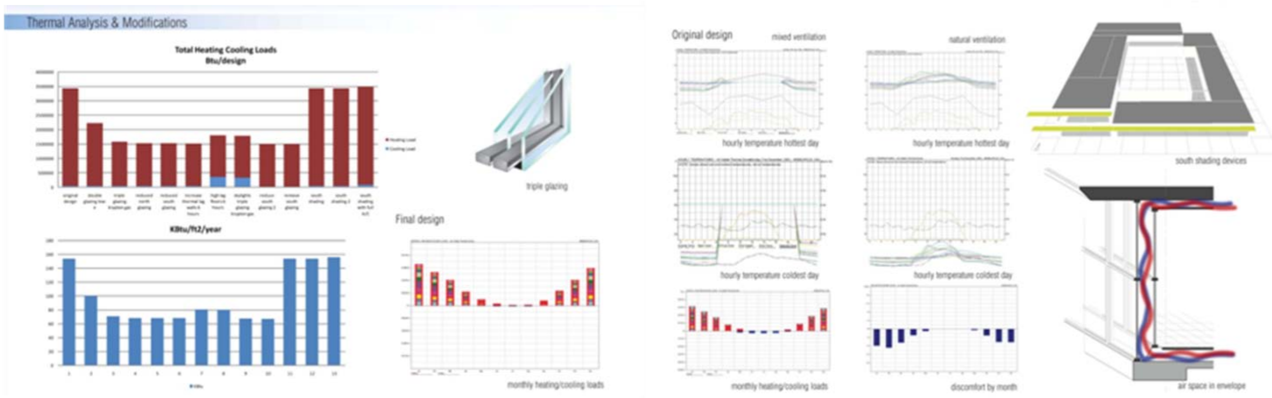
ARCH 5516 • LUMINOUS AND THERMAL DESIGN
ECOLOGICAL DESIGN FOR THE 21ST CENTURY



"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: Adrian Marsh

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 2.0 Optimizing the Envelope & Whole Building Thermal Analysis

Due Dates
Step A: Parametric Analysis Optimizing the Envelope – Due 10:00AM Friday Feb. 11*
Step B: Integrated Thermal Design and Analysis - Due 10:00AM Wednesday Feb. 14*
** in-process critique*
Step C: Final Thermal Design Presentation **-** Due 10:00AM Wednesday Feb. 16
Pin-up in Courtyard

Reading
Lechner, Norbert; Heating, Cooling, Lighting. New York: John Wiley & Sons (2nd or 3rd ed.)
Please Read: Chapter 4: Thermal Comfort; and Chapter 15: The Thermal Envelope

Objectives
- To demonstrate competence in thermal design refinement.
- To understand and compare the metrics of thermal design performance and the related impact on lighting quality and energy use in buildings.
- To develop the knowledge and skills needed to evaluate thermal envelope and passive solar design strategies and thereby *optimize* performance through an iterative or *parametric analysis* approach.
- To demonstrate the ability to make sound decisions about passive design strategies integration and about envelope material choices.
- To demonstrate the application of whole building analysis of the proposed addition to Rapson Hall as a design intervention and compare to the "baseline case."

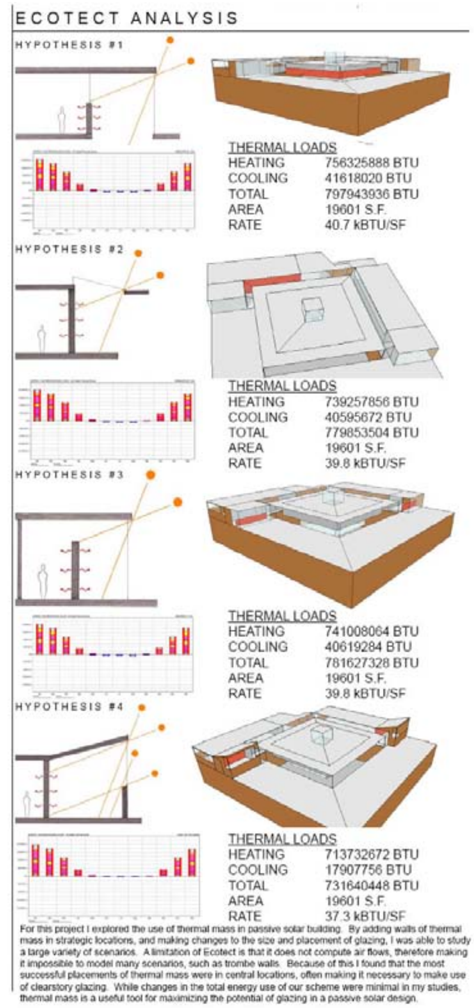
Overview
In the first step of phase 2.0, Step A, teams will explore the process of design evaluation and incremental improvement through hypothesis, and testing using the ECOTECT thermal and daylight simulation tools. Teams will begin optimizing thermal design parameters based on the findings of your Phase 2.0 analysis and methodical testing of strategies intended to improve thermal performance. In other words you will make modifications to your building model, using Ecotect, testing your hypotheses and examining the resulting impacts on building loads and other performance criteria.

