Low-carbon Housing Project

Fall 2021
ENGR333ab
Calvin University
Prof. Heun

In 2020, residences used 16.5% of all final energy in the United States, and residences were responsible for 19.3% of all U.S. CO_2 emissions. Although residential is not the largest energy consuming sector or the largest CO_2 emitting sector (the transportation sector wins that race), residences are the location of energy consumption and carbon emissions in which many people have the freedom to make decisions that determine their energy use and carbon emissions.

That said, when any home is constructed, its design suggests patterns of use that last for decades or even generations. Indeed, a home's design locks in energy consumption rates (in MJ/year), energy expenditure rates (in $/year), and carbon emissions rates (in tonnes CO_2/year) for decades to come, because it is both expensive and difficult to change a furnace, add insulation, or change major appliances in a home. For example, a house's installed furnace determines the heating *fuel*, and its size and wall construction determine the required heating *rate* in winter. If a homeowner desires to reduce energy expenses or carbon emissions, it is best to make energy efficiency choices before a house is constructed rather than after a home is occupied.

Note that homes are thermal systems! They convert final energy carriers purchased by homeowners (natural gas and electricity) into forms of useful energy (heat, light, and mechanical drive) that combine with the infrastructure (walls, lights, and appliances) to produce energy services (thermal comfort, illumination, and hygiene). Because homes are thermal systems, they provide opportunities to reduce energy consumption and carbon emissions while providing the same energy services. I.e., homes provide good opportunities for energy efficiency interventions.

As it happens, Habitat for Humanity for Kent County is endeavoring to design homes that reduce energy consumption, energy expenditures, and carbon emissions. (Habitat for Humanity is a global nonprofit housing organization working in local communities across all 50 states in the U.S. and in approximately 70 countries around the world. Habitat's vision is for a world where everyone has a decent place to live.) Habitat for Humanity (Kent County) is embarking upon a "carbon footprint build" this autumn, located at **726 London St SW**. The goal of the carbon footprint build is to fabricate a home that minimizes energy consumption and carbon emissions, both during construction and across the lifetime of the house. (Carbon emitted during manufacturing of building materials in the supply chain and construction of the house onsite are said to be "embodied" in the structure of the house.)

Connecting the dots among house construction, home use, thermal systems, and ENGR333, we find that homes provide excellent opportunities to develop thermal systems analysis and design skills around energy and carbon emissions. This semester, we will explore energy consumption and carbon emissions of homes, using Habitat's carbon footprint build house as our example thermal system. The first question to guide our work this semester is:

What is the expected carbon emissions savings of the carbon footprint build house?

If the carbon footprint build house is not carbon-neutral, you must answer a second question: *How can carbon emissions be reduced by a further 20%*?

The baseline against which carbon emissions will be compared is another Habitat home in the same neighborhood. For ENGR333A, the baseline home is located at **536 Stolpe Ave SW**. For ENGR333B, the baseline home is located at **930 Woolsey SW**. Habitat for Humanity Kent County is very interested in the answer to this question, because the carbon footprint build is the first Habitat home in Kent County to be designed with carbon emissions in mind. Our answer to the question above will guide future house designs and affect the carbon emissions of Habitat homes far into the future.

You (ENGR333 students) will pursue an answer to this question in groups of 4–5, with each section developing an independent (and possibly different) answer. Your response to the questions ("*What is …*" and "*How can …*") should take the form of two reports (one from each section, both questions must be answered in each section's report) containing your section's answer to the question and comprehensive and accurate information on your analyses. A suggested outline for each section's report is a main technical memo followed by one appendix from each group in the section. Each appendix should be its own technical memo. Each appendix must be thorough and provide your customer (see below) and others with enough information to evaluate your answer and, ultimately, to make wise decisions about the design of future energy- and carbon-efficient homes.

The customer for your work is Mark Ogland-Hand, faith relations director at Habitat for Humanity of Kent County. Mark has extensive homebuilding experience and can provide access to the carbon footprint build site and baseline house plans.

Each group of 4–5 students must analyze a different aspect of the main question, such as:

- What is the expected (or actual) embodied carbon of the houses (materials)?
- What is the expected added embodied carbon of the houses due to onsite energy consumption during construction?
- What is the expected (or actual) natural gas consumption rate of the houses after occupation?
- What is the expected (or actual) electricity consumption rate of the houses after occupation?
- How can the design of the house be changed to reduce carbon emissions further?

