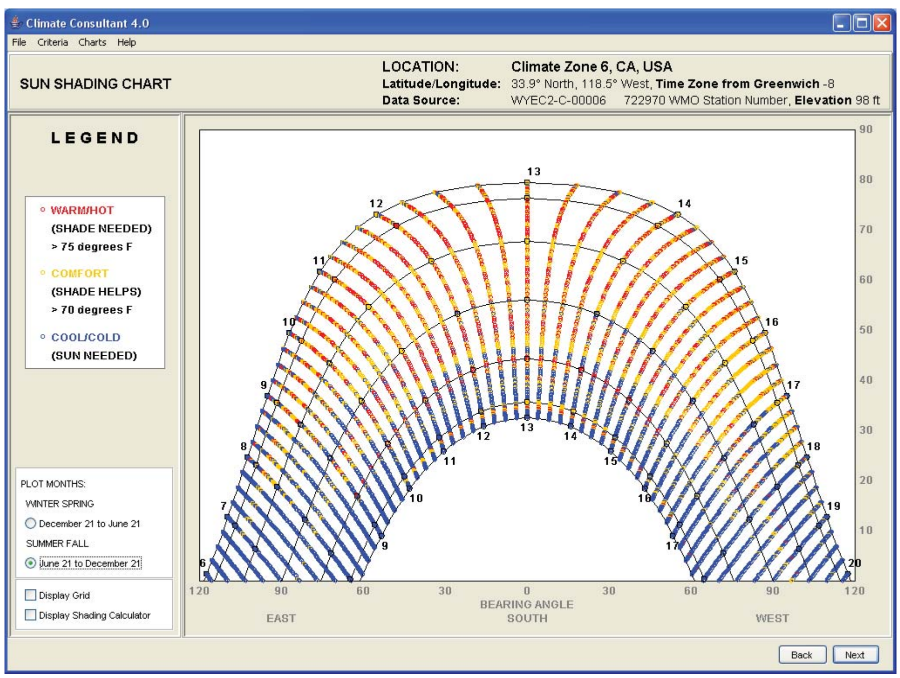


Fig 2: Sun path diagram with hourly temperatures

Solar Site Analysis (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007 graduate/undergraduate elective 'Topics Studio'

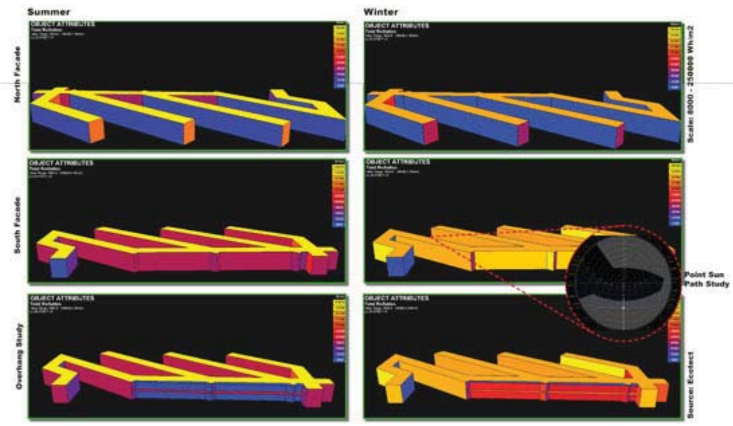
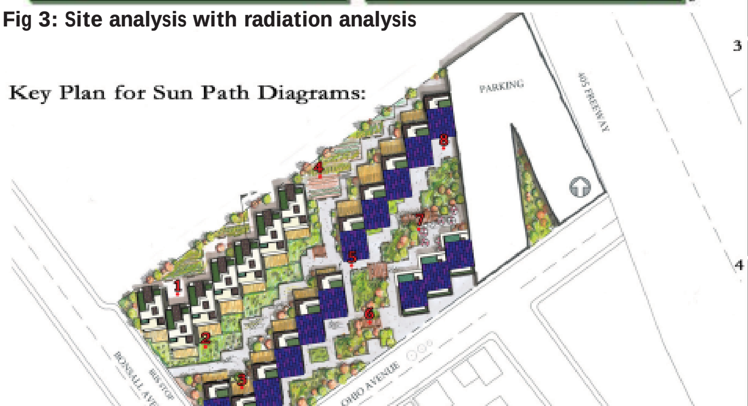


Fig 3: Site analysis with radiation analysis



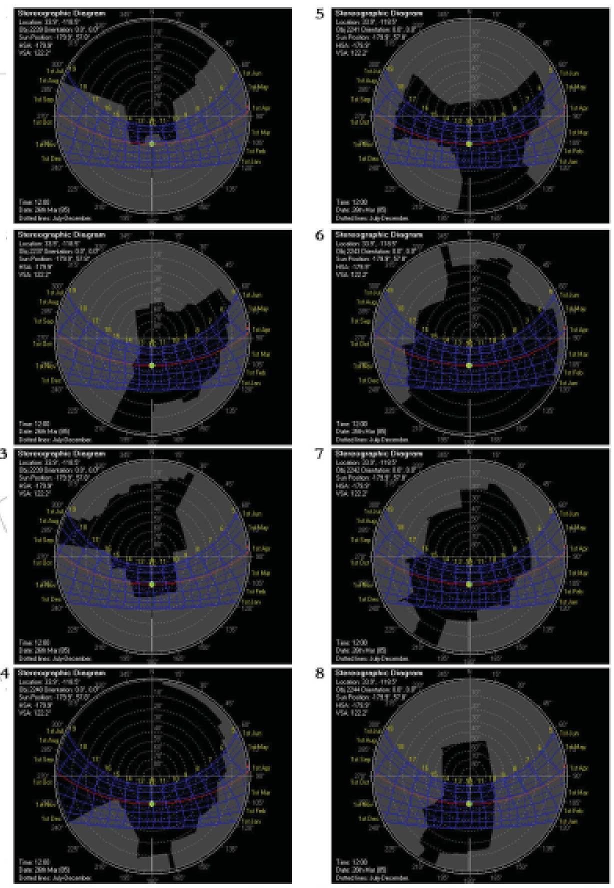


Fig 4: Site analysis with sun path diagrams for different locations

2.2. Orientation and Energy Use.
HEED is used to determine the optimum orientation as a function of energy use. The same building is rotated in different schemes and yearly energy use in the BEPS window or different schemes in the energy costs screen can be compared. All other variables being equal, the building with the lowest energy consumption should be selected.

