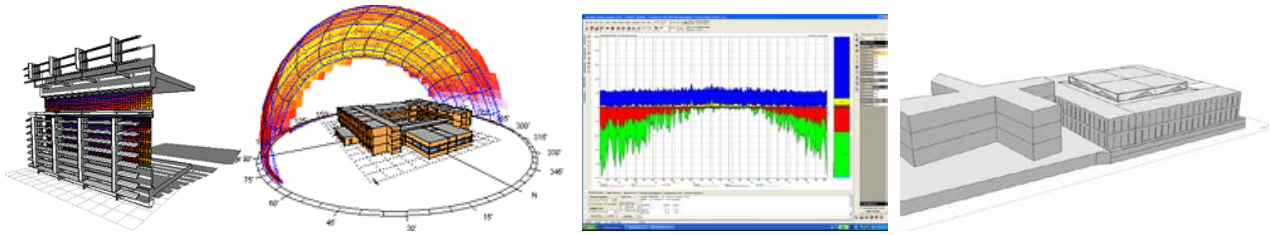
ARCH 5516•LUMINOUS AND THERMAL DESIGN
ECOLOGICAL DESIGN FOR THE 21ST CENTURY



"Thermal analysis basically means using a manual calculation or computer program to mathematically model the interplay of thermal processes within a building. There are a wide range of mathematical models used for this purpose, all of which vary significantly in both in ease of implementation and comprehensive.
_Source: Ecotect website

The useful practice of the 'ancients' should be employed on the site so that loggias should be filled with winter sun, but shaded in the summer. -Leone Battista Alberti, De Re Aedificatoria, 1452

PROJECT TWO: THERMAL DESIGN

Phase 1.0: Precedent Study, Passive Design and Baseline Thermal Analysis of thermal performance

Due Dates

Step A: Preliminary Thermal Design and Precedent Study, and Ecotect Analysis
Due Friday Feb. 4, 10:00AM in-process desk critique

Step B: Initial Baseline Thermal Analysis – Due 10:00AM Wednesday Feb. 9: in-process pin-up; mezzanine

Step C: Project Two Phases 1-2 - Due 10:00AM, Wednesday Feb. 16: formal presentation; courtyard

Phase Grade weighting: 10% total grade (100 points); team grade

READING ASSIGNMENTS

- Lechner, Norbert; Heating, Cooling, Lighting. New York: John Wiley & Sons (2nd or 3rd ed.)
  Please Read: Chapter 3: Thermal Principals; and Chapter 7: Passive Solar

OBJECTIVES

- To study the relationships between solar exposure, envelope design and thermal loads.
- To develop the knowledge and skills needed to conduct thermal design assessments and to evaluate thermal envelope and passive solar design strategies.
- To better understand heat flow in buildings, thermal comfort, and the effects of thermal mass.
- To be able to calculate passive gains, temperatures, heating and cooling loads and to interpret the results.
- To understand and compare the metrics of thermal design performance and the related impact on lighting quality and energy use in buildings.

Introduction

Buildings are complex in that they respond to both internal and external fluctuations in heat gains and losses. In the recent past, buildings have tended to ignore solar radiation both when desirable and sometimes when undesirable. Architectural form dictates to a large extent a building's ability to benefit from solar flux. Proper orientation of glazed openings, adequate thermal mass and summer shading are the primary factors determining the efficacy of a "passive" building design, however, placement of operating windows and wind shaping through intelligent roof and building form also play a significant role. In Project Two you will explore critical questions concerning thermal comfort and building loads in your designs for a mnZED Lab addition to Rapson Hall.

In this phase of Project Two, teams will complete a precedent study and assess the thermal performance analysis of their initial design scheme using the ECOTECT thermal simulation tool. The results of this analysis will become the "baseline case" and be used as a reference for comparison in all future incremental design improvements. Teams will determine appropriate envelope materials and insulation values as well as select appropriate glazing systems. The results of this analysis will become your "Baseline Case" energy consumption for comparison with future design improvements and systems enhancements.