Initially, groups in each section will be organized around the topics above.

The deliverables are:

(a) two written final reports (one per section) that provide detailed descriptions of your work during the semester,
(b) an Engineering department seminar on **Wednesday, 1 December 2021** at 3:30 PM in SB010 (both sections in one seminar).
(c) one poster per section to be presented at the Calvin Environmental Assessment Program (CEAP) conference at 3:30 PM on **Thursday, 2 December 2021** (date is approximate, venue TBD).

Each ENGR333 student must attend either (a) the Engineering department seminar or (b) the CEAP poster session.

Each final report will consist of:

(a) paper copies of your final technical memo with extensive appendices,

(b) an electronic copy of your final report (.pdf format, one file per section) to be posted at http://www.calvin.edu/~mkh2, and
(c) a flash drive containing electronic copies of all models, spreadsheets, posters, presentations, programs, and software analysis tools that you developed during the project.

You must distribute copies of your final report (all three elements) to Prof. Heun. Final reports are due at the end of the final exam time (**Noon, Thursday 16 December 2021**).

Each section must send notes of appreciation to each person who provided assistance during the semester.

Posters must be prepared from a template to be provided later. You may change colors and design as you see fit. You must include a photo of your class on the poster. Unless instructed otherwise, posters must be submitted to Vikipedia Designs via email (calvinposters@gmail.com). Attach both a .ppt and .pdf version of your poster. Include BOTH a student last name and the class (ENGR333) in the filenames of the posters. Indicate that printing costs should be charged to the following ENGR department expense category: "Supplies & Equipment." Use sub-category of "Course Supplies." List the course number in the memo field. Posters must be submitted **three weeks** prior to the CEAP poster session date (i.e., **Thursday, 11 November 2021**).

Prior to the first class meeting each week (typically Monday), each student must submit a weekly timecard that includes

- hours worked on the project
- brief (1 paragraph) description of work accomplished.

Groups and sections are encouraged to share relevant information obtained from external sources and from your own research throughout the semester. To facilitate information sharing, each section should consider forming an executive team to coordinate the work of groups in each section and, where applicable, across sections. Executive team members should mostly be relieved of their group's analysis responsibilities.

The professor will select students to form groups. To apply for one of the available groups, prepare a cover letter and resume and deliver a paper copy to your professor on **Wednesday, 1 September 2021** prior to lecture. Your cover letter should indicate which group piques your interest and why you believe you are qualified to study the topic of that group. Group assignments will be announced via Moodle in the evening of **Thursday, 2 September 2021**.

An initial task for each group is to develop a schedule of your activities for the semester that includes all important dates and coordination among groups. Schedules must be discussed during oral progress reports (see below).

There will be three short, in-class progress reports in the form of oral presentations. There will be a longer in-class final presentation that summarizes the results of the project. Each student must give either (a) a progress report presentation or (b) part of the final presentation. The customer will be present at all presentations. The presentations must be professional quality, must concisely report your progress, and must provide sufficient technical detail for customer, professor, and peer review of your progress. Only 1 student from each team may participate in each oral progress report and 2 students (at most) from each team may participate in the final in-class report.

The in-class progress reports must follow this outline:

- Status relative to your schedule (and any re-planning that has occurred since your last report)
- Work accomplished since your last report (including technical and cost savings details)
- Issues or concerns (and plan for addressing them)
- Work planned for upcoming reporting period

The final in-class oral report should *not* follow the outline above. Rather it should summarize the final technical details of your work, how your technical work was used to estimate energy and carbon savings, and the conclusions of your group's work.

You must bring printed copies (6-up, double sided to save paper) of all in-class presentations for customer and professor.

The professor, in conjunction with the customer, will select an exemplary student from each section for a teamwork award at the end of the semester.

Despite the presence of an external customer for your work, the professor will assign final grades (in consultation with the customer). Students will be assessed on (a) the quality of their team's report, (b) peer evaluation, and (c) hours worked.

Supporting Resources:

- The customer: Mark Ogland-Hand, mhand@habitatkent.org, 616-299-3135. Mark is not in the habit of answering unknown phone numbers, so a quick text before calling might get quicker response. Please coordinate and aggregate questions before calling Mark.
- Project information on Moodle, including energy consumption and plans for Habitat homes in this study.
- Previous ENGR333 design projects available at http://www.calvin.edu/~mkh2/thermal-fluid_systems_desig/. See, especially, the 2014 class project on net-zero housing.
- Classroom learning on energy, exergy, economics, and thermal analysis
- Prior laboratory and lecture classes and independent research

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Note: bold schedule items indicate customer participation.