Evaluation Process

Class discussions and presentations of the information. The results should inform design decisions.

Evaluative Criteria

Shade or solar radiation should be provided during desired times in the outdoor spaces. Appropriate orientation should reduce energy use.

Cautions- Possible Confusions

Many students find the sun path diagram with the building outlines difficult to understand.

Duration of Exercise

One studio session.

Degree of Difficulty

Easy

References

http://www.energy.ca.gov/maps/building_climate_zones.html http://hes.lbl.gov gazetteer/places2k.html
http://www2.aud.ucla.edu/energy-design-tools/

Solar Site Analysis
Students

Serge Mayer, Ryan Cook, Marcos Garcia, John Duong, Ryan Hansanuwat,.

Mechanical and Electrical Equipment for Buildings, 10th edition, by Stein, Reynolds, Kwok and Gronzik published by Wiley, 2005.

Radiation Impact on Surfaces

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

Design/Performance Objective

Incident solar radiation can have a significant impact in buildings by affecting the surface temperature of opaque materials and increasing heat transfer by conduction or by radiation through windows.

Building surfaces receive varying amounts of solar radiation depending on the climate and latitude of the site and the orientation and tilt of the surface. This incident radiation affects the shading requirements and potential uses of the surface. Surfaces which receive more solar radiation might require additional shading during the summer, or would be suitable for placement of a solar hot water collector, or photovoltaic systems, or to place a window to provide solar gains to the interior of the building.

The objective of this exercise is to quantify and compare incident solar radiation on exterior building surfaces. Students will use this information to make more informed design decisions.

Investigative Strategy

1.1. Using Ecotect select the option for solar access analysis under calculate and analyze the irradiation over the exterior surfaces of the building.

1.2. Calculate radiation on building and site surfaces to determine solar impact and shading requirements. The 3d models describe the incident radiation on external surfaces. Fig 1 is the analysis of a shading system for an exterior space for underground dwellings, which must block direct solar radiation in the summer and allow it in the winter. Fig 2 describes the effects of solar radiation on building massing in a city block. The colors define different amounts of solar radiation. This analysis can be used to refine the design of the massing, exterior colors, fenestration and shading systems.

Evaluation Process

Numerical analysis of the information. Class discussions and presentations of the information.

