Bottom-up Electricity Demand Model Project

Spring 2017
ENGR333a
Calvin College
Prof. Heun

Last year, Calvin College spent $1,930,021.75 on electricity, and with today's financial challenges, Physical Plant is under pressure to reduce these costs. We are not alone. Businesses and educational institutions alike face reduced budgets, and stewardship of financial resources can be achieved by reducing utility expenses. As far back as 2003's *The Energy Smart Guide to Campus Cost Savings* (http://www.nrel.gov/docs/fy03osti/34291.pdf), the National Renewable Energy Lab was highlighting the importance of energy management to reduce expenses.

> Higher education executives today work in a climate as tough as that of any Fortune 500 company. The bear market took a heavy toll on many university portfolios. Budget shortfalls are a reality on many campuses. There continues to be a pressing need for new approaches to the oldest dilemma in education– how to do more with less, while not shortchanging students or demoralizing staff. In this high-stakes environment, business officers and facility managers play an increasingly important role, as they seek new technologies and methodologies for saving money. Energy management has emerged as a key area for these professionals.

Electricity costs can be reduced on the supply side or the demand side. Supply-side cost reductions can be achieved by negotiating better terms with the utility, but Calvin already purchases electricity at a favorable educational rate, so there is little room for improvement on the supply side. And utility rates are expected to go up through time.

Cost reductions on the demand side require reductions in electricity consumption. An intelligent approach to demand-side reduction involves assessing sources of demand and developing a demand-side management (DSM) strategy focusing on high-consumption activities with high potential savings. However, the sources of demand for Calvin's electricity are mostly unknown, except at a very aggregate level, specifically at the location of the main electricity meters on campus.

These meters indicate that a large proportion of Calvin's electricity consumption comes from the PE complex and the dormitories. Each of these areas has an electrical meter, and some sub-meters are also in place. But a bottom-up understanding of electricity demand is missing. Your question for this semester is:

> *Can you construct a fine-grained, bottom-up electricity demand model that predicts the annual electricity consumption for the dormitories (section A) and the PE complex (section B) for each year of the last decade with an accuracy of ±2%?*

A bottom-up model includes all possible sources of demand, an inventory of consumption rates (in units of watts), and estimates service duty of each demand item (in units of time/year). For example, section A might count light fixtures in the dorms and inventory the wattage for each fixture. A reasonable estimate or measurement of the number of hours of service for each fixture can then be used to calculate the total number of watt-hours/year of electricity consumed for lighting in the dormitories. Section B might count the number of air-handlers in the PE complex and inventory the wattage for each air handler. A reasonable estimate or measurement of the number of houses of service for each air handler can then be used to calculate the total number of watt-hours/year of electricity consumed for air handling in the PE complex. Such analyses need to be repeated for each source of demand and summed to predict the total electricity consumed in the two areas of campus (dormitories and PE complex).

The bottom-up analyses must be conducted independent of known electricity consumption at the main meters. Each section will need to compare their bottom-up model against metered energy consumption to assess whether they are within ±2% of the actual total. Frequent comparisons with meter totals are expected. After each comparison, iterations to and improvements upon the bottom-up demand models are expected.

There are many previous examples of developing energy demand models in this way. Vehicle Parc models estimate the number, type, efficiency, and average miles driven of vehicles in service. From that information, energy consumption is calculated and compared to national statistics on petrol and diesel purchases. Bottom-up models of residential energy demand have been made for countries for which there is little available data. See

- http://www.energy.gov.za/files/IEP/presentations/CurrentFutureTrends_SA_CarParc_30MArch2012.pdf) and
- http://www.sciencedirect.com/science/article/pii/S0360544211007110.

You will pursue this question in groups of 4–5 students. Your response to the main question ("*Can you construct* ...") should take the form of two reports (one from each section) containing comprehensive and accurate information on your approach to developing the demand models. A suggested outline is a main technical memo with one appendix from each group. Each appendix should be its own technical memo. Each appendix must be thorough and provide Physical Plant and the Calvin administration with enough information to understand your demand model and, ultimately, to make wise decisions about future electricity savings on campus.

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 at 3:30 PM on **Wednesday, 10 May 2017** (one seminar for both sections, venue TBD).
(c) one poster per section to be presented at the Calvin Environmental Assessment Program (CEAP) conference at 3:30 PM on **Thursday, 11 May 2017** (venue TBD).

Each ENGR333 student must attend either (a) the Engineering Seminar or (b) the CEAP Poster Session.

