Project notes for GEOS24705
EJM 5/5/2015

This handout provides some guidance on final class projects.

The purpose of a project is to give you a chance to dive into one topic in depth and have a chance to explore with great independent responsibility, rather than doing canned problem sets. That is, it's a chance to do something more like you'd do in the working world or graduate school. In choosing topics, above all the topic should be something that you are interested in. You may also want to choose an area you're weak in, to give yourself a new educational experience you can't get otherwise (e.g. policy people learning to build something, or science types learning to do business calculations). Conversely if you're closer to graduation you may want to choose something more directly related to your career, to give you more practice in the most relevant areas. Both are OK strategies.

The usual set of milestones for projects is

- Identify your project group, usually with a tentative project topic in mind.
- Explore your tentative topic or topics, come up with a draft question to address and some thoughts on how to approach it.
- Send as many group members as possible to lab the week of May 11-15 to discuss & get approval on your group and proposed project.
- Make a division of initial work & set a schedule of meetings for when to convene.
    - *It doesn't work to assign tasks and come together only for the final writeup. Successful project groups meet regularly, at least once a week, letting the project and task assignments evolve as needed, & letting people be informed by each others' work.*
- Begin the write-ups ***before*** reading period – document as you go.
    - *This practice saves a lot of pain. First, the whole group should outline the hypothetical final report before even starting, to structure the project. Second, the final write-up is much easier if many pieces are already assembled. And finally, writing up what you're doing during work-time lets your project members comment on it and catch any issues.*
- Presentations during exam time during finals week.
    - *Typically 15 minutes only to keep the length manageable. With slides, and every project member has to get up and speak.*
- Turn in report by the end of finals week. (Seniors wanting grades on time would turn in early).

The turn-in deliverable is a written report of order 10s of pages, that includes figures, figure captions, bibliography of all cited references, appendices describing calculations if needed. Something similar to the kind of report you'd produce in a company, or to the draft of a research paper for publication. The report should read as a unified whole and not as separate pieces written by separate people.

Guidelines below:

Project groups should be generally 4-5 people and integrated. Integrated means that they should comprise people with diverse backgrounds (major fields) and should not be all-male or all-female. The reason to require different backgrounds of group participants is to let you look at a topic in different ways, using the skill sets of different people. Not all policy people or all physics people. Groups of 3 or 6 can be OK, but 4-5 offers the best chance of success: being too small can mean you don't get enough done, too large can be too hard to coordinate.

Every project topic must be a question, that ends with an actual question mark. Not a general subject, but a specific question. ("Would proposed wind turbines in Lake Michigan off Evanston be profitable?" "Will the Illinois Renewable Portfolio Standard law achieve its stated goals?"). Even a build project should be phrased as a question that refers to the target for your design. ("Can I build a bicycle-powered generator that is cheaper than commercial systems?" "Can I build a wind turbine that produces a useful amount of power for typical Hyde Park wind conditions?"). *Don't pick a project for which you think you know the answer already.* The purpose is exploration, not advocacy.

Project questions should be interesting to someone other than yourself. At minimum, remember that your project will be read and graded by someone else (me), so if your particular topic has no interest to anyone besides yourself, it will be a very boring effort for the person grading it.

Projects should be rooted in reality. No studies of idealized cases ("imagine that technology X exists..") or generalized global estimates that don't depend on particulars. Since the project goal is to getting you grappling with real problems, make it as real as possible. The best projects also get you out of paper and screens and involve your having to pick up the phone and call someone (a facilities manager, an industrial energy user, a city planner).

Project questions should be of a scale that you could make progress in a few weeks. They aren't book reports where you do nothing other than summarize other reports. On the other hand, they also shouldn't be thesis-size questions on which you can make no progress at all. Think of a question whose answer you'd be interested in, and which you could go some distance towards answering in a few weeks of group reading and calculating. That being said, in one case a student project was eventually turned into a scientific paper (after another year of work). So extension is possible, but you want to have something that can feel satisfying by finals week.

Projects should be quantitative and involve an original calculation. To serve this goal, there is a requirement that every project must involve some graph that you make yourself. (A table is not enough - it should be a visual display of information). For some projects, it might be OK if the data that you graph are only compiled with no separate processing involved, but check with me if that looks like it will be the case for your group. I'm not looking for a level of calculation beyond that of the problem sets, but am looking for some ownership of the research - you have asked a question and you're going to make the calculations needed to answer it. If you can't think of a graph that's relevant to your project question, you're probably not asking a good question.

Project types:

The most common projects in the past have been **analyses of particular proposed energy systems** (technical and economic feasibility, or the implications of existing or proposed legislation). For this kind of project, the more specificity the better - you can analyze an actual proposal, or a plausible proposal on a real location, so that you have to grapple with the minutiae of real-life concerns that actually affect a project's success (land prices, zoning laws, market competition from other local providers, local regulations, energy markets, local regulatory landscapes). Specificity is your friend - it makes a project richer and more real (and more fun).

Some students have opted to do "**build projects**" that involve making something. Building something for educational demonstrations that can be used in future labs is especially encouraged. Build projects can be a great educational experience, but think through the logistics carefully. Where will you get materials, where will you assemble and test, do you have the requisite skills in the group, do you have access to the necessary test equipment? Do you have enough time? Build projects always, always take longer than you expect and always involve some setback to fight through. (That's what makes them educational). We can reimburse expenses up to a few $100. Check in with a proposed budget before proceeding. Note that build projects aren't graded on your technical skills and a build that fails to perform can still get an A, as long as you understood and analyzed what went wrong.

No one has yet opted to do **historical projects** but those would be very possible as well.

