Energy Efficiency Projects

Fall 2019
ENGR333ab
Calvin University
Prof. Heun

Firms, universities, and consumers use energy efficiency as a way to reduce energy consumption and energy costs. But does improvement of device-level energy efficiency actually save energy at the economy-wide level? At the device level, behavioral changes can result in expected energy savings being "taken back" from an energy efficiency intervention. (Leaving an LED light switched on longer than the incandescent light it replaced will result in less energy and cost savings than expected.) At the economy-wide level, monetary savings from an energy efficiency intervention can be spent in the economy, with energy consequences.

Saving less energy than expected from an energy efficiency intervention is called energy *rebound*. Energy *backfire* occurs when *more* energy is consumed after an energy efficiency intervention than before. Rebound and backfire can be quantified at both the end-use device level and the economy-wide level.

In this semester, we will explore energy efficiency, rebound, and backfire through (a) a series of short lectures by Prof. Heun on the topic and (b) analyses conducted by ENGR333 class members. The question to guide our work this semester is

How much energy does energy efficiency save?

Students will pursue an answer to this question in groups of 4–5 students, with each section developing an independent (and possibly different) overall answer. Your response to the question ("*How much …*") should take the form of two reports (one from each section) 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 (a) future research into energy efficiency and (b) future energy efficiency projects on campus and elsewhere.

The customer for your work is Dr. Paul E. Brockway, University of Leeds, UK. Dr. Brockway was awarded a prestigious early-career fellowship from the UK's Engineering and Physical Sciences Research Council entitled "Applying thermodynamic laws to the energy-GDP decoupling problem." He applies exergy analysis to the energy-GDP decoupling problem in an international research network that includes Prof. Heun. Three key research questions form the basis of Prof. Brockway's fellowship:

Q1. What is the relationship between energy efficiency and energy rebound?
Q2. How much primary energy will we need in the future to meet our energy service demands?
Q3. To what extent can we decouple primary energy use from GDP?

While providing support to Dr. Brockway's fellowship, Prof. Heun developed a way to link device-level energy rebound to economy-wide energy rebound. (Theory to be discussed in short lectures.) As Prof. Heun's lectures will show, assessing the potential for rebound (or backfire) from any

energy efficiency intervention requires determining 8 economy-wide rebound parameters: $\dot{E}_{emb,EE}$, $\dot{E}_{emb,base}$, $\dot{E}_{dir,base}$, $\dot{E}_{dir,EE}$, $\dot{C}_{repl,EE}$, $\dot{C}_{repl,base}$ p_E, and Re_{dev}. $\dot{E}$ indicates an annual rate of final energy (usually electricity or refined petroleum products) in MJ/yr, $\dot{C}$ indicates an annual rate of cost in $/yr, Re indicates dimensionless energy rebound, and p indicates energy price in $/MJ. For subscripts, "E" indicates final energy consumed by the end-use device, "dir" indicates device-level direct energy consumption, "emb" indicates embodied energy (the sum of all energy consumed in the supply chain to produce the energy efficiency device), "repl" indicates replacement, "base" indicates the base configuration (before the energy efficiency intervention), and "EE" indicates the energy efficient configuration (after the energy efficiency intervention). See http://www.circularecology.com/embodied-energy-and-carbon-footprint-database.html for embodied energy coefficients.

Each team must analyze two energy efficiency interventions. One must be "small" (less than, say, $500 initial cost), and one must be "large" (at least $1000 initial cost). At least one energy efficiency intervention must be related to life on Calvin's campus. The value of all 8 parameters must be determined by each group for their small energy efficiency intervention and for their large energy efficiency intervention for a total of 16 numbers. Results from each section's analyses will be used as test cases for Prof. Heun's new energy rebound theory. Exceptional student analyses may contribute to a paper to be submitted by Prof. Heun (with co-author Gregor Semieniuk) to the journal *Energy Economics*. Students whose work is used in the *Energy Economics* paper will receive named attribution in the acknowledgements of the article.

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, 4 December 2019** 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, 5 December 2019** (date is an estimate, 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, Tuesday 17 December 2019**). Each section must send notes of appreciation to each person who provided assistance during the semester.

Posters must be prepared with the CEAP template found at https://calvin.edu/dotAsset/3b6542cc-fe22-45df-9e07-e89fbc1fbbc4. You may change colors and design as you see fit. You must include a photo of your team 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 ENGR department AV account: 1-1-01110-50305. Posters must be submitted **three weeks** prior to the CEAP poster session date (i.e., **Thursday, 14 November 2019**).

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 research 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, 5 September 2018** prior to lecture. Your cover letter should indicate four energy efficiency interventions you are interested to study (two large, two small) and why you are qualified to study those energy efficiency interventions. Group assignments will be announced via Moodle in the evening of **Thursday, 6 September 2018**.

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 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 savings and rebound for your section, 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: Prof. Paul E. Brockway, Leeds University, UK
- Previous ENGR333 design projects available at
  http://www.calvin.edu/~mkh2/thermal-fluid_systems_desig/
- 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	**3 Sep**	**Project introduction, objectives, deliverables**
Wed	4 Sep	Resumes and cover letters due to Prof. Heun at class.
Tue	10 Sep	Rebound lecture and project work day (Meet in the classroom)
Tue	**17 Sep**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	24 Sep	Rebound lecture and project work day (Meet in the classroom)
Tue	**1 Oct**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	8 Oct	Rebound lecture and project work day (Meet in the classroom)
Tue	15 Oct	Rebound lecture and project work day (Meet in the classroom)
Mon	**21 Oct**	**In-class group presentations (5 minutes + 2 for questions) **Monday** Use required outline.**
Tue	29 Oct	Project work day (Meet in the classroom for group work)
Tue	5 Nov	Project work day (Meet in the classroom for group work)
Wed	13 Nov	Project work day (Meet in the classroom for group work)
Fri	15 Nov	Project work day (Meet in the classroom for group work)
Mon	18 Nov	Project work day (Meet in the classroom for group work)
Tue	19 Nov	Project work day (Meet in the classroom for group work)
Wed	**20 Nov**	**Project final presentations (10 minutes + 4 for questions) Report on final results.**
Fri	**22 Nov**	**Project final presentations (10 minutes + 4 for questions) Report on final results.**
Mon	2 Dec	Peer and Project Assessment due (3:30 PM)
Wed	4 Dec	ENGR Department Seminar 3:30 PM (SB010)
Thur	5 Dec	CEAP Poster Session, 3:30 PM (Venue TBD)
Tue	17 Dec	Final reports due at Noon

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Peer and Project Assessment

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**** Consider asking students for a bullet point list of key takeaways, policy actions, or personal actions as a result of the knowledge gained from the semester-long project. ****

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 Energy Efficiency Projects 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 2 December 2019** 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) 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?

3) 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.

4) 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?

5) 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?

6) 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.

7) 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.]

8) 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?