Calvin Solar Farm Project

Fall 2024
ENGR333AB
Calvin University
Prof. Heun

One of today's grand challenges is eliminating CO_2 emissions from energy generation and consumption. Individuals, households, universities, corporations, nations, and other entities tackle the challenge in different ways and for differing reasons, according to their spheres of influence. Universities reduce their carbon emissions to reduce costs, to do right by the environment, and, in Calvin's case, to demonstrate care for creation in accordance with item 4 of our Statement on Sustainability. (See https://calvin.edu/offices-services/provost/files/sustainability-statement.pdf.)

To demonstrate Calvin University's commitment to reducing carbon emissions, then-president Michael Le Roy signed the President's Climate Commitment on 6 December 2017. (See https://calvin.edu/dotAsset/f294c564-3660-47fc-aa72-0b5baeea94c2.pdf and https://calvinchimes.org/2017/12/08/calvin-commits-to-carbon-neutrality-by-2057/.) In doing so, President Le Roy committed Calvin to carbon neutrality. Progress on the climate commitment has been mixed (https://calvinchimes.org/2021/12/05/calvins-progress-on-carbon-neutrality-sustainability-murky-during-pandemic/), with CO_2 emissions reductions likely caused by both improved energy efficiency (especially in lighting) and lower enrollment.

Simultaneously, Calvin University is facing the need to upgrade its energy infrastructure, with many systems having several decades of service. The need to upgrade provides an unprecedented opportunity to replace CO_2-emitting technology with greener options. One greener option under consideration is electricity production from solar photovoltaic (PV) panels. The question for this semester is

What should be the design of a Calvin Solar Farm?

There are many considerations to answering this question, including, but not limited to:

- Where should PV panels be located?
- What manufacturer and model panels should be used in the solar farm?
- How much energy cost savings can be expected from the solar farm?
- How much will it cost to emplace the solar farm?
- Where can we raise money to purchase and install the solar farm?
- How will the solar farm integrate with the rest of Calvin's energy infrastructure?
- How will the solar farm integrate with the electric grid in West Michigan?
- Should Calvin take advantage of IRA incentives which require domestic sourcing vs. international sourcing?
- How does expected remaining roof life affect solar farm design and economics?
- What type of inverters should be used (micro vs. string)?
- Should Calvin explore energy storage (battery or other)?
- How does net metering affect the economics of the Calvin Solar Farm?

This project will be pursued by a consortium of three classes, ENGR333, PHYS131, and ENGR327. The responsibilities for each class are:

ENGR333	Overall system design and initial performance modeling
PHYS131	System performance details (starts 2nd half of semester)
ENGR327	Structural design

ENGR333 students can use Sunny Design (https://www.sma.de/en/products/apps-software/sunny-design) or other system modeling software to estimate system production. PHYS131 students will perform detailed analysis of system performance using own calculations. ENGR327 students will assess structural aspects of the Calvin Solar Farm using own calculations, too.

You (the ENGR333 students) will pursue an answer to this question in groups of 4–5 students each, with each section developing an independent (and possibly different) answer. Your response to the question ("*What should be the design …*") should take the form of two reports (one from each section) containing your section's answer to the question and comprehensive and accurate information from your analyses. A suggested outline for each section's report is a main technical memo followed by one appendix from each group. 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 carbon-efficient energy systems for Calvin.

The customer for your work is Dirk Pruis, CFO of Calvin University.

There are three typical mounting locations for solar panels in a solar farm: ground, rooftop, and carpark. Initially, the ENGR333 classes will be organized around these mounting options, with other groups focusing on infrastructure and performance modeling common to all options. Thus, the initial teams will be

- Ground mounting off campus (including partnerships with utilities or joint ventures with other schools),
- Ground mounting on campus,
- Carpark mounting on campus,
- Rooftop mounting on campus, and
- Campus infrastructure and performance modeling.

You may find it necessary to adjust the configuration of teams and the size of teams throughout the semester. You could even split teams across the two sections of ENGR333, if that will help your work. Please consult with the professor before changing teams.

Each group will select a delegate to join a management team to coordinate across groups, across sections of ENGR333, and across the PHYS131 and ENGR327 sections. This management function will be crucial to the project's success, as PHYS131 and ENGR327 will need initial designs for each mounting option by the midpoint of the semester (24 October 2024). Mid-semester deliverables

- an initial panel model selection,
- cost per panel for installation,

- area that can be covered in panels,
- relevant details about the installation area (orientation and slopes of roofs, geometry of obstructions by neighboring trees and buildings), and
- rough performance estimates

should be provided to the other classes by the third in-class project presentations on Thursday, 24 October 2024. These deliverables should be coordinated across sections of ENGR333 such that we provide a single initial design to the other classes.