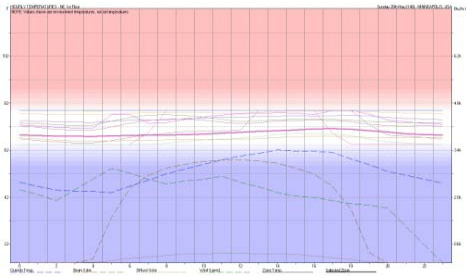
STEP A: DEVELOP A PRELIMINARY THERMAL DESIGN CONCEPT

1. **Evaluate the design concepts presented for Project One:** As a team, take time to discuss the results of Project One. Evaluate your 2 design concepts and evaluate how well each responds to the programmatic, bio-climatic, and other aspects of the project. Consider how you might improve the passive design strategies to capture and store thermal energy in winter and to reject unwanted thermal gains in the summer. Discuss the pros and cons of each design and decide what aspects of your designs you wish to retain in your initial thermal design concept for further analysis. You might consider:
   - *Climate*
   - *Massing and orientation strategies*
   - *Building program and relative need for thermal comfort*
   - *Surrounding buildings that block sun and wind*
   - *Daylighting and thermal design integration*
   - *Existing building systems integration*
   - *Circulation vs. continually occupied spaces*
   - *Building envelope materials and R-values*

2. **Thermal Strategies Precedent study:** Assign at least 1 precedent research task to each individual in your team pertaining to the various strategies included in your Project One design proposal and as modified by Step 1 (above.) The research assignments should include all critical strategies which will impact the thermal performance of your building. You might consider:
   - *Solar control strategies active and passive*
   - *Glazing materials, technologies and systems*
   - *Thermal envelope materials and insulating methods*
   - *Living Walls, arbors and trellises*
   - *Intelligent Skin concepts*
   - *Phase change thermal storage systems*
   - *Superinsulated Envelope*
   - *Thermal mass materials and configuration*
   - *Natural ventilation strategy*
   - *Cool roof and Green roof strategies*
   - *Passive solar heating strategy*
   - *Passive and Active Solar integration*
   - *Double Envelope Concepts*
   - *Other innovative Thermal Approaches*

3. **Thermal Computer Model Preparation**
   Construct a thermal model of your proposed design using ECOTECT. This model will be used to study the various performance aspects of your thermal design. At this stage it is advisable to simplify the model in order to get quicker results. Follow the *Thermal Analysis* tutorials provided (see Course Website) to ensure that you have constructed the model correctly in order to do the prescribed thermal analysis.

4. **ECOTECT Thermal Analysis:** As a group, you will investigate the climate responsiveness and overall thermal performance for your building. ECOTECT will calculate internal temperatures, spatial comfort and heating and cooling loads for models with any number of zones or type of geometry. You will need to assign material choices to all objects. You will also need to assign HVAC mode and operational schedules for occupancy. For this portion of the analysis you will select "full air conditioning" for your HVAC type. Perform the following studies to verify that your model is correctly constructed and to evaluate your initial thermal design concept:
   a. Temperature Profile Study: Calculate the hourly temperatures for all thermal zones for the hottest and coldest days of the year. Check the Average Hottest and Coldest Days Are they the same? You may highlight a particular zone to see whether the calculated temperature falls within the comfort range.



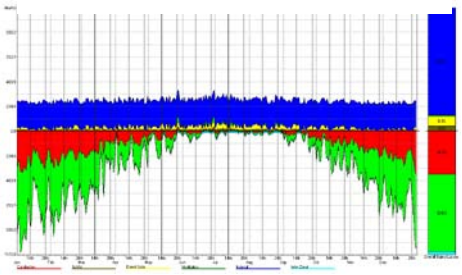
Hourly Temperatures by zone for Peak Heating day

b. Heating and Cooling Loads Studies: Calculate the average monthly heating and cooling loads for your project and create a graph showing the monthly heating and cooling loads for your building for a typical year. Export (or copy) the data table showing the monthly heating and cooling loads values and the peak loads conditions to a table in Word or Excel or another suitable application.

Monthly Heating and Cooling Loads

c. Passive Gains Analysis: Create a diagram showing the passive gains breakdown of your design. Use the Thermal Analysis Wizard if you prefer. Does your design take advantage of solar radiation at the appropriate times? How much of your total passive gains come from solar

d. Passive South Window Study: Vary the size or shading of some south facing window(s) of your model or the overhang depth and evaluate the impact on thermal loads and your passive gains breakdown.



Passive Gains Analysis

STEP B: INITIAL BASELINE THERMAL ANALYSIS

1. **ECOTECT Thermal Model Refinement:** In Step 1 you began construction of a thermal model of your proposed design using ECOTECT. Remember to simplify your model in order to get quicker results. Follow the *Thermal Analysis* tutorials provided (see Course Website) to ensure that you have constructed the model correctly in order to do the prescribed thermal analysis.

   a. Evaluate the results from the simulations you ran in Step? Do they look reasonable? Why or Why not?
   b. Investigate any problems and troubleshoot simulation errors and model construction problems. E.g., see "Error Messages" topic in the ECOTECT HELP!
   c. Make corrections and/or simplify your ECOTECT Model for better or quicker thermal simulation results.
   d. Set appropriate values for object materials, HVAC system mode (Full Air Conditioning), occupancy load and schedules, internal loads for lighting and equipment and establish the appropriate operating schedules.