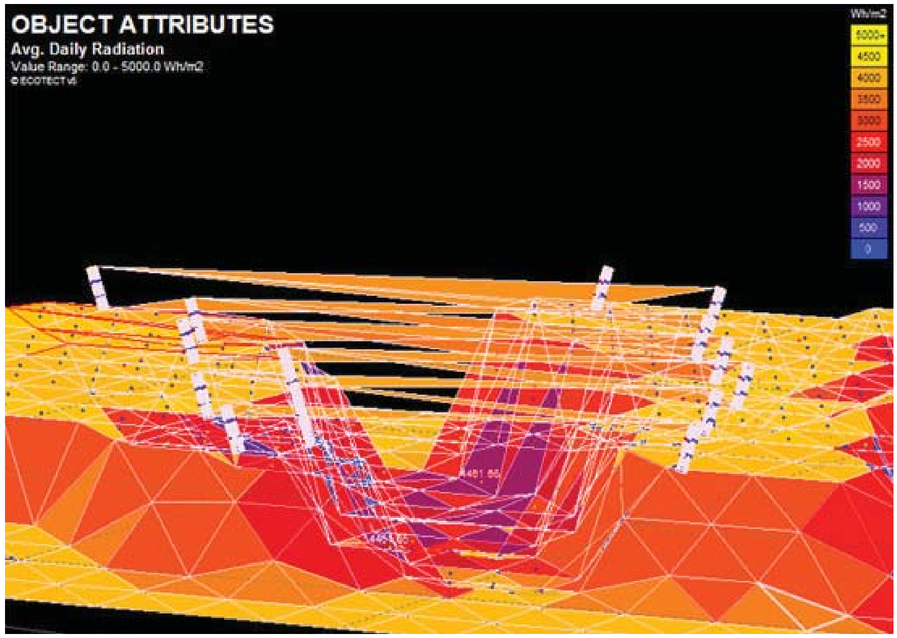


Fig 1: Solar radiation through a shade system in an exterior space

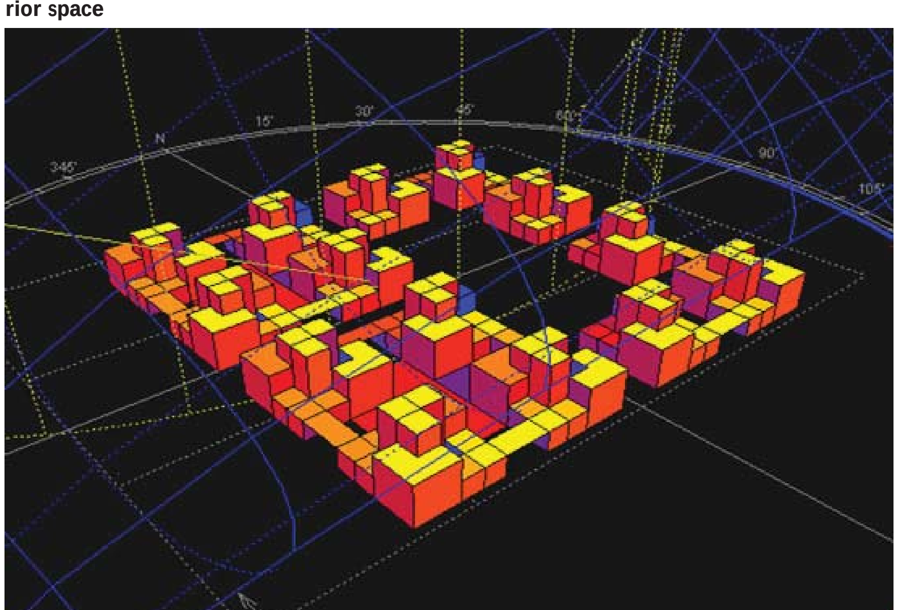


Fig 2: Solar radiation in exterior mass in Palm Springs

Radiation Impact Analysis
Students Name

Fig 1:(top) Jon Gayomali, Garret Van Leeuwen, Brandon Gulloti

Fig 2: (bottom) Jonathan Reimann, Nick Pierotti, Greg Ladjimi

Radiation Impact on Surfaces (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

Evaluative Criteria

Incident solar radiation must usually be minimized during the cooling season and maximized during the heating season. Comparison of solar radiation values permit the student to continue envelope design with a better understanding of the effects of the sun on the building. This information is not used directly in the calculations of heat gain and losses, because energy modeling software is used for this. However it serves as a starting point for design ideas that respond to more than solely solar geometry, they also respond to the actual amounts of incident solar radiation.

Cautions- Possible Confusions

Student must understand the effect of the seasons. Simulations should be performed for the whole year, and for the cooling and heating seasons. Mid seasons and extreme months could also be considered. The student must understand what he is looking for in each season and for each building surface

Duration of Exercise

One studio session to explain and do the exercise and another session to analyze the results.

Degree of Difficulty

Easy.

References

http://ecotect.com/

Mechanical and Electrical Equipment for Buildings, 10th edition, by Stein, Reynolds, Kwok and Gronzik published by Wiley, 2005.

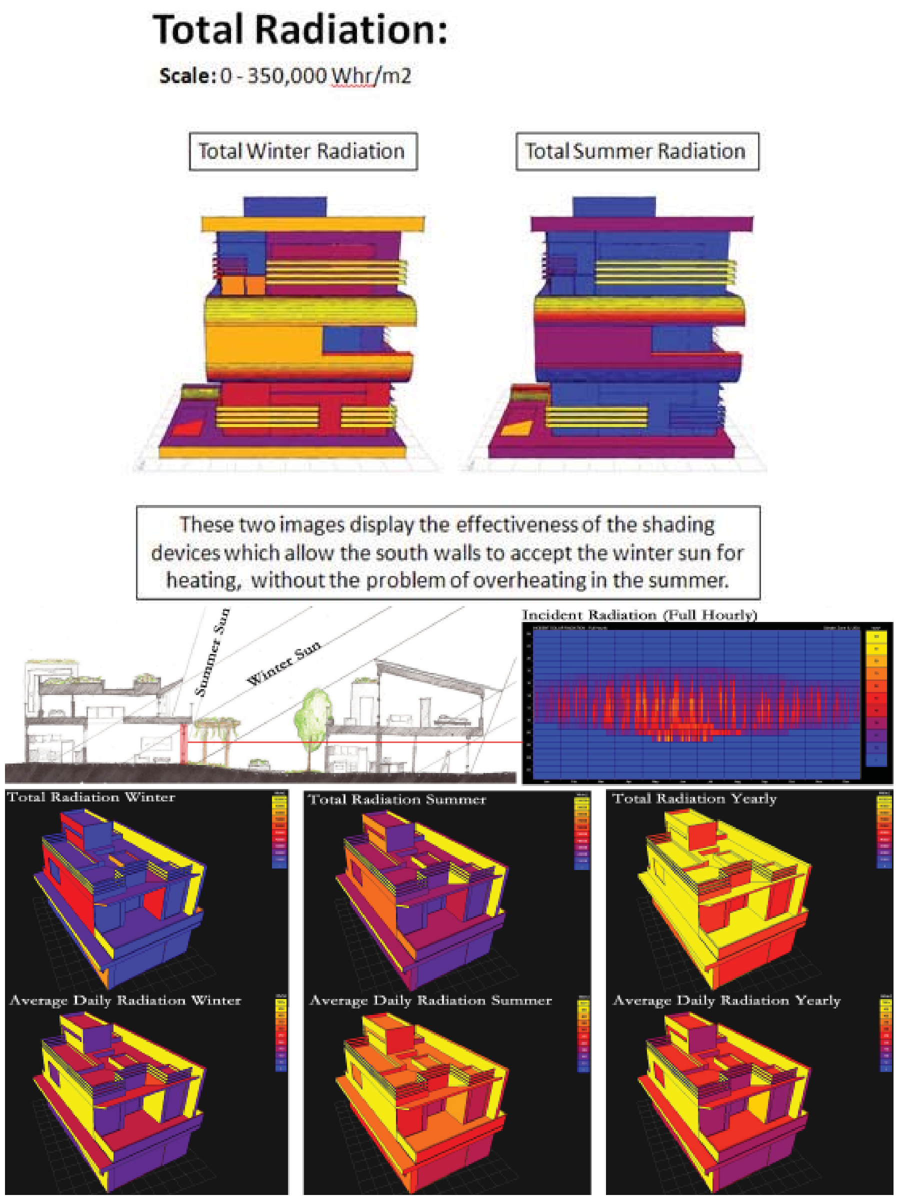


Fig 3: Solar radiation analysis of exterior surfaces in West Los Angeles

Radiation Impact Analysis
Students Name

Fig 1:(top) Ryan Cook

Fig 2: (bottom) Serge Mayer, Ryan Cook, Marcos Garcia, John Duong, Ryan Hansanuwat,

