Columbia GSAPP
Advanced Energy Performance (AEP)
ARCH A4682
Spring 2015

Instructor: Michael Marvin michael.marvin@burohappold.com

Class Hours: Wednesdays, 9:00 to 11:00 AM

Course Goals

- **This is not a course to learn software.**
- Using open source programs, this course will show how disparate concepts of sustainability, lighting, façade, and architectural design can be brought together to create architecture that is greater than the sum of its parts.
- The concepts of energy analysis will be used to teach the principals of integrated quantitative design.

Description

Contemporary architectural practice is broken.

As design professionals, we love to organize, categorize, assess, rate, compare. We break the design process apart into different silos. We have a structural engineer, a mechanical engineer, a lighting designer, a façade consultant, an interior designer, even a vertical transportation consultant. The architect oversees all of these team members. The division of work is a necessary requirement to get the project done by breaking it down into more manageable pieces, but all too often results not just the work being divided, but makes the work become disintegrated. The natural overlaps between structure and architectural form become lost. The impact of a building's form on façade design and daylighting can be ignored. The very details that define architectural richness disappear from a design entirely because the integration of design aspects are lost.

The problem becomes further exacerbated when one considers the challenges that we face as designers in a world of increasing scarcity and growing population. The reintegration of our design process becomes of critical importance when we are increasingly challenged to do more with our architecture while at the same time using less; less material, less energy, less water, less time for design.

Achieving higher performance architecture involves the integration of the qualitative skills that we have learned as students of space and experience with the quantitative knowledge that our engineering colleagues have become expert in. We are living in an exciting era where the digital realm gives us the ability to reintegrate the architectural disciplines to maximize our design potential. The architect must again become the master builder, knowing a little about a lot. That is what this course is about.

Course Structure

The class will be organized into weekly discussions surrounding the application of different concepts that students learn in the class and will draw heavily from their prior knowledge in architectural design and construction detailing. In the early parts of the semester the class will focus on giving students the skills they need to gain a reasonable proficiency in the use of energy analysis software and accompanying tools for high performance building design. Each week a new concept will be introduced that will inform a series of studies to be undertaken over the following week and to be uploaded to the class Dropbox drive for instructor review. These assignments will be part of a semester long design project that will have new layers of detail overlaid each week to build a detailed and integrated advanced energy design to be presented in a final review.

Software Tools

Energy Analysis: Energy Plus v. 7.0
Geometry Modelling: Sketchup 2014 / NREL Open Studio (Energy Plus Plugin)
Heat Transfer Simulation: LBNL Therm 7.3 / LBNL Window 7.3
Lighting Analysis: Autodesk Vasari
PV Watts: Online photovoltaic calculator

All analysis tools are distributed free of charge online at the links indicated above. Additional software tools will be used for presentation purposes and students should already have familiarity with these software packages from courses already completed at the GSAPP.

Presentation Tools: Adobe Creative Suite, Autodesk AutoCAD / Revit, Microsoft Office

Students are expected to have all software downloaded and installed prior to the first class meeting.

Semester Project

In 2010 the US accounted for 19% of global energy consumption, second only to China's 20.0%. Buildings accounted for 41% of total US energy consumption, more than both the industrial and transportation industries.[1] Residential buildings accounted for more than half of that energy consumption (54.8% of building sector energy consumption, or 22.5% of total US consumption).

Within residential buildings, 68% of building annual energy is consumed by space heating, cooling, lighting and water heating. As architects, our design decisions have the direct ability to influence the energy consumed by these end uses. Through a deeper, integrated understanding of the behavior of our buildings we can provide richer designs that are not only aesthetically beautiful, but are thermally comfortable, while still being highly energy efficient.

Our focus this semester will be on the design and construction of a simple single family residence, which we will craft into a high performance building. This building typology has been chosen as it is likely to be a project type that you will doubtless encounter in your career. The small size of this project will also allow for architectural design intent be established and for performative information to quickly be layered into the project, adding an additional layer of richness that would not be possible with larger project types within one semester.

Your client, a married couple with two children, has approached you to design a vacation home for them. For the purposes of the class, each student will be assigned a unique location for the home to be constructed. These locations will be randomly assigned at the first class meeting. The locations are:

- Lancaster, CA
- Binghamton, NY
- Boring, OR
- Weaton, MN
- Apalachicola, FL

The project will be a high performance building and must be a net-zero energy building as there are no utilities present on the site. Electricity will be provided by a photovoltaic array located on site.

The site is adjacent to a small brook, which is known to flood in the spring during the melting of the mountain snow. The project will not have a basement because of this, and the underside of the home will need to be elevated 18" above grade to allow water to pass beneath it.

The spaces required in the home are listed below. These are intended to be maximum floor areas due to project cost, and designers are encouraged to reduce the floor area of the home without compromising it's architectural quality.

