A Personal Perspective on Sustainability Through Energy Efficiency

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These relatively simple lifestyle changes enabled one individual to reduce energy costs by $2,000/yr and his carbon footprint by one-third.

How far would you go out of your way and how long would you wait in line if you could buy gasoline at a 15% discount? Last year, a service station near my home offered a 15¢-off promotion. The response was remarkable — cars lined up five to eight deep, and even blocked the right lane of a major highway to buy the cheaper gas — and save about 5%.

What if you could change your driving habits and reduce your gas consumption by 15%? How much change would you be willing to make? What would you do to reduce energy consumption and costs in other areas of your life?

This article describes the journey I have taken to reduce energy costs and my associated carbon footprint. Some things I discuss may not apply to your situation, but I encourage you to consider how you might take a similar journey.

Energy costs as a motivation

The U.S. has an energy problem. My own energy problem hit me one morning when the newspaper reported that my electricity rate would soon rise by 77%. I recalled learning about supply, demand, and elasticity in my college economic classes, and that when costs go up, consumption should decline. So I set about to reduce the amount of electricity I use by identifying how I am using energy in ways that are not cost-effective at the higher price.

I began by looking at my electric meter. I switched off the electric water heater, the heat pump, and the refrigerator — the intermittent users of electricity that might confuse my interpretation of the meter's reading. I was surprised to see how fast the dial was turning, particularly since I did not think that any of the major electricity users were on. The dial, which measures 0.01 kWh per revolution, was turning two revolutions a minute. That translated to 860 kWh/mo — about $120/mo at the new cost — with "nothing" on!

Clearly, something was still on. Although I was the only person in the house awake, I had turned on eight light fixtures. The computer was still on, and I found that it was not going into hibernate mode. And, I had used some electrical heating tape to keep a sink from freezing and I had forgotten to unplug it. It took me less than five minutes to identify and eliminate these electrical loads, and the meter slowed down to one-half revolution per minute. That was worth $90/mo.

Later, I purchased a Kill-A-Watt meter (Figure 1) for about $25. This device measures instantaneous and time-integrated electricity use by appliances. I've used it to evaluate parasitic loads, like the computer modem, and to find the energy use of the refrigerator and television. Data from these tests taught me that a new, more-energy-efficient refrigerator will not have a very rapid payback. I also learned that energy use of the TV and DVR is rather low, so I unplug them only when I am taking extended trips.

So, how fast is your meter turning? (Don't forget to restart the refrigerator.)

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,

■ Figure 1. The Kill A Watt meter is an easy-to-use tool to measure the power consumption of plug-in appliances. Photo courtesy of P3 International.

SAVE ELECTRICITY

- Check the power demand when the large, variable electricity users are off. Target a goal of less than 0.005 kWh/min — half a revolution per minute on my meter.
- Turn off lights, televisions, game stations and radios when not in use. Explain to children why this is good for the environment.
- Make sure that computers go into standby or hibernate mode when not in use. You should have to push the power button to restart.
- Use low-flow shower heads.
- Wash most clothes in cool water.
- Dry most clothes on a rack or line. Air-dry the final moisture from "almost dry" clothes.
- Replace most filament lightbulbs with compact fluorescent lightbulbs (CFLs). Recycle the bulbs at the end of life. Note that CFLs contain small amounts of mercury. Avoid using these bulbs in fixtures where they are likely to get broken. Consult manufacturers' Internet sites for suggestions on how to safely clean up a broken fixture.
- Start using the energy-saving settings on refrigerators, dishwashers, washing machines and clothes dryers. Review the owner's manuals for a full description of these features.
- Use fans instead of air conditioning on temperate days. Use fans to take moisture from bathrooms during humid weather or if condensation is an issue. Set back the air conditioner during summer afternoons if no one is at home.
- Clean the coils on the refrigerator. Consult the owner's manual on how to do this.
- Lower the thermostat on the water heater to 140°F (60°C) or cooler. Turn off the water heater when you are traveling.
- Measure the consumption of the parasitic loads in your house. Unplug chargers and other energy consumers when not in use.
- Calculate the value of adding additional insulation to your water heater. The American Council for an Energy Efficient Economy recommends a water heater blanket for all water heaters old enough to be insulated with fiberglass instead of foam.

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.