Fenestration and Shading

Pablo La Roche
California State Polytechnic University Pomona

Spring 2008 Undergraduate Studio

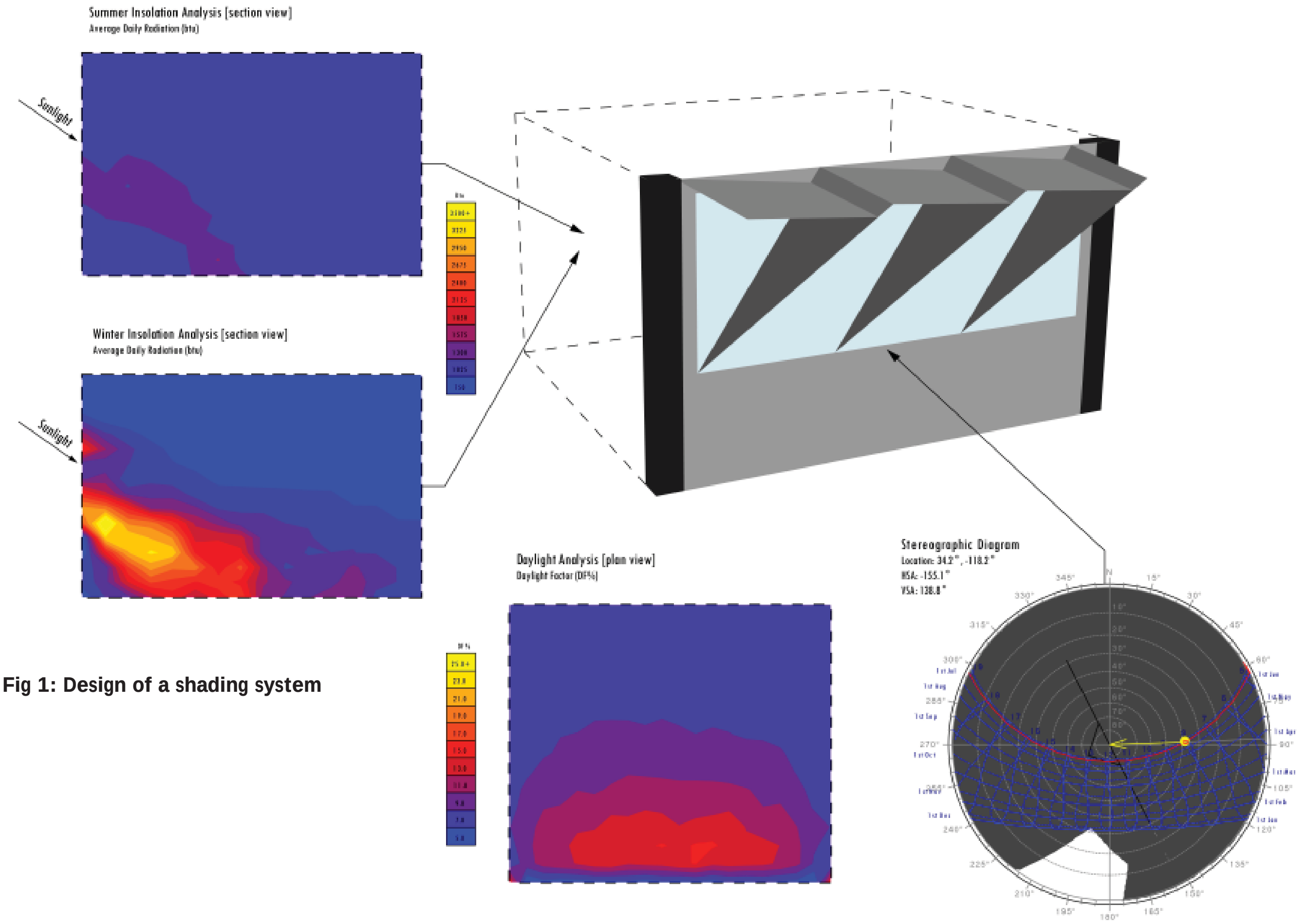


Fig 1: Design of a shading system

Fenestration and Shading

Students

Tyle Tucker, Emmanuele Gonzalez, Rogelio Diaz.

Design/Performance Objective

Solar radiation through windows can contribute a significant amount of heat into the building. This radiation can be beneficial when heating is required but can also be a liability when cooling is needed. It can be regulated with properly designed shading systems that block the heat when it is not required and allows it when it is desirable. Daylighting, however, should be provided during the whole year.

The objective is to design and optimize an integrated window and shading system to provide the necessary solar protection in the summer and solar radiation in the winter (if required) while providing daylight. All of this with minimum use of materials.

Investigative Strategy

1.1.Climate analysis to determine shading needs. Analysis of weather files with the BBC or the psychrometric chart indicate when solar radiation is needed inside the space. The sun shading chart in Climate Consultant plots solar position with outdoor temperature and dates and times in one diagram. This chart shows when shade is needed as a function of the shade line which can be adjusted by the user in the criteria screen.