In Step B, teams will establish the basic thermal design for their projects by bringing together the most effective thermal strategies explored in the previous phases. Teams will evaluate the results of their parametric analyses optimizing thermal design parameters and incorporate them into their final thermal design. In addition, they will perform any other trial and error testing of other thermal strategies intended to improve thermal performance to further get to their performance goals. In other words you will make modifications to your building model, using Ecotect, and compare to the "baseline case" established in Phase 1.0.

STEP A: PARAMETRIC ANALYSIS - OPTIMIZING THE ENVELOPE

1. SETTING GOALS AND DESIGN REFINEMENT
   a) If you did not set goals already, establish clear, measurable thermal design and energy goals for your project. Write them down and continue to revisit and expand them as you move forward. You might consider:
      - *Thermal Comfort (by zone)*
      - *Energy Use Intensity (KBtu/sf)*
      - *Passive Gains (% of total)*
      - *Ease of future RE Integration*
      - *Energy Use Reduction (% from Baseline)*
      - *Load Reduction (heating and cooling – by %)*
      - *Holistic Integration (of heating and cooling strategies)*
      - *Bio-climatic responsiveness*
   b) Review the design proposal which you analyzed as your Baseline for comparison. Continue to develop and refine your proposed design to better meet the program requirements, thermal and luminous design goals and – update building plans, sections, elevations and 3D models as necessary to document revisions and improvements.
   c) You will want to save your baseline model for future reference. Create a new thermal model in Ecotect by making the necessary revisions and corrections. If your ECOTECT model has too many zones, you may want to simplify it for better or quicker thermal simulation.
   d) Investigate problems and troubleshoot simulation errors and model construction problems. E.g., see "Error Messages" topic in the ECOTECT HELP!
   e) Verify that appropriate values for object materials, HVAC system mode, occupancy load and schedules, internal loads for lighting and equipment have been set.
2. HYPOTHESIS FORMULATION
   a) *As a group:* review your Phase 1.0 precedent research and thermal analysis results and formulate at least six (6) hypotheses that you suspect to be true about your building regarding its thermal performance. In other words, what changes in the design do you think would improve thermal performance? Select the 4 best hypotheses for testing – one tested by each team member.
   b) *As individuals (but coordinating with team):* begin to work with ECOTECT and your building model if you have not already done so. Become a "champion" for one of the hypotheses - preferably your favorite.
3. RESEARCH
   As a "Champion" for one hypothesis: each team member will investigate the data relating to that specific hypothesis in order to modify your model and test the hypothesis. *i.e., what are the appropriate materials choices and related properties: such as thermal insulation u-values, specific heat, solar absorptance, or glazing properties including visible light transmittance, u-value and solar heat gain coefficients, etc?*
4. TESTING AND EVALUATION
   a) As a "Champion" each team member will need to make the necessary modifications to the ECOTECT model that your hypothesis test involves.
      – Vary one parameter of your hypothesis (e.g., wall or roof insulation value or glazing type and u-value) from an excessively low value to an excessively high value.
      – Copy and paste the MONTHLY HEATING/COOLING LOADS data from the Analysis page of your ECOTECT model for each iteration into an Excel Workbook or *other data analysis tool* and analyze the data to determine the optimal design. An Excel Spreadsheet for that purpose has been provided (see file entitled *"2011_5516-P2Ph2-Data Manager for Parametric.xls"* on the Moodle website in Week Four.)
      – Determine the optimal value(s) based on the "law of diminishing returns."

b) As a team you should review the results of the various optimization exercises to determine:
   - Was your original hypothesis correct?
   - Which of your hypotheses had the greatest impact on building loads or performance?
   - For each hypothesis tested what do you feel is the optimal design condition or material property for your particular building and why?
   - What were the limitations of the ECOTECT software that hindered your analysis?
   - Based on your overall findings, what other design elements would you consider for further analysis?