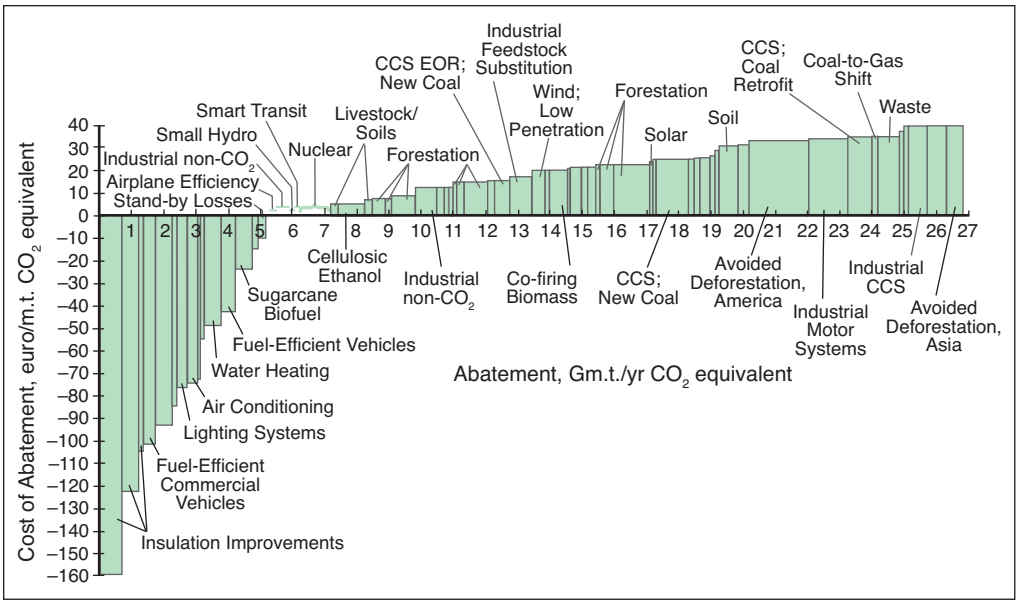
Home heating and air conditioning (HVAC)

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 not sealed well, and I quickly found systems at the local hardware store to correct this.

The house has always felt drafty during very cold weather. A few places seemed unusually drafty, but I did not understand why. The ACEEE website suggests that to find poorly sealed construction, look for stained or dirty insulation. Fiberglass insulation is an effective filter for dust, and dirty insulation is the mark of an air current from the house to the attic.

I inspected the insulation and found some surprises. The builders left an unsealed "pipe chase," a passageway from the basement through the two-story house into the attic with connections to the joists between the first and second floors. During cold weather, this pipe chase acted as an internal chimney. Because the draft of a chimney is a function of the difference between the house temperature and the attic temperature, we felt a draft only during cold weather. I sealed this hole and found numerous other, smaller leaks where the insulation was stained. The house is now far less drafty. I believe that leak detection and repair was the most cost-effective change I made, and it made our home more comfortable.



■ Figure 2. A waterfall diagram ranks global opportunities to reduce carbon dioxide emissions in sequence of costs. Reference 1 provides further details. Diagram used with permission of Vattenfall.

The best opportunities to reduce overall leakage are often found at the top and the bottom of the house — for example, plumbing vent stacks, electrical penetrations, chases around chimneys, open tops of interior partitions, and gaps around the penetrations for mechanicals such as ductwork, recessed lights and bathroom

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):

$$UA = \frac{Q}{T_{house} - T_{outside}}$$

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.

REDUCE HVAC COSTS

- Set back your thermostat. (If you use a heat pump, do research to learn how to raise the setpoint temperature without triggering less-efficient electric resistance heat.)
- Change the air filters at least quarterly, monthly for heat pumps.
- Seal ductwork passing through unconditioned space.
- Seal leaks, giving particular attention to the basement, crawl space, and attic.
- Look for totally uninsulated areas. For my house, it was the above-grade cinder block foundation.
- After sealing leaks, increase insulation to U.S. Dept. of Energy suggested resistance values
- If you are adding or replacing an air conditioner to a house heated with fossil fuel, consider purchasing a heat pump instead. Use the heat pump when the outside temperature above 40°F, when the heat pump is especially cost-effective. You may need the HVAC company to increase the ductwork size or fan speed to assure adequate air distribution.

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

Many of my colleagues believe that the most cost-effective way to reduce fuel consumption is to drive less. They carpool, ride the bus, walk to work, work from home part-time, or bike to work.

Another way to reduce fuel consumption is to drive in a way that maximizes fuel efficiency. By watching the fuel-economy gages in my cars, I've learned that I can improve my fuel economy in suburban driving by approximately 20% by changing my driving habits.

A recent article in the American Automobile Association (AAA) magazine suggested several ways to improve fuel economy *(3)*:

- use the right grade of motor oil
- keep the tire pressure close to recommended levels
- avoid traveling with unnecessary weight
- remove ski and bike racks from the car when they are not in use
- avoid using the air conditioner or defroster when they are not needed
- accelerate gradually
- avoid excessive speed.