1.2. Incident Solar Radiation.
In Ecotect use the option for solar access analysis and select the option to determine the incident solar radiation. A grid should have been created inside the space and the option to select objects in analysis grid should be selected. It is usually easier to visualize average daily values. An analysis for both the winter and summer seasons must be performed.

1.3. Daylight Analysis
A simple daylighting analysis using Ecotect permits to indicate if the shading system is also providing enough daylight inside the space. Ecotect's analysis uses the CIE standard overcast sky. This should ensure enough daylight but in constantly clear skies opens the possibility of glare and overheating.

Fenestration and Shading (cont.)

Pablo La Roche
California State Polytechnic University Pomona

Spring 2008 required 2nd year Studio and Fall 2008 graduate/undergraduate elective 'Topics Studio'

Evaluation Process

Analysis grids should be placed in section through the windows and in plan to visualize the data inside the space.

Evaluative Criteria

In general, solar radiation penetrating through the window should be reduced during the summer and increased during the winter. An ideal summer number would be as low as possible (zero ideal). Numbers should be expressed as average daily values which are easier to understand.

Cautions- Possible Confusions

This project focuses on solar radiation penetrating the space instead of incident solar radiation on the exterior surfaces of the objects. Students are analyzing the effects of the shading system on solar radiation and daylighting but a separate analysis must be done for each one.

Duration of Exercise

This exercise would be ongoing during the quarter. It takes very little time to test a window with a shading system, but the objective is to improve their performance with each iteration, creating a form that is architecturally integrated with the project and performing correctly.

Degree of Difficulty

Easy. This work is suitable for second year students.

References

www.ecotect.com

Mechanical and Electrical Equipment for Buildings, 10th edition, by Stein, Reynolds, Kwok and Gronzik published by Wiley, 2005.

S. Szokolay, Solar Geometry PLEA Notes 1, Design Tools and Techniques, 1996.

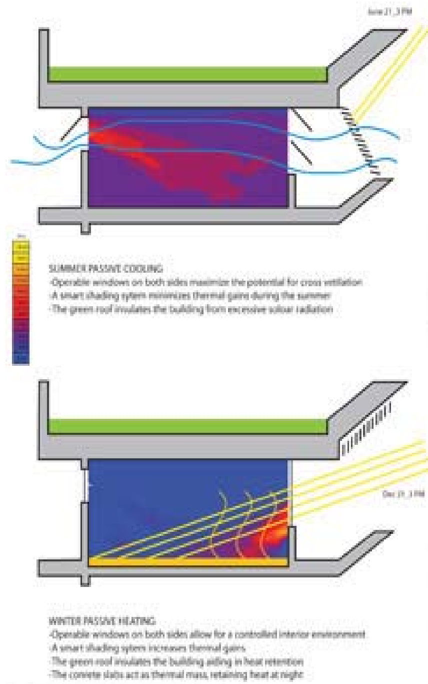


Fig 2: Design of a direct gain / shading system.

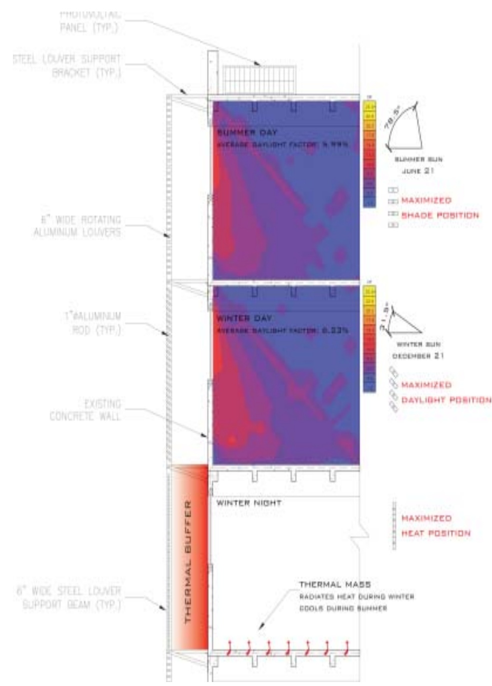


Fig 3: Design of a direct gain / shading system.

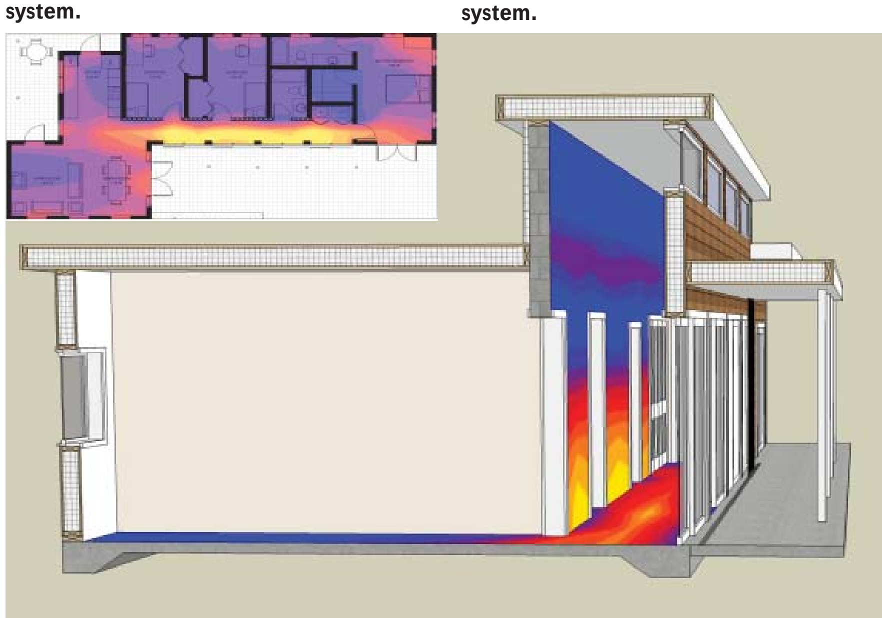


Fig 4: Design of a residential direct gain system with summer shading

Figure 2: Ryan Dayag Jeremy Brunnel
Fig 3: Greg Sagherian, Sandeesh Sidhu
Fig 4: Kim Black, Sarah Buck