Each final report for the project 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 single file) 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 Physical Plant and your professor. Final reports are due at the end of the final exam time (**Noon, Thursday 18 May 2017**). 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://www.calvin.edu/admin/igs/research%20poster%20templates/.
Posters must be submitted to Instructional Graphics via email to posters@calvin.edu. Attach both a .ppt and .pdf version of your poster. Include BOTH your last name and the class (ENGR333) in the filenames. Indicate that printing costs should be charged to the ENGR department AV account number: 1-1-01110-50305. The professor will submit a Job Request Form at http://www.calvin.edu/admin/igs/request/. Posters must be submitted *three weeks* prior to the CEAP poster session date.

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 throughout the semester. For example, lighting analyses in the dormitories may be relevant to lighting analyses in the PE complex. You may wish to form a cross-section "lighting" technology team consisting of members from each section. Such technology teams provide a forum to share insights and knowledge about common electricity demand issues.

You may also want to form an executive team for each section to coordinate the work of groups in each section and, where applicable, across sections. Executive team members should be mostly relieved of group responsibilities.

Each section may choose to divide the work as it deems appropriate. An initial work breakdown structure is:

Section-Group	Responsibilities	Section-Group	Responsibilities
A-1	Hallway lighting	B-1	Lighting-TnT
A-2	Room lighting	B-2	Lighting-Venema
A-3	Computers and TVs	B-3	Lighting-Van Noord
A-4	Rechargeable gadgets	B-4	HVAC
A-5	Refrigerators	B-5	Computers and TVs
A-6	Pumps	B-6	Pool operations
A-7	HVAC		

The professor will select students to fill the groups. To apply for one of the available groups, prepare a cover letter and resume and deliver it to your professor on **Wednesday, 1 Feb 2017** before lecture. Your cover letter should indicate the group in which you are interested and why you are qualified for that position. Group assignments will be announced via Moodle in the evening of **Thursday, 2 Feb 2017**.

An initial task for each group is to develop a schedule of your activities for the semester that recognizes the dates of important events throughout the semester. Schedules must be discussed during oral progress reports (see below). Mandatory tasks include brainstorming as many sources of electricity demand as possible, assigning groups to develop sub-models for each source of demand, and documenting these responsibilities in oral progress reports.

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 may participate in oral progress reports and 2 students (at most) 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 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 compile the demand model for your section, and the conclusions for your group.

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

The professor, in conjunction with our external resource persons, 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 customers). Students will be assessed on (a) the quality of their team's report, (b) peer evaluation, and (c) hours worked.

Supporting Resources:

- Jack Phillips, Physical Plant, Assistant Director (Mechanical): the customer
  (616) 526-7074, jphill53@calvin.edu
- Previous ENGR333 design projects available from
  http://www.calvin.edu/~mkh2/thermal-fluid_systems_desig/
- Classroom learning on energy, exergy, economics, and thermal analysis
- Prior laboratory and lecture classes, especially ENGR382
- Independent research

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Note: bold schedule items indicate customer participation.

Day	Date	Activity
Mon	**30 Jan**	**Project introduction, objectives, deliverables**
Wed	1 Feb	Resumes and cover letters due to Prof. Heun at class.
Tue	7 Feb	Project work day (Meet in the classroom for group work)
Tue	**14 Feb**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	21 Feb	Project work day (Meet in the classroom for group work)
Tue	**28 Feb**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	7 Mar	Project work day (Meet in the classroom for group work)
Tue	14 Mar	Project work day (Meet in the classroom for group work)
		Spring Break
Tue	**28 Mar**	**In-class group presentations (5 minutes + 2 for questions) Use required outline.**
Tue	4 Apr	Project work day
Tue	11 Apr	Project work day (Meet in the classroom for group work)
Tue	18 Apr	Project work day (Meet in the classroom for group work)
Fri	21 Apr	Project work day (Meet in the classroom for group work)
Mon	24 Apr	Project work day (Meet in the classroom for group work)
		Academic advising
Fri	**28 Apr**	**Project final presentations (10 minutes + 4 for questions) Report on final results.**
Mon	**1 May**	**Project final presentations (10 minutes + 4 for questions) Report on final results.** Peer and Project Evaluations due (3:30 PM)
Wed	10 May	ENGR Department Seminar 3:30 PM (Venue TBD)
Thur	11 May	CEAP Poster Session, 3:30 PM (Venue TBD)
Thur	18 May	Final written reports due at Noon

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Peer and Project Assessment

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Throughout this semester, you developed a detailed, electricity demand model for the Calvin campus. Now, your professor would like your feedback about the process. Part of your grade for the Demand Model Project will be determined by the quality of your submission. Your response is and will remain confidential. Peer and project assessments are due at **3:30 PM** on **Monday 1 May 2017** 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?