Projects that worked well in the past include

- Evaluating trade-offs between closing Fisk and Crawford coal plants: increase in price of electricity vs. health effects. Students did a good job of really understanding the "dispatch stack" in the PJM market and the "shadow price" of electricity.
- Evaluating the likelihood of fulfillment of the Illinois RPS standard. This evolved over two successive projects and an additional year of work to become a paper in the peer-reviewed literature. (See http://geosci.uchicago.edu/~moyer/GEOS24705/Readings/RPS.pdf, but don't be intimidated by the scope of that final paper, which involved much additional work, including an entire full-time summer by the student who is the lead author.)
- Evaluating a proposed wind farm off of Evanston.
- Estimating the cost of various carbon sequestration options, including bio-sequestration: cutting down trees and sinking them into anoxic lakes. This could have been a silly or over-general project but the students got very serious and specific about estimating actual costs.
- Wind turbine build project. It was overambitious and students turned out to be better at building than at analyzing what they built (or designing to spec in the first place), but they learned a lot in doing it, and I learned something about how students think.

Projects that were almost there and could have been great include

- Building a Stirling-cycle engine – should be totally do-able from online models. Students just didn't have enough people in the group / building experience / time to complete.
- Analysis of German renewables mandates

Project ideas:

Of course you should follow your own interests, but I'll offer some miscellaneous things I've been curious about as inspiration. Some may be done already to the point that they are not good projects but simply would be book reports – it's always important to check that out before getting too wedded to a question.

NON-BUILD RESEARCH QUESTIONS

- Indoor farming: what is the business model of existing farms? What is their energy use, what do they sell their products for – can they be making money, or are they just burning investor money? (Note: this can become part of an op-ed)

- Oil trains: the fracking revolution has meant that a LOT of oil is moving by rail through Chicago. Everybody is very closed-mouthed about how much, but there is a lot. How much? What are the safety issues? Where is the oil going? I envision this project as including students taking shifts by the rails counting trains and photographing identifying markers, if there Is no other source of information. (With the right kind of effort this too could become an op-ed).

- Natural tendency of energy intensity ($/GDP) to evolve with the size of the economy. Most developed countries are showing decreases in carbon intensity over time - but how much of that is due to what we'd consider physical efficiency improvements, and how much is just due to the fact that an increasing fraction of the economy is in the service sector, which uses less energy? That is, what is the "natural" relationship of energy intensity to GDP, so that we could normalize by it and determine whether countries are more or less carbon intensity than expected for the size of their economies. (Note: this could become part of a paper – we have a paper scheduled on this subject)

- University of Chicago's energy systems: both Operations and the office of sustainability are doing a major re-thinking of the university's energy supply and conservation efforts. They will work with the class to develop questions that help them make real-world decisions.

- Batteries: Tesla's recent announcement of lower-cost utility-scale batteries has made headlines. What will these batteries do to the electricity sector? Will they hurt or help nuclear power? Nuclear was already in trouble in Illinois because subsidies for renewables were increasing total supply of electricity while keeping wholesale prices low (the latter issue exacerbated by cheap natural gas). Batteries can help renewables (which may be asked to provide their own backup), but can also totally change the workings of the electricity market by removing the price premium paid to peaking generators.

- How will different states approach the meeting of the EPA's new mandates for CO_2 emissions reduction under the Clean Air Act? (This question would obviously need to be fleshed out.)

- Fracking in Europe: Will fear of a Russian monopoly outweigh Europe's environmental scruples about fracking?

- History of the Industrial Revolution: what were capital costs for manufacturing industries in the 19th century? Was the rise of electrification really a factor in bringing capital costs down?

- Limitations on scale-up of alternative energy: what are mineral resources required for scaling up commercial solar PV cells? That is, given their current composition, what would a forecast in price and in trade be as the world scaled up? What countries control the limiting minerals; how big are reserves; how does price respond to demand; when do limitations kick in?

- Carbon sequestration in Illinois. Illinois is frequently mentioned as a geologically favorable site for carbon sequestration. If carbon were priced, how would a sequestration market in Illinois evolve? (That means considering the regulatory landscape as well as well as geology, local sources, costs of capture and shipping etc.). There is one active sequestration project in the state.

- Do energy use and GDP follow the same trajectory in developing countries regardless of when industrialization happened? What about income inequality? It would be very interesting to see not just comparisons across countries for GDP but for each country over time as each country evolved.

- Household electricity use: Using existing data (Chicago city data, the U.S. Residential Energy Consumption Survey) to evaluate aspects of home efficiency improvement programs – is there clear evidence that rental units and low-income owners have higher per-area home energy usage? (There is a new "energy lab" at the University of Chicago that may have access to data).

BUILD PROJECTS

The question for each build project is usually "Can I build device X that meets specifications Y?" (e.g. "Can I build a small wind turbine that produces enough power from average surface-level Chicago wind to light an LED lightbulb?") Your specifications then guide your design.

- Stirling cycle engine demonstration for lab (Students tried one year, did not succeed, but there are abundant examples documented in YouTube videos, and I have a model kit even.)
- Lightweight anemometer for making wind measurements from a weather balloon. Requires a bit of electronics and some fun with motors but very do-able from kit electronics. For a big project, could involve testing/demo-ing with wind measurements in various locations in the Chicago area, or just calibrate by driving around with it on the car roof.
- Build-your-own electric motor, with discussion of design issues. Can be done without any machining skills – there is lots of internet advice on simple builds involving e.g. winding motor coils around a plastic bottle.
- Building new lab demos: torque-speed of electric motors, a gas law lab, etc.
- *Basically anything fun and educational that would make a lab demo that you'd like to see …*