Day	Date	Activity
Tue	**31 Aug**	**Project introduction, objectives, deliverables**
Wed	1 Sep	Resumes and cover letters due to Prof. Heun at class.
Fri	3 Sep	Groups assigned.
Tue	7 Sep	Site visit to carbon build home (726 London St SW) with John Marek.
Tue	**14 Sep**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	21 Sep	Project work day (Meet in the classroom for group work)
Tue	**28 Sep**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	5 Oct	Project work day (Meet in the classroom)
Wed	13 Oct	Project work day (Meet in the classroom) **Weds**
Tue	**19 Oct**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	26 Oct	Project work day (Meet in the classroom for group work)
Tue	9 Nov	Project work day (Meet in the classroom for group work)
Mon	15 Nov	Project work day (Meet in the classroom for group work)
Tue	16 Nov	Project work day (Meet in the classroom for group work)
Wed	17 Nov	Project work day (Meet in the classroom for group work)
Fri	19 Nov	Project work day (Meet in the classroom for group work)
Mon	**22 Nov**	**Project final presentations (10 minutes + 4 for questions) Report on final results. Don't go home early for Thanksgiving break!**
Tue	**23 Nov**	**Project final presentations (10 minutes + 4 for questions) Report on final results. Don't go home early for Thanksgiving break!**
Mon	29 Nov	Peer and Project Assessment due (3:30 PM)
Wed	1 Dec	ENGR Department Seminar 3:30 PM (SB010)
Thur	2 Dec	CEAP Poster Session, 3:30 PM (Venue TBD)
Wed	8 Dec	Final report due

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Peer and Project Assessment

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Throughout this semester, you analyzed rebound and backfire for energy efficiency interventions. Now, your professor would like your feedback about the process in the form of a peer and project assessment. Part of your grade for the project will be determined by the quality of your peer and project assessment. Your response is and will remain confidential. Peer and project assessments are due at **3:30 PM** on **Monday 29 November 2021** in Prof. Heun's office.

1) Write one paragraph identifying one or two members of the class who performed exemplarily during this project. Provide examples of their supererogatory efforts.

2) Create a bullet-point list of 3 personal learnings (takeaways) from the project.

3) Create a bullet-point list of 3 suggestions for future low-carbon home designs. In other words, what suggestions do you have for future Habitat for Humanity home designs?

4) Write one paragraph answering these questions: If you put this project on a resume, would you list it as "community service?" Does engineering (as a discipline) value volunteer work and community service? Why or why not?

5) Write one paragraph describing if or how your participation in this project caused you to alter your behavior this semester. Did you see any connections between your own personal behavior and energy efficiency? If you didn't change your behavior at all, describe why not.

6) What nontechnical skills did you learn in the course of this project? Do you expect that these non-technical skills will be relevant to your future work as an engineer? If so, why? If not, why not?

7) Write three paragraphs addressing this question: what are the connections between (a) energy efficiency and (b) the twin challenges of (i) energy resource depletion and (ii) climate change caused by global warming?

8) Write one paragraph detailing your role and contributions to your small group team. Conclude the paragraph by assigning yourself a letter grade for your work on the project. Justify your grade.

9) Write one paragraph each detailing the roles and contributions of the three (or four) other team members. Conclude the paragraphs by assigning a letter grade for your teammates' work on the project. [Total of three (or four) paragraphs and three (or four) individual letter grades.]

10) Write one paragraph indicating any topics relevant to the content of ENGR333 that, in your opinion, would be interesting for future classes to study. Also provide any suggestions for improvements to the structure of this project in future years.

When writing paragraphs assessing yourself and your peers, you may wish to use the following rubric.

Did the individual:

- Research useful information for your group?
- Display punctuality in meeting deadlines?
- Thoroughly complete assigned duties?
- Share equally in work performed by the group?
- Perform work of high quality or did their work often require revision?
- Help direct the group in setting goals?
- Help direct the group in meeting goals?
- Encourage group members to share ideas?
- Display empathy during group discussions and work?
- Listen to ideas from other group members?
- Participate in helping the group work together better?