Daylight Analysis

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

Design/Performance Objective

It is important to achieve a controlled distribution of light inside a space. Adequate illuminance levels should be provided while eliminating glare. This exercise focuses on achieving a major portion of this with daylight.

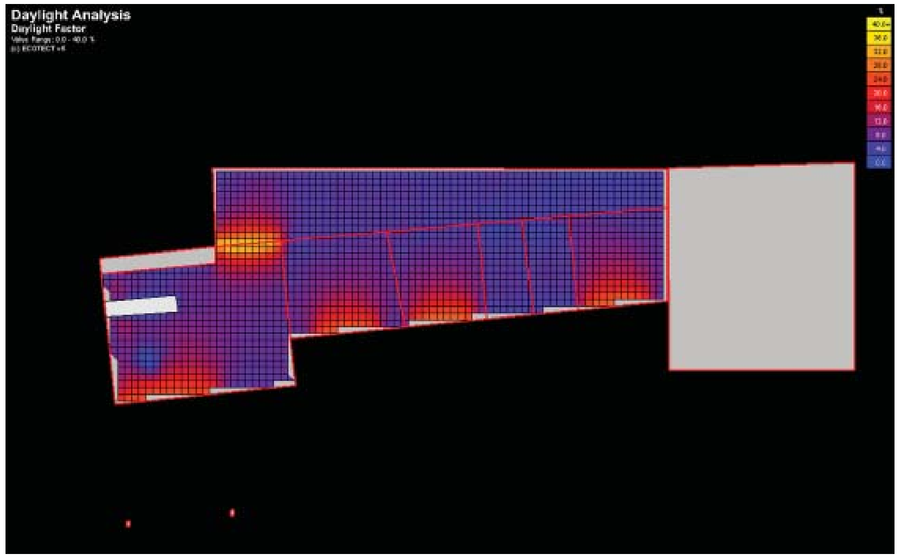
Investigative Strategy

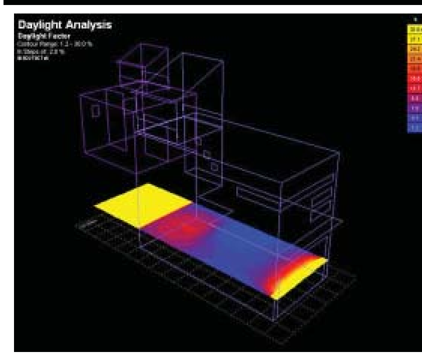
Illuminance is a measure of the illumination of a surface and luminance is a measure of brightness of a surface when looked at from a given direction. Students must design the fenestrations to achieve the necessary illuminance levels while minimizing glare. Students will use Ecotect and Radiance to determine illuminance and luminance levels inside the house. The objective is to ensure sufficient illuminance with daylight without excessive differences in illuminance values.

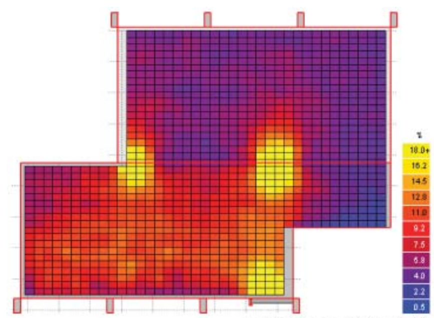
1.1. Students calculate interior illuminance using Ecotect. The SI unit of illuminance is the lux, or lumen per square meter. In the US, the foot-candle (fc), or lumen per square foot is used (1 fc = 10.764 lux). Students do a set of Initial calculations with Ecotect to determine the daylight factor, which is the ratio of indoor to outdoor illuminance. This analysis gives a preliminary idea of building performance under a standard overcast sky. This calculation is independent of climate data, so values will not change with different dates or times. The only parameters that affect these daylight factors are the geometry of the design and the materials it is made off, permitting to compare one option with another. The analysis grid. Illuminance values can be obtained from Ecotect by assigning a design sky value.

1.2. Additional illuminance calculations are done with Ecotect and Radiance. The data is exported to radiance and students used contour lines to show illuminance values in Lux or Fc. Radiance is used because it provides the option to use weather files and generates results for specific days and hours.

1.3. Luminance Calculations
Luminance (L) is measured brightness. The units of Luminance are candelas per square







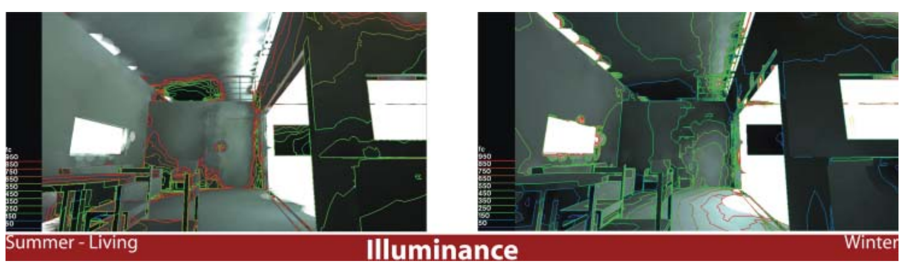


Fig 1 (top): Daylight factor with Ecotect
Fig 2 (middle left): Daylight factor with Ecotect
Fig 3 (middle right): Daylight Factor with Ecotect
Fig 4: Illuminance with Radiance and Ecotect

Daylight Analysis
Students Name

Fig 1 (top): Charles Campanella, Serge Mayer

Fig 2 (middle left): Garrett Van Leuween

Fig 3 (middle right): Don Bui, Megan Gorman

Fig 4 (bottom): Alexandra Hernandez, Aireen Batungbakal

Daylight Analysis (cont.)

