Homework exercises, due Thursday, February 21 at beginning of class

These exercises explore the implications for consumers of demand response, particularly seeking to understand the value of electricity consumption. Two exercises consider demand response that might be facilitated by the smart grid. They are aimed at helping to understand what applications make sense for demand response and what do not. The focus will be on the total economic value to end-use consumers of various activities that involve electricity consumption.

1. Complete economic analysis should consider investment and operations, with inflation and investor expectations about return on equity also modeled. Nevertheless, back-of-the-envelope analysis ignoring such issues can be helpful to give order-of-magnitude estimates, so long as the limitations are kept in mind. We will perform back-of-the-envelope calculations in this question and the next. In this first question, we will investigate a hypothetical smart grid application of a "smart appliance" that allows for the energy for making coffee to be re-scheduled to another time (perhaps off-peak times or during times of excess renewable production). The benefits of such re-scheduling are due, for example, to moving energy consumption from on-peak times to off-peak times (or to times when renewables are producing.) This question, however, will focus on the implications for end-use consumption to understand the significance of the energy in the value chain.

a) Find a typical purchase price for a coffee maker. If you like espresso, you can use a fancy espresso machine as the purchase price. As a ball-park, assume that the coffee maker will last for 10,000 cups (representing, for example, a ten year lifetime with roughly three cups per day brewed). We will estimate the cost of equipment per cup. Strictly speaking, to amortize the cost of the coffee maker over the 10,000 cups we need to consider inflation and return on equity, but for our calculation, just divide the purchase price by 10,000 to get an order-of-magnitude evaluation of the cost of equipment per cup.

b) Find the typical purchase price for a pound or kilogram of ground coffee. How much ground coffee do you need per cup? What is the price of ground coffee per cup? We will neglect the cost of other ingredients to make the coffee, such as water, milk, and sugar, on the basis that the costs of these ingredients are relatively small compared to the cost of coffee.

c) Find the electrical energy utilized to make a cup of coffee with your coffee maker. (You may have to estimate it from approximate power consumption multiplied by the time to make coffee.) Using your local retail cost of electricity, what is the cost of purchasing this energy?

d) Add up the cost of equipment, cost of coffee, and cost of energy to make a cup of the coffee. Since we have ignored items such as return on equity and your labor, let's double that cost as a very rough ballpark estimate of the costs of everything that goes into making a cup of coffee.

e) Find the typical price of a cup of coffee bought at a coffee shop. We can think of this as a proxy to the consumer willingness-to-pay for freshly made coffee.

f) What is the difference between the cost of making and the willingness-to-pay for coffee? We can think of this as the economic welfare of fresh coffee consumption, meaning the value of consumption minus the cost of making it.

g) Given the answer to the last part compared to the cost of the electrical energy involved, is it likely that re-scheduling coffee making will be a compelling smart grid application? Bear in mind that re-scheduling of coffee making might regularly require you to drink stale coffee and might occasionally involve you having to buy a cup of coffee instead of make your own.

h) What are some other examples of uses of electricity that are likely to be poor candidates for demand response because the economic welfare of the use far exceeds the cost of electricity?

2. This question repeats the analysis for the coffee maker in the previous question, but considers an electric vehicle.

a) Find a typical purchase price for an electric vehicle. If you like to drive fast, you can use the purchase price of a Tesla Model S.

b) An important issue in assessing total costs is how many charge-discharge cycles before the need for battery replacement. This is a contentious figure. We will conservatively assume that the car will last for 2,000 charge and discharge cycles of its battery and that this determines the lifetime of the car. The assumption about lifetime conflates costs, such as the battery cost, that depend on the number of cycles with costs that do not, but will give an approximation to the main determinants of cost since batteries make up a large part of total electric vehicle costs. We will roughly calculate the cost per charge and discharge cycle. Strictly speaking, to amortize the cost of the car over the 2,000 charge and discharge cycles we need to consider inflation and return on equity, but for our calculation, just divide the purchase price by 2,000 to get an order-of-magnitude evaluation of the cost of equipment per charge and discharge cycle.

c) Find the total electrical energy added to the batteries in a charge cycle. Using your local retail cost of electricity, what is the cost of purchasing this energy?

d) Find the electrical energy utilized to drive one kilometer with the car and evaluate the cost of the electrical energy to drive one kilometer.

e) Estimate the cost of equipment per one kilometer driven.

f) Other costs besides the cost of vehicle and fuel are an important part of overall costs. These include maintenance and insurance, and may only be roughly related to distance traveled. However, as a rough estimate, assume that the maintenance and insurance is as much as the cost of equipment per kilometer.

g) Add up all costs of driving one kilometer, including the electricity, equipment costs, and maintenance and insurance.

h) Find the typical price of traveling one kilometer by taxi. (Ignore the price of the initial charge on the basis that this reflects the convenience of being able to hire a vehicle at will. Consider only the additional cost of additional increments of transport.) We can think of this as a proxy to the consumer willingness-to-pay for point-to-point transport.

i) What is the difference between the cost of transport and the willingness-to-pay for transport? We can think of this as a very rough proxy to the economic welfare of transport, meaning the value of consumption minus the cost of providing it.

j) Given the answer to the last part compared to the cost of the electrical energy involved, is it likely that re-scheduling the charging of electric vehicles to times of low cost of electricity production will be a compelling smart grid application by itself? Bear in mind that re-scheduling of charging might very occasionally involve you having to catch a taxi if your car is not charged to a high enough level, but that you will almost always have enough charge from off-peak charging to get to your destination.