2. **Whole Building Analysis – Establish a Baseline**

As a group, you will investigate the climate responsiveness and overall thermal performance for your initial thermal design and use the results as your performance *Baseline Case* for comparison as you proceed to improve your design and work toward achieving a Net-zero energy, carbon neutral *Final Design Case*. Use ECOTECT to establish performance characteristics which will become the minimum standard against which your proposed improvements can be compared. If you have not already done so, assign material choices to all surfaces and objects. Verify that your HVAC mode is set to or "full air conditioning" and that occupancy loads and schedules for operation are correctly set.

a. Perform a Thermal Comfort Study: Calculate the hourly the average hours when temperatures are not within established comfort ranges for all thermal zones.

b. Heating and Cooling Loads Studies: Calculate the average monthly heating and cooling loads for your baseline case and create a table showing the monthly heating and cooling loads for your building for a typical year. Export (or copy) the data table showing the monthly heating and cooling loads values and the peak loads conditions to a table in Word or Excel or another suitable application.

MONTHLY HEATING/COOLING LOADS

All Visible Thermal Zones
Comfort: Zonal Bands

Max Heating: 39224.4 Btu/hr at 05:00 on 31st December
Max Cooling: 10706.2 Btu/hr at 14:00 on 28th May

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
Jan	17911208	0	17911208
Feb	13847516	0	13847516
Mar	9948593	0	9948593
Apr	4544896	0	4544896
May	1370772	236687	1607459
Jun	74218	612719	686937
Jul	0	663750	663750
Aug	0	474338	474338
Sep	702927	1628	704554
Oct	4613660	0	4613660
Nov	9527052	0	9527052
Dec	15650158	0	15650158
TOTAL	78191000	1989122	80180120
PER M²	1404797	35737	1440534
Floor Area:	599.12 ft2		

c. Passive Gains Analysis: Create a diagram showing the passive gains breakdown of your design. Use the Thermal Analysis Wizard if you prefer.

d. Compare your final "baseline case" thermal performance results to the Phase one results. Discuss these results as a team. Consider the following questions:
- Do these results look credible?
- Do you believe that you have corrected any problems with your thermal model detected in Step 1?
- Is this the result you expected?

3. Graphical studies and a brief written narrative highlighting the key concepts and describing the thermal design intent and Passive Solar Integration:
- Annotated building wall sections at an appropriate scale (e.g. ¼" – ½"=1'0") explaining your passive design integration strategies.
- Or include other diagrams to explain your passive integration, e.g., exploded view diagrams, cutaway perspective or axonometric studies. Include sufficient annotation to convey design intentions clearly.
- Written narrative– 2-4 paragraphs with bullet points

PRESENTATION CHECKLIST: PROJECT TWO
Phase 1.0: Pinup Wednesday Feb. 9, 10:00am on the mezzanine

Work as a team to create an informal presentation.
Suggested format: informal collage in an area no more than 72" W x 36" H. *Label all charts, tables, graphs, sections and other diagrams. Include graphical scale where appropriate.*

1. Results of precedent Study - 1 building precedent with strategy and/or concept per team member.

2. ECOTECT Baseline Thermal Analysis:

a. Thermal Comfort Study:
- Thermal Comfort Chart from Ecotect with HVAC set at "None" – Degree Hours
- Thermal Comfort Chart from Ecotect with HVAC set at "Full Air Conditioning" - Degree Hours

b. Heating and Cooling Loads Studies:
- Average Monthly Heating and Cooling Loads Chart from Ecotect
- Monthly Heating and Cooling Loads Data Table showing Peak Heating and Cooling Loads and days - Exported from Ecotect in a table or spreadsheet format

c. Passive Gains Analysis *from Ecotect.*
- Passive Gains Breakdown chart from Ecotect for all zones – *for Jan 1-Dec 31*
- Passive Gains Breakdown chart from Ecotect for only South Facing Window zones – *for Sep 1- Mar 31*

3. Graphical studies and a brief written narrative highlighting the key concepts and describing the thermal design intent and Passive Solar Integration:
- Annotated building wall section at an appropriate scale (e.g. ¼" – ½"=1'0") explaining your passive design integration strategies.
- Or include other diagrams to explain your passive integration, e.g., exploded view diagrams, cutaway perspective or axonometric studies. Include sufficient annotation to convey design intentions clearly.

GRADING CRITERIA - Project Two – Phase 1: *10% total of ARCH 5516 grade (100 pts)*
• Depth of precedent research and appropriateness and relevance to project
• Clarity and accuracy of quantitative analysis charts, graphs and annotated drawings
• Demonstrated understanding of the thermal analysis process being used
• Clarity and accuracy of conclusions drawn