- Living Room 180 SF
- Kitchen 150 SF
- Bathroom 50 SF
- (2) Bedrooms 120 SF
- Master Bedroom 240 SF
- Home Office for 2 People 150 SF
- Mechanical Room 50 SF
- Circulation Allowance 300 SF
- **TOTAL** **1240 SF**

Site plans are provided on the class Dropbox account in CAD format.

[1] Data given taken from 2010 US Department of Energy Buildings Energy Data Book.

Lessons (Overview)

1. **1/21 - Integrated Design / Data Gathering:** Defining the parts that go into integrated analytical models. Sources for data. Understand what really needs to go into a model and why.
2. **1/28 - Envelopes 1**: Therm and Window, why / when to use them, and how to use them quickly for design rather than just verification.
3. **2/4 - Energy Analysis 1**: Building a baseline energy model using data from the ASHRAE standards.
4. **2/11 - Energy Analysis 2 – Interpretation**: You've generated a ton of data. Now you need to know how to interpret it and express it to others.
5. **2/18 - Envelopes 2**: Inputting Therm data into an energy model. Understand condensation and curtain walls.
6. **2/25 - Solar Modelling**: Performing daylight and glare calculations
7. **3/4 - Artificial Lighting**: Overview of artificial lighting and how to properly analyze a lighting design and take energy credit for lighting reduction in your model.
8. **3/11 - Desk Crits**
9. **3/18 - SPRING BREAK - NO CLASS**
10. **3/25 - Midterm Review**
11. **4/1 - Energy Analysis 3 – Optimization**: How to structure a quantitative design study to help inform design decisions.
12. **4/8 - Renewable Energy**: Learn how to size renewable energy systems and what systems are appropriate where.
13. **4/15 - Desk Crits**
14. **4/22 - Desk Crits**
15. **4/29 - Final Review**

Lessons (Detailed)

1. **1/21 - Defining Integrated Design / Data Gathering**: A discussion on the role of the architect in the traditional sense versus architecture in contemporary times and what the architect's role will be in the future. This discussion will be framed into understanding the digital tools that exist that allow the architect to conduct detailed quantifiable design studies. The semester project will be presented in this class.

   The presentation will also discuss the various approaches, codes, and standards that exist today pertaining to energy conservation, façade design, and mechanical design and how those codes shape architectural design. Students will understand the difference between prescriptive and performance-based code compliance. Inputs required for understanding building energy consumption in detail will be reviewed. Students will understand what energy models are and how they can be used as powerful design tools.

   Assignment: Using the knowledge you've acquired in prerequisite courses, prepare a parti for the home described in the semester assignment. Your parti should consider the following sustainable design features:

   a. Orientation / Solar considerations
   b. Window-to-Wall Ratio
   c. Exterior shading
   d. Opportunities for daylighting

   Prepare a PDF package that shows the basic parti diagrams of all plans, (2) simple building sections (include scale figures), and a simple axonometric drawing or rendering. All diagrams shall be drawn to scale. The rendering or axon must be illustrative of design concept and need not be photo realistic. All drawings should be prepared in AutoCAD or Revit formats for ease of interface with future software packages.

   At this stage, no design is expected to be final, and will be expected to change as future studies help inform the building concept.

2. **1/28 - Envelopes 1:** The basic concepts of boundary conditions and heat transfer will be quickly reviewed and students will be reintroduced into Therm and Window. Due to the perception that analysis in these tools is slow or cumbersome they are often overlooked in the design process. Particular attention will be paid to the proper way to model quickly in these tools to make them usable as design aids. Sources for reliable performance information will be reviewed.

   Assignment: Prepare line drawings in CAD, Revit, or Eq. of each of the following concept details in your building:

   a. Plan detail of a typical wall assembly
   b. Section detail of a typical floor assembly
   c. Section detail of a typical roof assembly
   d. Plan detail of a window jamb
   e. Section detail of a window head and sill

   Refer to the samples shown in the Dropbox folder for examples of the level of detail and quality required for these details. Each detail should then be imported into Therm for Analysis. Provide a PDF package showing the details and the results of the Therm analysis. Upload the Therm files themselves to your folder on Dropbox.

3. **2/4 - Energy Analysis 1**: Concepts involving energy analysis studies will be explained. Students will be instructed in the proper way to frame a comparative energy conservation measure study. Open Studio will be introduced as the energy analysis program of choice for the remainder of the semester. Students will also understand the proper way to input a code baseline design for comparative analysis.

   Assignment: Using your parti from the previous week, prepare a chart that compares the minimum performance levels that your project must achieve using ASHRAE 90.1-2007. The chart should include:

   - Minimum R-Values / Maximum U-Values for the building envelope based upon climate zone and construction from Chapter 5 of ASHRAE 90.1.
   - Lighting Power Allowances using the Space-by-Space method in ASHRAE 90.1.
   - Equipment Power Allowances calculated using the Building Energy Databook

   Then, using your evolving project design and referencing the NREL tutorials available online, build the baseline model of your project in Open Studio. Simulations should be run and results brought to class for discussion.

