Future Energy: Opportunities and Challenges

Part III. Energy Demand

Chapter 20. Energy Conservation and Efficiency

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Future Energy:
Opportunities and Challenges

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Energy Conservation and Efficiency

The Main Points

- **Conservation and efficiency improvements are the quickest and cheapest ways to reduce energy consumption.**
- **Benefits of efficiency improvements range from cheap and immediate to expensive and long-term.**
- **40 percent of U.S. energy consumption is under the direct control of citizens.**
- **Energy used to provide goods and services accounts for 60 percent of U.S. consumption.**

20.1 Introduction

There have been many accounts in the media about ways to reduce energy consumption by implementing conservation and efficiency improvements. Previous chapters have described the technology behind these measures. This chapter provides a brief summary of efficiency improvement and conservation activities that can reduce energy consumption.

Energy conservation is the reduction of activities that consume energy. Improving energy efficiency is the reduction of energy needed to accomplish some activity.

Energy conservation and efficiency improvements are often touted as the quickest and cheapest ways to reduce energy consumption and related undesirable environmental effects. Some measures require lifestyle changes, and some require technological steps. Some lifestyle changes can occur with little or no negative impact on the quality of life. Some changes provide immediate payback, and others require investments that will provide payback in the future.

Individuals, businesses, and government all have a role.

20.2 Individual Actions

20.2.1 Purchases

The things that we purchase require energy to produce, package, and transport the products and to dispose of associated waste. The energy required for these operations is called embodied energy. Sometimes we have choices between different products that can serve the same purpose, but with significantly different embodied energies. Some examples of embodied energies are shown in Table 20-1.

Table 20-1. Embodied Energies[1]

Material	Embodied Energy (BTU/pound)
Paper	15,500
Glass	10,900
PET Plastic[a]	46,500
Aluminum	62,000
Steel	9,300

[a] Polyethylene terephthalate (PET): a plastic used for beverage containers

Information about embodied energy can help consumers who want to help with energy conservation.

20.2.2 Residential Energy Use

Residential energy use accounts for around 21 percent of total American energy consumption. The breakdown of energy by type of use in residential consumption provides insight into the ways that energy is used (and possibly misused) in homes. Energy use data were presented in Table 15-1 and are shown here in Figures 20-1 and 20-2. See Table 15-2 for the breakdown of electrical energy use in homes. Possible savings in energy and its cost depend on the characteristics of the residence and the local climate. The

Department of Energy provides detailed information on options for residential energy savings[2].

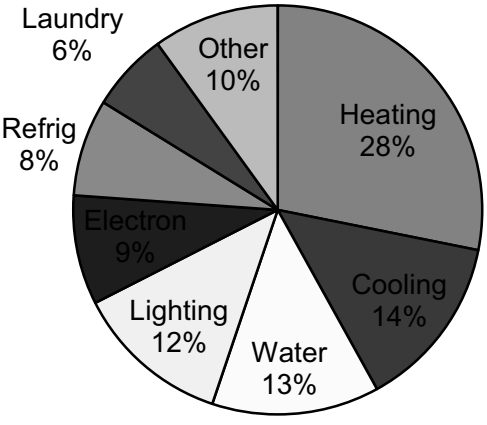

Figure 20-1. Residential Primary Energy End Uses

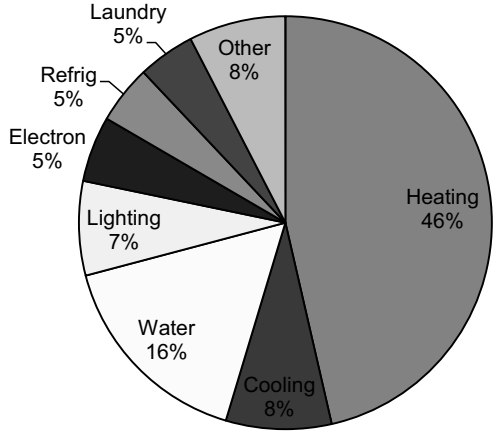

Figure 20-2. Residential Delivered Energy End Uses

Conservation in the Home

Conservation involves no cost, but may require acceptance of some loss of comfort or convenience. The most important residential conservation options are as follows:

- Reduce heating and cooling energy use by increasing thermostat settings in summer and reducing settings in winter.
- Set the thermostat to reduce heating and cooling energy even more when the home is unoccupied.
- Close vents and doors to unused rooms.
- Reduce or eliminate lighting in unoccupied rooms.
- Lower hot water temperature and reduce the quantity used for bathing or showering.
- Reduce energy use for laundry by washing only full loads and air drying (maybe even use outdoor clotheslines).
- In winter, open curtains when solar heating is available and needed and close curtains to reduce heat loss when solar heating is unavailable.
- In summer, close curtains when solar heating is available but unwanted.
- Open windows when outside air is at a comfortable temperature.
- Minimize the number of times that the refrigerator is opened. (Collect as many items as possible to be placed in the refrigerator before opening the door.)
- Use local heaters such as space heaters and electric blankets for heating highly local areas.

- Use fans in summer to achieve comfort with higher thermostat settings.

- Turn off electronic equipment when not in use.

- Unplug appliances and devices with phantom loads when not in use.

- Clean washable HVAC (heating, ventilating and air conditioning) filters regularly.

- Clean refrigerator coils regularly.

- Close the chimney flue (damper) when the chimney is not in use.

- In winter, leave bath water in the tub until it cools, thereby transferring heat and humidity into the living space.

Home Efficiency Upgrades Involving Little or No Cost

Energy efficiency measures that require small out-of-pocket expenditures are outlined below:

- Install a programmable thermostat (set to reduce heater or air conditioner operation when not needed).

- Install high efficiency lighting. Compact fluorescent lights cost three or four times as much as incandescent lighting, but use around one-third as much energy and last up to ten times as long.

- Seal around windows to close leaks.

- Weatherstrip doors to close leaks.

- Install low-volume shower heads.

- Plant deciduous trees on the south side of the home (provides shade in summer and admits sunlight in winter).

- Install storm doors and windows.

- Install exhaust fans to draw cool night air into the home in summer.

Home Efficiency Upgrades Involving Significant Cost
Upgrades of energy-consuming equipment and systems that involve significant cost will provide future rather than immediate cost savings. Owners must decide about future benefits versus current expenditures.

Major options are as follows:

- Replace the HVAC system with a more efficient model (possibly a ground effect heat pump or a dual-mode, heat pump+gas furnace system.)

- Replace appliances with more efficient models. (Refrigerators, washers, dryers, and dishwashers with improved energy efficiency are available.)

- Replace furnaces with units with greater efficiency. (Since the efficiencies of many existing furnaces are quite high, only small improvements are likely.)

- Replace water heaters with units having higher efficiencies (possibly the newer tankless types.)

- Insulate or upgrade insulation in walls, floors, and ceilings and around water heaters and pipes.

- Seal and insulate ductwork.

- Install energy efficient windows.

- Install an attic exhaust fan.
- Install on-demand lighting where appropriate.
- Install a solar water heater.
- Install a photoelectric system.
- Install retractable awnings.

New Home Construction

New homes can incorporate all of the measures described above and, in addition, apply measures that are impractical for retrofitting. Major options are as follows:

- Place the house and design it so most of the windows face south.
- Use smaller windows.
- Incorporate energy capture features such as Trombe walls (see Section 15.3.4).
- Incorporate an energy storage mass (thermal mass) to store heat. (Excess heat, usually daytime solar heat, is stored on winter days for subsequent release when needed. In summer, the mass is cooled with cool night air and then used to subsequently provide cool air when the daytime temperature rises.)
- Incorporate ground effect heat pumps. These are less expensive and less disruptive to install during initial construction (see Section 15.3.3).
- Incorporate a wastewater heat exchanger to heat incoming fresh water. This requires special plumbing, a storage tank to hold preheated water for future injection into the water heater, and a controller.

- Install dark-colored roofing for cold climates and light-colored roofing for warm climates.