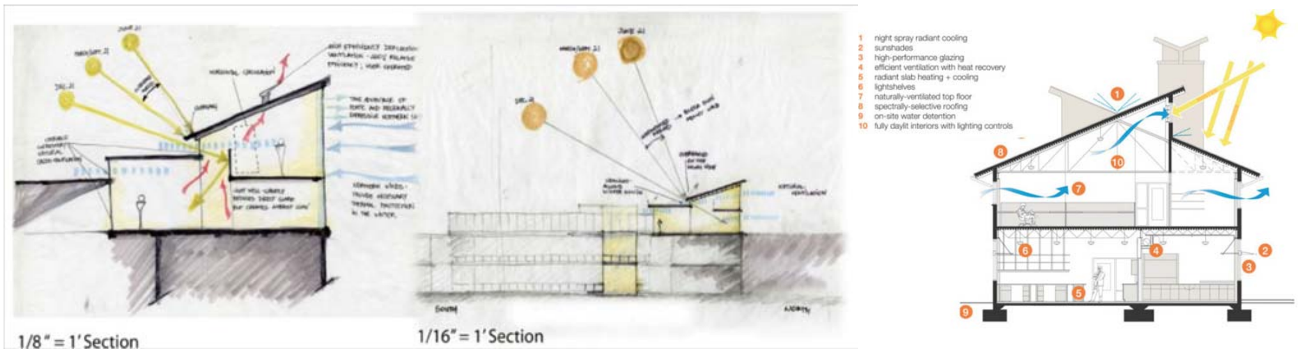
5. CONCLUSIONS
   Prepare an informal graphic presentation to present and discuss the findings of your analysis. Please include the following in your presentation:
   1) State clearly each hypothesis considered by your group and the primary reason(s) why it was chosen for testing.
   2) Review the test method for each hypothesis and the design conditions modeled in the analysis. Use diagrams where appropriate.
   3) Provide the appropriate graphs, charts or tables showing the results of your analysis including the range and types of data collected. Be clear about the scale of data and the units being presented.
   4) Conclusions – what conclusions can be drawn from the results of your analyses?

STEP B:

1. FINAL THERMAL MODEL REFINEMENT
   a) Continue to refine and develop your overall design based on your conclusions from Step A.
   b) Make changes to your ECOTECT Model based on the findings of your Parametric Analyses. Incorporate the optimal values of the design parameters you tested.
   c) Incorporate any other thermal design strategies from your Phase 1.0 precedent studies or other research that have proven to be beneficial through "trial and error analysis," (i.e., they improve the thermal performace relative to the "baseline case" established in Phase 1.0).
   d) Investigate any recurring problems and troubleshoot simulation errors and model construction problems. E.g., see "Error Messages" topic in the ECOTECT HELP!
   e) Create the necessary output charts and data tables that best communicate the thermal performance of your design.

2. COMPARISON TO "BASELINE CASE"
   a) Return to your previous *"baseline case"* model and make any necessary corrections. Run any necessary simulations and create the necessary output charts and data tables similar to Step 1.e.
   b) *Compare the results* of the final Phase 2.0 project design to the performance results for your "baseline case" from Phase 1.0.
   c) *Consider the following questions*:
   - Has the thermal performance improved compared to the *"baseline case?" If so, how much – in Kbtu/SF and by % change?*
   - What impact, if any, will the changes made have on the daylighting performance analyzed for Project One?

– What potential problems may need to be addressed in future design interventions? E.g., inadequate shading or excessive internal temperatures, excessive brightness or inadequate illumination, aesthetic integration of the new addition to the existing building, etc.



STEP 3: CONCLUSIONS AND FINAL PRESENTATION

Prepare a graphic presentation to present and discuss the findings of your analysis. Please include the following in your presentation:

a) Summarize the most relevant precedents reviewed from Phase 1.0.
b) Summarize the results of your Parametric Analysis from Phase 2.0. State the four hypotheses formulated and review the parametric analyses performed to test your hypotheses and the design parameters modeled in the analysis. What was the optimal condition? Use diagrams where appropriate.
c) Provide the appropriate graphs, charts or tables showing the results of your analysis including the range and types of data collected. Be clear about the scale of data and the units being presented.
d) Conclusions – what conclusions can be drawn from the results of your analyses? Briefly describe your basic design concept, key strategies and conclusions of your analyses: E.g., 1) What are the strengths and weaknesses of your thermal design? 2) how successful were you in achieving your thermal and energy goals? 3) What might you further develop in Project Three?