The end-of-semester deliverables are:

(a) an Engineering department seminar on **Tuesday, 10 December 2024** at 4:00 PM in the **CFAC recital hall** (both sections in one seminar).
(b) one poster per section to be presented at the Calvin University Sustainability Showcase at 3:30 PM on **Thursday, 12 December 2024** (**** venue TBD ****).
(c) two written final reports (one per section) that provide detailed descriptions of your work during the semester, due on the final day of classes (**4 PM, Thursday, 12 December 2024**).

Each ENGR333 student must attend either (a) the Engineering department seminar or (b) the Sustainability Showcase 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 https://matthewheun.com, and
(c) a flash drive or other means of conveyance containing electronic copies of all models, spreadsheets, posters, presentations, programs, and software analysis tools that you developed during the project.

You must submit copies of your final report (all three elements) to Prof. Heun.

Posters must be prepared from a template provided on Moodle. Posters must be submitted via email to slc@calvin.edu **one week** prior to the Sustainability Showcase poster session date (i.e., **Thursday, 5 December 2024**).

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

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

- hours worked on the project and
- a 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 the 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 submit on Moodle by 8 PM on **Tuesday, 3 September 2024**. Your cover letter should indicate which group piques your interest and why you believe you are qualified

to be included in that group. (You may supply first and second choices.) Group assignments will be announced via Moodle by the evening of **Thursday, 5 September 2024**.

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. A longer, in-class final presentation will summarize 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, professor, and resources.

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: Dirk Pruis, dirk.pruis@calvin.edu. Be aware that email messages are screened by the CFO's assistant. Please coordinate and aggregate questions before reaching out to CFO Pruis.
- Calvin administrators:
  - Greg Elzinga, Acting President, greg.elzinga@calvin.edu, (616) 526-6389.
  - Jennifer Ambrose, Director of Physical Plant, jambrose@calvin.edu, (616) 526-6342.
  - Chuck Holwerda, Calvin University Electronics Shop, holwerda@calvin.edu (616) 802-4903.

- Previous ENGR333 design projects available at https://matthewheun.com.
- Classroom learning on energy, exergy, and economics
- Prior laboratory and lecture classes, especially business and electrical engineering courses
- Independent research

ENGR333
Calvin Solar Farm Project schedule
Fall 2024

Note: Bold schedule items involve customer and resource participation, 13:05–15:00 in NH050.

Day	Date	Activity
Tue	**3 Sep**	**Project introduction, objectives, deliverables**
Thur	5 Sep	Resumes and cover letters due to Prof. Heun
Thur	5 Sep	Groups assigned via Moodle
Tue	10 Sep	Project work day (Meet in the classroom for group work) (Section A during session b; Section B during session a)
Tue	**17 Sep**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	24 Sep	Project work day (Meet in the classroom for group work)
Tue	**1 Oct**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	8 Oct	Project work day (Meet in the classroom for group work)
Tue	15 Oct	Project work day (Meet in the classroom for group work)
Thur	**24 Oct**	**In-class group presentations (5 minutes + 2 for questions) Use required outline. **** Note: Thursday******
Tue	29 Oct	Debrief presentations
Tue	5 Nov	Project work day (Meet in the classroom for group work)
Tue	19 Nov	Project work day (Meet in the classroom for group work)
Tue	21 Nov	Project work day (Meet in the classroom for group work)
Tue	**26 Nov**	**Project final presentations (10 minutes + 4 for questions) Report on final results. Don't go home early for Thanksgiving break!**
Tue	**3 Dec**	**Project final presentations (10 minutes + 4 for questions) Report on final results.**
Thur	5 Dec	Peer and Project Assessment due
Tue	10 Dec	ENGR Department Seminar 4:00 PM (CFAC recital hall)
Thur	12 Dec	Sustainability Showcase poster session, 3:30 PM (Venue TBD)
Thur	12 Dec	Final report due

Calvin Solar Farm Project
Peer and Project Assessment

Fall 2024
ENGR333
Prof. Heun

Throughout this semester, you analyzed rebound and backfire for CO_2 emissions reductions. 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 **Thursday, 5 December 2024** 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 ways to reduce Calvin's CO_2 emissions. In other words, what are your personal suggestions for Calvin moving forward?

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 CO_2 emissions reduction? 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?