Recycling

Recycling generally does not save energy or money for the individual home occupant. Instead, recycling may be done because of a sense of civic duty and/or because of local regulations. Because of the energy consumed and the manpower required for collection, hauling, sorting, and processing recycled materials, it is not always obvious that recycling reduces total energy use. However, studies show[3] recycling metals, glass, and paper all reduce the energy required to produce new products relative to the energy required for production from raw materials. For example, recycled aluminum uses only about 5 percent of the energy needed to produce aluminum from bauxite ore. Recycling other materials reduces energy required by 25 to 75 percent. Recycling also reduces the rate of depletion of ores and forests, and it reduces the volume of material placed in landfills.

20.2.3 Transportation Energy Use

Energy use for transportation accounts for around 27 percent of American energy use. Personal transportation accounts for 59 percent of transportation energy use. The Department of Energy provides detailed information on options for reducing the energy needed for personal transportation[4].

Conservation in Personal Transportation

The most important energy conservation measures in personal transportation are as follows:

- Reduce driving by careful route planning to accomplish required tasks with minimum travel distance. (For example, wait until several stops in a given area are required before traveling.)

- Reduce driving by carpooling.

- Reduce driving by using public transportation.

- Avoid high speed driving.
- When possible, travel when congestion is light.
- Avoid unnecessary braking by gradual deceleration before stops.
- Eliminate driving to work when work-at-home options are available.
- Use teleconferencing instead of face-to-face meetings when possible.
- Avoid trips for comparison shopping by using the telephone and/or the Internet.
- Adopt a four-day work week when possible.

Transportation Efficiency Upgrades with Little or No Cost

- Perform regular vehicle maintenance.
- Maintain proper tire inflation pressure.

New Vehicle Purchases

Vehicle buyers face choices that will impact the energy efficiency of their travel. Some options will reduce initial cost (for example, a smaller car), and some will increase initial cost (for example, a plug-in hybrid). The buyer must weigh initial capital outlay versus lifetime costs.

Major options for increasing transportation energy efficiency in new vehicle purchases are as follows:

- Buy a small vehicle.
- Avoid high performance vehicles with large, high-horsepower engines.

- Buy a hybrid vehicle.
- Buy an all-electric vehicle for urban commuting.

20.3 Business and Industry Actions

Because of their constant concern about profitability, businesses and industry are more likely than private citizens to implement energy efficiency measures. Commercial businesses use about 18 percent of total U.S. energy, and industry uses about 33 percent.

The main measures for retail, wholesale, and service businesses are the same as those for individuals, but the relative impact of each depends on the differences in facilities and mode of operation. The U.S. Department of Energy provides detailed information on reducing energy needed in commercial buildings[5] and in industry[6].

Some energy-saving measures that businesses can take are:

- Install photovoltaic systems.
- Optimize delivery routes to minimize energy use.
- Use energy-efficient (possibly electric) vehicles for deliveries.
- Install zone control to use lighting, heating, and cooling only when needed.
- Upgrade insulation.
- Install skylights and fluorescent lighting.
- Install energy-efficient windows.

Energy efficiency measures that may be taken by industry are somewhat different than in residences and businesses and include the following:

- Install cogeneration equipment.
- Install heat recovery systems.
- Replace auxiliary equipment such as fans, pumps, and motors with more efficient models.
- Implement improved control strategies and install new control equipment.
- Seal leaks.
- Insulate piping and process equipment.
- Install advanced boilers and furnaces.
- Recycle waste material.

20.4 Government Actions

20.4.1 Tax Credits

The government can and does offer tax credits for selected energy-saving investments. These credits reduce the effective cost of items and increase the incentive to purchase them.

20.4.2 Regulations

The government mandates performance standards for energy-consuming systems. For example, the CAFE (Corporate Average Fleet Efficiency) standard imposes mileage requirements for the mix of automobiles manufactured by an automaker.

20.4.3 Being an Example

The government itself is a major energy consumer. Improvement in the energy efficiency of government facilities and vehicles demonstrates possibilities and limitations. In addition, government expenditures for energy-saving measures encourage the market to expand and innovate.

20.4.4 Research

The government funds energy research and encourages commercialization of appropriate new technology.

20.4.5 Education

The government provides information that is needed to understand energy-related issues. Information from government sources is especially valuable because it is considered less biased than information from business sources.