PRESENTATION CHECKLIST: PROJECT TWO – Final Presentation

PINUP WEDNESDAY, FEBRUARY 16, 10:00 AM IN THE COURTYARD

Required format: 4-6 (no more than six) 24"W x 36"H (vertical format.) *Label all charts, tables, graphs, sections and other diagrams. Include graphical scale where appropriate.* <u>Please also submit (2) 11"x17" color prints of your presentation and upload your Ecotect model and PDFs of your boardsto the course Moodle website. Carefully review the "submission checklist" below:</u>

1. <u>Phase 1.0: Precedent Study:</u> *(1 board suggested)*

- Minimum 1 precedent (e.g. a project, strategy or concept) per team member
- Precedent project name, location and architect; include all bibliographic citations
- Description of relevant strategies or design conditions being cited (this is important).

2. <u>Phase 2.0: Results of Parametric Analysis:</u> *(2 boards suggested)*

Provide the following information for each hypothesis tested (minimum 1 per team member):

<u>See WebVista for previous student graphic layouts</u>

- Statement of the hypothesis and description of isolated design parameter varied in the analysis.
- Charts comparing performance of each iteration in terms of annual heating and cooling loads.
- Annotated drawings and descriptions as needed to communicate the nature of the various design conditions studied and identifying the resulting optimal condition(s). Label all charts and provide diagrams or annotated sections to indicate the design condition being tested for each result.

3. ***Phases 1 and 2: Final Thermal Design & Whole Building Thermal Analysis*** *(1-2 boards suggested)*
Show the following information for both the "Baseline Case" from Phase 1 and "Final Design Case" from Phase 2:

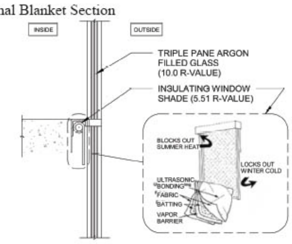
   a. ***Thermal Comfort Study:***
   - Thermal Comfort Chart from Ecotect with HVAC set at "None" – Degree Hours
   - Thermal Comfort Chart from Ecotect with HVAC set at "Full Air Conditioning" - Degree Hours (optional)

   b. ***Heating and Cooling Loads Studies for "baseline case" and final design case:***
   - Average Monthly Heating and Cooling Loads Charts from Ecotect
   - Monthly Heating and Cooling Loads Data Tables showing Peak Heating and Cooling Loads and days.
   - Passive Gains Breakdown Charts from Ecotect
   - Comparative Energy Use Index (EUI) in **KBtu/Ft^2**
   - Label all charts and provide diagrams or annotated sections to indicate the design condition being tested for each result.

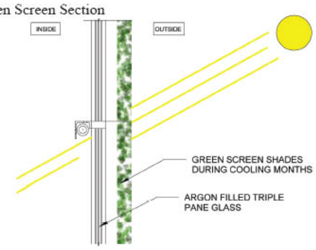
4. ***Graphical studies and a brief written narrative highlighting the key concepts and describing the thermal design intent and Passive Solar Integration:*** *(1 board suggested)*

- 1/16" annotated building plans, section(s), and elevations (whole building) for your "Final Thermal Design Case".
- Briefly describe your basic design concept, key strategies and conclusions of your analyses. Include any caveats or explain any strategies which could not be modeled in ECOTECT.
- Supporting Design Drawings:
  – Annotated building wall section(s) and/or details at an appropriate scale (e.g. 1/8" – 1/4"=1'0") explaining your passive design integration strategies.
  – 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.

Thermal Blanket Section



Green Screen Section



Tentative Project Two Grading Summary for Phases 1.0 and 2.0

GRADING CRITERIA - Project Two: *30% total of ARCH 5516 grade (300 pts)*

Teams will be asked to complete a confidential peer evaluation for all team members. This evaluation is advisory to the instructors and may impact the individual grades by +/- 10%.

1. Phase 1.0: Thermal Precedent Study and Creating an Initial Baseline Case (100 points)
- Clarity, craft, and execution of precedent study
- Depth of 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

2. Phase 2.0: Parametric Analysis, Refined Thermal Design & Whole Building Analysis (200 points)
<u>*Comparison to Phase 1.0 "Baseline Case"*</u>
- 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
- Clarity of design intentions demonstrated in the drawings and analysis
- Clarity, craft, and execution of design intentions demonstrated in the digital models, representations and drawings