Sustainability as a motivation

My understanding of sustainability has been profoundly influenced by my professional experience. I've worked on waste minimization, emissions reduction, energy efficiency, and characterization of product lifecycle environmental impacts. I've learned to recognize the factors beyond personal costs that are drivers for reducing energy use:

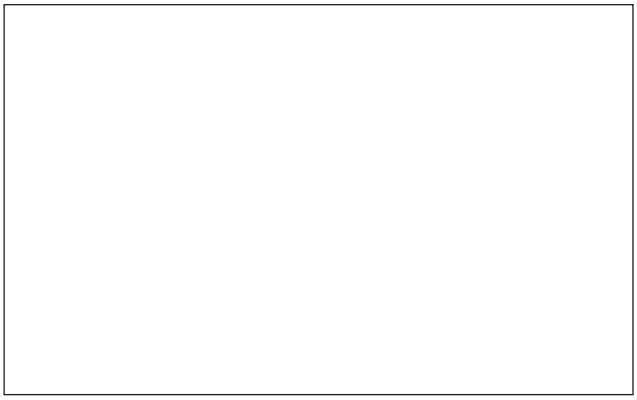
Global warming impacts. Two hundred of the 500 largest global companies, and many of the major employers of chemical engineers, have set goals of reducing global warming impacts. The combustion of fossil fuels to generate electricity and to power transportation is the largest source of carbon dioxide, the most prevalent greenhouse gas.

Air toxics. If you are a global warming skeptic, consider the sources of toxic exposure in today's society. Many major U.S. cities continue to have a difficult time maintaining summer ozone levels low enough to meet health standards. Nitrogen oxides from electricity generation and transportation are major sources of this ozone (or smog). Gas-fired peaking turbines spew yellow and brown plumes of NOx into the air on the hottest days with the highest ozone concentrations (although they may be used fewer than 500 h/yr). Lifecycle assessment studies often identify heavy metals released during coal combustion to make electricity as a major source of human and environmental toxins.

Macroeconomic drivers. At times, the supply and demand of petroleum is in close balance, and this leads to substantial price volatility. The global economy is vulnerable to an interruption in supply on any of four continents. The cost of imported petroleum to the U.S. is on the order of $300 billion/yr, or $1,000 per individual per year.

Water use. When I visited the southeastern U.S., I was shocked by the water shortage of 2006–2007 (which in some places continues today). People watered houseplants with gray water, and governors argued about who owned the streams and even about the state boundaries. Missing from the discussion was the fact that industrial cooling is a major user of water. The generation of electricity from nuclear and fossil-fuel sources results in the discharge of low-grade heat into cooling systems, such as rivers and cooling towers. Because about 50–70% of the total heat release is discharged that way, 3–5 lb of water are evaporated for each kilowatt-hour of electricity produced by these sources.

These (and other) social and environmental factors tie energy to the three pillars of sustainability — economic,



environmental, and social. The coupling of personal decisions about energy use with sustainability has helped me to better understand and articulate the overall concept.

My curiosity about marginal value has led me to studies by the European utility company Vattenfall (Figure 2). Vattenfall proposes that on a global macroeconomic scale, reductions in climate change gases of 7 gigatonnes per year (Gm.t./yr) can be accomplished with zero annual costs by improved energy efficiency. Global emissions can be reduced by 27 Gm.t./yr at an annual cost of no more than 40 euros/m.t. A report by McKinsey & Co. *(1)* elaborates on this chart.

Figure 2 suggests that energy efficiency improvements, such as better insulation, can in some cases pay for themselves. Gaining an understanding the economics of these and other options for reducing environmental impacts — such as increased energy awareness, new technology, or lifestyle changes (not shown in Figure 2) — will allow us to give extra consideration to those that are most cost-effective.

A personal mission statement

My wife does not like to be cold, especially in her own home. We needed to reconcile her desire to be warm with my newfound interest in energy conservation. A mission statement became helpful for this.

I modified my employer's mission statement to:

"I will seek to reduce my energy use without inconvenience to my family and neighbors and with a return on any investment which exceeds the average return on my savings."

This statement has helped me to focus on engaging others in my plans, and has placed an emphasis on savings that can be accomplished with minimum investment.

Home heating and air conditioning (HVAC)

The American Center for an Energy Efficient Economy (ACEEE) website (www.aceee.org/Consumer/consumer.htm) is a particularly useful source of ideas for reducing energy use in heating and cooling.

This site led me to think more about air leaks into our home (which was built in 1977). I knew that the doors were

exhaust fans *(2)*. These leakage points are often more accessible and cheaper to correct than leaky window frames and leaks in other locations in the occupied portion of the house. Buoyed by my success with the pipe chase, I tackled other areas of the house. I have substantially sealed the attic access door and the whole-house fan housing. I am currently replacing the original vented "top hat" type ceiling light fixtures with modern sealed fixtures rated "IC" for insulation contact.

The forced-air ductwork passes through heated portions of the house. In many U.S. homes, however, the ductwork passes through unheated crawl spaces or attics. Many experts believe that air leaks from such pressurized ductwork through unconditioned space account for approximately 20% of home heating energy use.