Figure 3. The fuel economy of stopped traffic approaches zero. Avoid congestion to improve your energy efficiency.

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 "Energy Star" and similar energy-use ratings.
- Consider energy efficiency when selecting a dwelling. If you will be living in an apartment, which side of the building would you like to live on? If you are moving into an existing home, ask to see utility bills. If you are buying a new home, ask if it has an Energy Star rating, and inquire about how the design and construction assure energy efficiency. If the builder offers an insulation upgrade, add that. Inspect the new home while it is under construction; look for high-quality air infiltration barriers and sealing at all penetrations of the shell and floors.

The big picture

The value of metrics cannot be overemphasized as a motivator for change — whether for electricity, heating, or fuel economy. You are unlikely to reduce your energy use if you do not measure it.

Where can you get ideas for changes to reduce your energy use? You may live in a dramatically different climate zone than I do, so your HVAC energy requirements may be very different from mine. I live in a suburban area; if you live in a rural area or a major city, your transportation options will be different from mine. The tradeoffs I make might not align with the tradeoffs you are willing to make, so my choices are not necessarily your choices. You have to search to find energy saving ideas that fit your lifestyle.

I am concerned about global warming, and I acknowledge limitations in the supply of electricity and fuel. As a result of the modest changes that I have made, I have reduced my carbon footprint associated with personal energy use from 20 tons/yr to about 14 tons/yr. And in doing so, I am saving $2,000/yr. Increased energy efficiency is the first step to a more sustainable environment for many of us. We

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! CEP

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Literature Cited

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2. **Keefe, D.,** "Air Sealing in Occupied Homes," *Home Energy Magazine Online,* www.homeenergy.org/archive/hem.dis.anl.gov/eehem/95/951111.html (Nov/Dec 1995).
3. **McLaughlin, T.,** "Top Ten Ways to Improve Fuel Mileage," *AAA World* (Sept/Oct 2008).
4. "Green Driving Tips," *Time,* Special Advertising Section, p. 84 (Oct. 20, 2008).

For More Information

Home energy-efficiency tips from the U.S. Dept. of Energy:
www.energy.gov/energytips.htm

Energy-efficient appliances and buildings, as recommended by the U.S. Dept. of Energy:
www.energy.gov/energyefficiency/energystar.htm

The American Council for an Energy-Efficient Economy Home Energy Checklist:
www.aceee.org/consumerguide/checklist.htm

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

OPPORTUNITIES TO PARTICIPATE IN SUSTAINABILITY ACTIVITIES

The Institute for Sustainability (IfS) offers numerous projects related to sustainability to engage both companies and individuals. Contact ifs@aiche.org for more information.

The **Center for Sustainable Technology Practices (CSTP)** is an industry consortium that focuses on discussing and developing sustainable technology practices.

"CSTP Sustainability Guide" — Covering economic, environmental and societal impact issues, as well as corporate business strategy and management issues, this guide will enable a company to develop and implement more sustainable products and processes. It identifies more than 150 key questions that are relevant at each stage of the value chain, including when during the product/process development or improvement effort the questions should be asked and which business function should be engaged to answer them.

CSTP is currently working on projects to raise the awareness of sustainability, and to develop an inventory of sustainability tools of interest to industry. It is also exploring the development of a sustainability supply chain forum and a full-cost accounting forum, as well as certification of sustainability along the supply chain. It publishes a newsletter, and holds short (30 min. or less) virtual meetings on topics such as evaluating greenhouse gases in the supply chain, greening the supply chain, and applying for the Presidential Green Chemistry Award, among others.

The **Sustainable Engineering Forum (SEF)** is a forum of 1,200 members that focuses on bringing scientific rigor to analyzing sustainability through the use of appropriate metrics. It organizes sessions at national meetings in three main areas — sustainable energy, sustainable biorefineries, and general sustainability. Sessions planned for the Annual Meeting in Nashville, TN, Nov. 8–13, 2009, include:

- Sustainability Plenary
- Design for Sustainability
- Sustainability Education
- Systems Analysis of Sustainability
- Sustainable Water
- Interface of Water and Energy Use
- Sustainability of Water Use
- Innovations in Sustainable Process Engineering
- Sustainability Metrics, Assessment and Prediction
- Sustainable Value Chain
- Green Engineering in the Pharmaceutical and Fine Chemical Industry
- Sustainability Under Uncertainty

SEF is co-sponsoring the First International Congress on Sustainability Science and Engineering, ICOSSE, in Cincinnati, OH, Aug. 9–12, 2009. For more information, see p. 64.

SEF's Virtual Meetings have proven successful. Topics in 2008 included sustainability ethics and engineering practice, sustainability and the Olympics, and individual sustainability. Topics for 2009 are being planned.