20.5 How Individual Citizens Use Energy

We have seen American citizens use about 330 million BTU per person per year. This includes direct energy use and indirect energy use. Direct energy use includes energy for personal travel and energy for providing personal comfort and convenience. Indirect energy use includes the energy consumed in producing, hauling, and selling the *stuff* that we use. Table 20-2 shows the relative energy use for these activities.

These statistics do not account for energy used to produce U.S. exports or for energy used to produce U.S. imports. Since America is a heavy importer, the actual total energy consumption that is required for each U.S. citizen is slightly higher than the U.S. figures cited.

We have seen in previous sections that viable options already exist for reducing energy for direct use. The largest reductions are possible with transportation and for lighting and appliances. Savings of as much as 50

Table 20-2. Energy Use by an Average American

Activity	Percentage of Per Capita Energy Use
Direct Use	
Personal Transportation[a]	19
Home Heating and Cooling	8
Home Water Heating	3
Home Lighting and Appliances	10
Total Direct	40
Indirect Use	
Producing Stuff[b]	35
Hauling Stuff	8
Selling Stuff	17
Total Indirect	60
[a] Includes travel on buses and aircraft	
[b] "Stuff" as defined here is the total of goods and services consumed	

percent are possible in these applications, but they can only be realized as older items are replaced with newer, energy-efficient items. Decisions must be made about replacements when existing systems end their useful life and when new systems offer annual savings that may justify replacing systems that are still operable. Such savings would reduce total annual consumption and expenditures by as much as 15 percent.

Reducing indirect energy use is also possible, but achieving reductions is more complicated. Industrial production is driven by profitability, and profitability depends on production costs and consumer demand. Production costs include raw material cost, energy cost, labor cost, debt service, taxes, and compliance cost. The government impacts production costs through regulations, taxes and/or incentives, and consumers impact demand for specific products by their purchasing decisions.

Government and citizens can influence indirect energy use, but every decision requires an informed assessment of costs and benefits. For example, if government policies and personal choices lead to the increased use of hybrid or electric cars, total energy consumption for transportation decreases, but this requires increased electricity production, transmission,

and distribution. If the increased electricity is provided with new coal-burning power plants, then increases in greenhouse gas release and pollution become an issue.

20.6 The Bottom Line

The energy conservation and efficiency measures outlined above do not include estimates of the actual energy savings. Estimating energy savings is hampered by strong dependence on local conditions where measures are implemented, on the extent of the changes that are made, and on assumptions about their effectiveness. However, it is safe to say that no single measure is a panacea. Each measure can provide small incremental improvements. Fortunately, there are many energy-saving opportunities and, if a number of them are implemented, their cumulative effect will be significant.

References

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2. "Energy Savers: Tips on Saving Money & Energy at Home" U.S. Department of Energy, Energy Efficiency and Renewable Energy at http://www.energysavers.gov/pdfs/energy_savers.pdf.

3. Choate, A. et.al. "Waste Management and Energy Savings: Benefits by the Numbers" Study for the U.S. Environmental Protection Agency, 2005, at http://www.epa.gov/climatechange/wycd/waste/downloads/Energy%20Savings.pdf.

4. "Tip: Driving and Car Maintenance" U.S. Department of Energy, Energy Efficiency and Renewable Energy at http://www.energysavers.gov/tips/driving.cfm.

5. "Commercial Building Design Guide" Commercial Building Initiative U.S. Department of Energy, Energy Efficiency and Renewable Energy at http://www1.eere.energy.gov/buildings/commercial_initiative/guides.html#strategies.

6. "Industries and Technologies" Advanced Manufacturing Office U.S. Department of Energy, Energy Efficiency and Renewable Energy at http://www1.eere.energy.gov/manufacturing/industries_technologies/.

Exercises

20-1. On a winter day, the outside temperature is 30°F, and the indoor thermostat is set at 70°F. Estimate the percentage of energy use that would be saved if the thermostat were set at 68°F. (Hint: Remember heat transfer is a gradient-driven process.)

20-2. How much energy is required to produce 3,000 pounds of steel used in an automobile? How many gallons of gasoline would provide the same energy?

20-3. Developed nations are currently (at the time of this writing) moving toward the elimination of incandescent light bulbs in favor of compact fluorescent lamps. Estimate the total reduction in U.S. electricity consumption if all residences switch to CFLs.