4. **2/11 - Energy Analysis 2 - Interpretation:** Iterative energy analysis yields a massive amount of data that needs to be interpreted by an analyst to inform the design process. Students will be introduced to concepts that will inform them of how to understand the results of their analyses, as well as methods to express those results to the layperson. This understanding will be used to build a plan for future energy conservation studies.

   Assignment: Develop a preliminary strategy for reducing annual energy consumption in your project and demonstrate that strategy in an energy conservation measure matrix.

5. **2/18 - Envelopes 2**: Concepts such as thermal mass and phase change materials will be discussed. A detailed discussion on curtain wall detailing will be conducted. Condensation and overheating challenges will be discussed.

   Assignment: Using the results of the Therm analyses conducted in Assignment 3, input the proposed construction information into the energy model you constructed the previous week. Run the simulation and upload the models, as well as graphs of the results, to the Dropbox folder.

6. **2/25 - Solar Modeling:** Understand the process associated with conducting solar insolation analyses. Understand daylight tools available and the proper way to conduct daylight studies. Review and understand the challenges posed by glare and how to mitigate it.

   Assignment: Using Radiance in Open Studio, test whether your initial sustainable design assumptions are performing as you expected them to. In particular, test the daylight levels that you are seeing in the spaces in the building and if possible focus on reducing the window area while still maintaining adequate daylight levels for the tasks associated with that zone. Test any exterior shading that you have included in the design to ensure that it is contributing to blocking solar heat gain during summer months. If any of your design assumptions are not correct, modify the design as required. The goal is to maximize the daylit area of your building without compromising envelope performance or solar gains.

7. **3/4 - Artificial Lighting:** Understand how to decorative and process lighting works in a building. Understand how circuiting of multi-scene lighting works. Understand how occupancy sensors and time clocks work and how to take credit for them. Understand how ballasts work in fixtures. Review light levels for tasks and how to place lights to achieve optimal effectiveness. Do artificial lighting level calculations to reduce the lighting power densities used in your model from last week below the baseline levels.

8. **3/11 - Pulling it all Together:** A full session devoted to desk crits and answering questions regarding all of the inputs and modelling done to date.

9. **3/18 - Spring Break – NO CLASS**

10. **3/25 - Midterm Review:** Midterm review of the baseline and proposed house designs at BuroHappold's offices featuring invited guests from BH's analytics, façade, and lighting team, as well as invited professionals from outside the office.

    Deliverables: Projects will be presented in Powerpoint format. Presentations shall be uploaded to the Dropbox account prior to arrival at the office. The following items will be required:

    - Floor Plans (1 per level as required)
    - Exterior Elevations. Identify window-to-wall ratios
    - (1) Longitudinal Building Section
    - (1) Wall Section, showing the exterior envelope. Identify:
        - Structural system selected and, if using a stud system, spacing on center
        - Insulation thickness and R-Values
        - Location of vapor barriers and waterproofing membranes
    - Results of Therm Analysis on the proposed envelope details
    - Calculated Lighting Power Allowances
    - Diagrams supporting the solar design approach
    - Illuminance maps illustrating the amount of daylight present in the building.
    - Results of the Proposed and Baseline energy analysis. Demonstrate:
        - Annual Energy Consumption (in MMBtu)
        - Annual Equivalent Energy Cost (in US$, based upon EIA Utility Rates)
        - Annual Equivalent Carbon Emissions (in tons CO_2e, based upon eGrid State Rates)

11. **4/1 - Energy Analysis 3 – Interpretation:** After conducting a series of optimization studies, a discussion on how to interpret the results of the energy analyses. Interpretating data accurately is sometimes more important than producing the models.

12. **4/8 - Renewable Energy:** Students will learn how to size a photovoltaic array, wind arrays, and solar thermal arrays. Thermal storage and cogeneration / trigeneration will be discussed. Discussion will focus on the appropriateness of various types of renewables on a project site. The difference between energy conservation and energy cost conservation measures will be discussed.

13. **4/15 - Desk Crits:** In preparation for the Final.

14. **4/22 – Desk Crits:** In preparation for the Final.

15. **Final Review:** At BuroHappold.

Grading

Attendance / Participation	20%
Assignments	40%
Final Project	40%

High Pass	>90%
Pass	75-90%
Low Pass	60-75%
Fail	<60%

Resources

ASHRAE 90.1-2007: Energy Standard for Buildings Except Low-Rise Residential Buildings
https://law.resource.org/pub/us/code/ibr/ashrae.90.1.2007.pdf

ASHRAE 62.1-2007: Ventilation for Acceptable Indoor Air Quality
http://www.mintie.com/assets/pdf/education/ASHRAE%2062.1-2007.pdf

ASHRAE 55-2004: Thermal Environmental Conditions for Human Occupancy
http://www.almasesepahan.com/fh/download/ASHRAE_Thermal_Comfort_Standard.pdf

Buildings Energy Data Book
http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.1.16

NREL Open Studio Training Videos
https://www.youtube.com/user/NRELOpenStudio

LBNL Therm / Window Users Manual
http://windows.lbl.gov/software/therm/6/THERM63_docs.htm