My wife thinks that the best thing we have done to make the house more comfortable is to install propane logs in the family room. This room has been very difficult to keep warm — it is the lowest room in the house, has high ceilings, is exposed on three sides, and has a large sliding glass door on the north side. I had tried adding heat to the room with a portable electric heater, but the heat losses overwhelmed the heater's capacity. The propane logs keep this room very comfortable without heating unoccupied areas of the house. This concept, referred to as zone heating, matches the heater size to the heating needs.

How would I know if I have made the house too tight? My metric is condensation on the windows during the winter. Condensation builds up in the bathrooms during a shower, but it disappears quickly and does not spread into adjacent rooms. It is essential to control the humidity of a home to prevent the formation of condensation behind the walls, which can lead to a mold problem and reduce the effectiveness of insulation.

It's easy to read an electric meter, but it is harder to create metrics around the heating system. Developing metrics is particularly challenging for a system that combines a heat pump, a backup oil furnace, and propane-log zone heating. This is where I put my chemical engineering education to use.

The oil heat is capable of transferring about 70,000 Btu/h (20.5 kW) into the house. So I use the oil furnace to add 50,000 Btu to the house, and then measure the time for the house to cool back to the starting temperature. From this, I calculate an overall value for *UA* (the composite heat-transfer rate times the surface area of the house):

This equation ignores radiant heat transfer to the house, which can have a big impact, so I make my heat-loss measurements at night when there is no radiant heat input.

This heat-transfer model has several potential uses. It can be used to estimate the expected savings associated with adding insulation to the attic or basement, of sealing leaks, or of lowering the thermostat. The relationship can also be used to approximate the efficiency of a heat pump or other heating systems.

Over a period of several years, I have cut my home's heating, ventilation and air conditioning (HVAC) energy use by approximately 33%.

Transportation fuel use

I was already doing those things, so I needed to look deeper. Two simple changes made a difference for me.

First, I try to avoid traffic congestion (Figure 3). For example, I get an early start to my day, and I go to a bus stop that is a little less convenient but for which the park-and-ride lot requires a shorter and less-congested drive.

Second, I have learned to anticipate stopping and I take my foot off the accelerator pedal early. A friend who drives a Prius gets a little over 50 miles per gallon. My Buick LeSabre will also get about 40 mpg under ideal conditions, if I never brake. The Prius recovers kinetic energy during braking to charge its battery. Since I do not have a hybrid car, my strategy is to reduce the energy lost to braking by coasting to slow the car before stopping.

The National Auto Dealers Association recently advised drivers to "avoid a driving style that leads you to accelerate until the point of needing to brake. By looking ahead, anticipating turns, hills and stoplights, you will be able to ease the transition from 'Go' to 'Whoa'" *(4)*. Perhaps more drivers will learn to improve fuel economy this way.

Of course, it's important to consider the potential for road rage that this strategy may evoke. Remember that my mission statement is "I will seek to reduce my energy use *without inconvenience to my family and neighbors …*" I'm very alert to the vehicles around and behind me, and I make sure I don't hold up traffic by driving too slowly.

My car has a fuel-economy metering system, which I reset often to track my progress. It has taught me how to improve the fuel economy during my suburban driving from an average of 20 mpg — the EPA estimate — to 24 mpg. That 20% increase is better than the 5%-discounted gas I mentioned earlier, and I do not have to wait in line.

New purchases

I'm reluctant to replace a functioning appliance or vehicle simply because it is not as energy-efficient as a newer model. If you are starting a new household, however, you are making decisions that will impact your energy costs and environmental footprint for many years. Take the time to consider the energy implications of your most important decisions. For instance:

- How long will your commute be?
- Is public transportation or carpooling available?
- If you need to own a vehicle, what fraction of the time will you need the people-carrying or cargo capacity of a large vehicle? How can you meet your needs with a fuel-efficient vehicle?
- Do you really need a very large refrigerator? Why?
- An LCD television uses much less electricity than a plasma TV of the same size. Why buy the plasma model?
- Before buying any appliance that will frequently (or always) be on (*e.g.*, a refrigerator), consider the annual energy costs to operate it. Give special consideration to

can also learn how to do a better job of reducing and recycling wastes, and of reducing water use.

As chemical engineers, we have been educated in thermodynamics, heat transfer, and mathematical modeling. We can use our education and experiences to influence the people around us about the economic and environmental benefits of modest changes in the direction of a more sustainable planet.

Let's engage others in what we can do to promote a more sustainable lifestyle!

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4. "Green Driving Tips," *Time,* Special Advertising Section, p. 84 (Oct. 20, 2008).

For More Information

H e e e g -ef cie c i f he U.S. De . f E e g : www.energy.gov/energytips.htm

E e g -ef cie a ia ce a d b i di g , a ec e ded b he U.S. De . f E e g : www.energy.gov/energyefficiency/energystar.htm

The A e ica C ci f a E e g -Ef cie Ec H e E e g Chec i : www.aceee.org/consumerguide/checklist.htm

G g e "measures of carbon footprint" to find numerous websites that help you convert your energy use into a carbon footprint.