Pablo La Roche
California Polytechnic State University

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

foot (cd/ft2) or candelas per square meter (cd/mt2). Students measured luminance using a false color scale.

Evaluation Process

Students must provide enough daylight while reducing glare. The students have to use these images to improve the design of their fenestration system.

Evaluative Criteria

The students must provide the required illuminace levels (measured in Lux, Fc, or daylight factor) for the activity according to tables. Students had to achieve a minimum 2% DF in living rooms and bedrooms and a minimum 4% DF in kitchens. Luminance analysis must demonstrate reduced glare.

Cautions- Possible Confusions

Students must know that the daylight calculations inside Ecotect assume a standard overcast sky.
Students confuse illuminance with luminance and the meaning of the colors in the scale.

Duration of Exercise

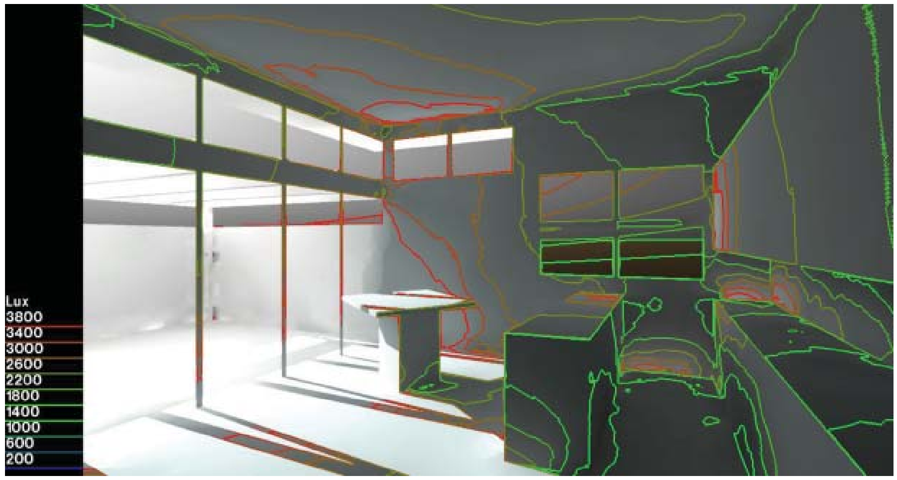
The first iteration with ecotect and daylight takes a very short time. Installing and exporting to radiance takes more time. The process can be explained in one class and results can be discussed in the following class.

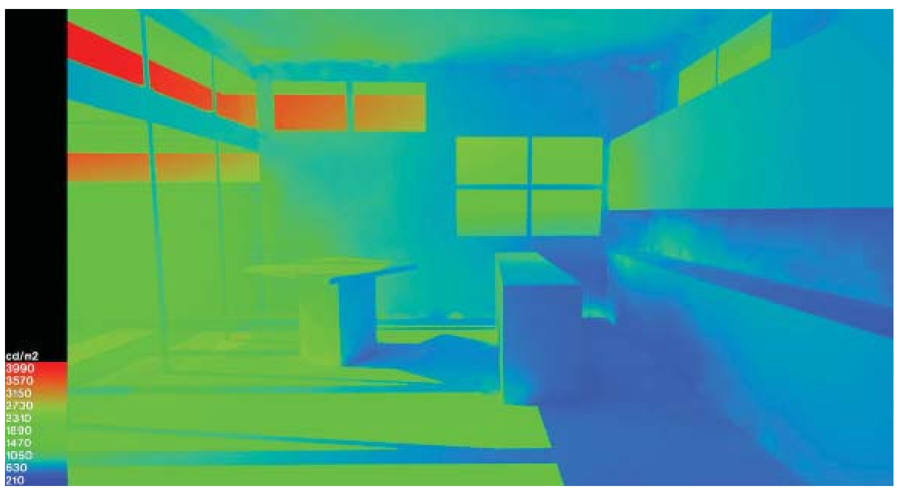
Degree of Difficulty

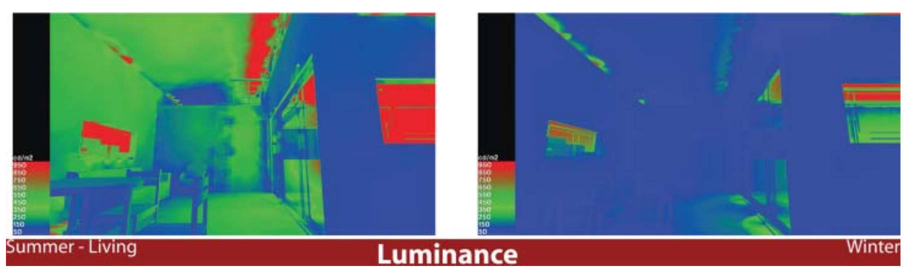
The first iteration with Ecotect and daylight is very easy and suitable for beginning design students. Installing and exporting to radiance is more difficult. It is helpful to use Ecotect first because you get usable results very fast.

References

http://ecotect.com/
http://radsite.lbl.gov/deskrad/
Mechanical and Electrical Equipment for Buildings, 10th edition, by Stein, Reynolds, Kwok and Gronzik, Wiley, 2006.
Daylight in Buildings. International Energy Agency, 2000.
Architectural Lighting, Second Edition. M. David Egan, Victor Olgyay. McGraw Hill, 2nd Ed, 2002
Daylighting, Performance and Design, Gregg Ander, 1995, Van Nostrand Reinhold.
8. Simplified Design of Building Lighting (Parker/Ambrose Series of Simplified Design Guides), Marc Schiler, 1992)
Daylight Design of Buildings. Nick Baker and Koen Steemers, James and James (2002)







Luminance with Radiance and Ecotect
Charles Campanella, Serge Mayer,
Alexandra Hernandez,
Aireen Batungbakal

Air Flow Analysis

Pablo La Roche
California State Polytechnic University Pomona

Fall 2007, 2008 graduate/undergraduate elective 'Topics Studio'

Design/Performance Objective

Natural ventilation can be a very effective cooling strategy. In hot and humid climates it can provide evaporative cooling in our skins. In hot and dry climates it can cool the interior structure of the building which would then act as a heat sink during the day. If natural ventilation is desired then it is necessary to determine how the air flows through the space with the openings.

Investigative Strategy

Using Ecotect and Win Air determine the pressures and direction of air movement through different areas of the house. Layers should be cut in different horizontal and vertical layers to understand this pattern. The model is analyzed inside Ecotect exported to WinAir and then imported back to Ecotect.

If these digital tools are not available a wind tunnel can be used. Simple tunnels have been built by my students in different courses from 2nd to 5th year.

This exercise introduces students to air flow analysis and introduces the student to the basic principles that will help him understand how the air moves inside the space.

Evaluation Process

CFD analysis in key sections should indicate adequate air movement through the spaces when the windows are open.

Evaluative Criteria

If air movement is required this analysis permits to determine if the air is moving as expected.

Cautions- Possible Confusions.

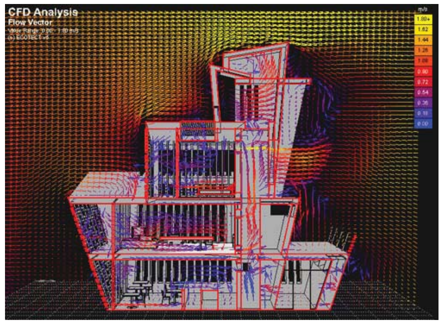
Students should understand that they are analyzing one direction and air velocity at a time.

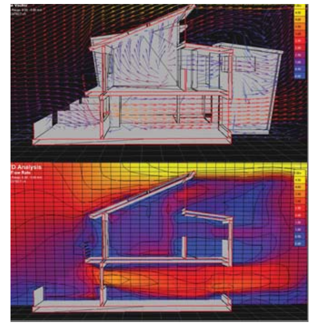
Duration of Exercise

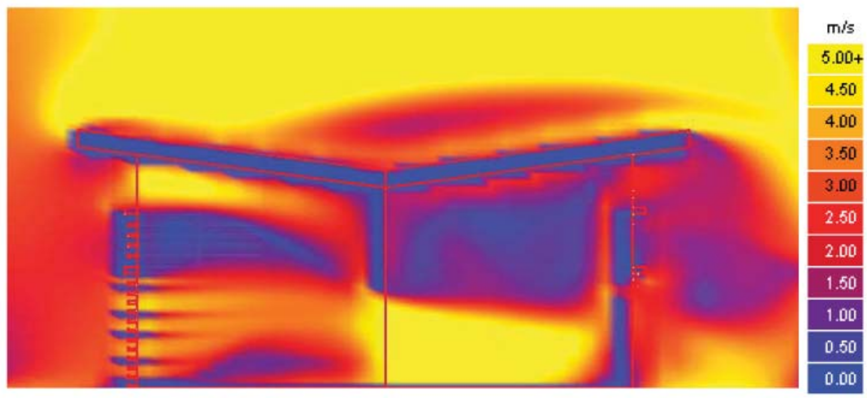
Two classes

Degree of Difficulty

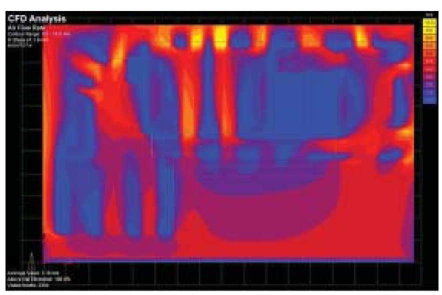
Medium

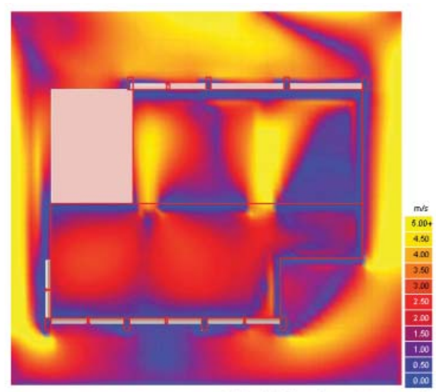






CFD Air Flow Rate: 0.0-5.0 m/s





CFD Air Flow Rate: 0.0-5.0 m/s

References

www.ecotect.com
http://www.cardiff.ac.uk/archi/asg_about%20us.php

Air Flow Analysis with winair and Ecotect
Greg Ladjimi, Don Bui and Megan Gorman, Sarah Buck and Kim Black, Marcos Garcia