Future Energy: Opportunities and Challenges

Part IV. Creating Sustainable Energy

Chapter 22. Summing Up

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Summing Up

Previous chapters should have made it clear that the transformarians (whom we met in Chapter 1) have a lot of work to do. Four issues drive the urgency of transforming our energy habits:

1. The world's population will increase by an estimated 50 percent in coming decades.

2. Oil is running out.

3. Climate change concerns will constrain the use of fossil fuels.

4. Replacing traditional energy sources with sustainable sources will be slow, difficult, and expensive.

Previous chapters should also have made it clear that effective planning requires quantitative analysis of the current and future possibilities for dealing with energy issues. The performance of energy-producing and energy-consuming systems depends on the underlying science. The science is well established, well understood, fully verified, and, for the most part, quite simple. The science tells us what is possible and, probably more important, what is impossible. Science provides a framework into which we can insert real-world data and draw conclusions. But the science is only part of the story. The technology used to exploit the science determines whether an implementation is practical.

As populations grow and lifestyle expectations increase (especially in developing countries), energy needs will grow. This growth will outrun any reductions in energy consumption achieved through conservation and improved efficiency in energy production and consumption. America can certainly reduce its energy consumption through conservation and improvements in energy efficiency, but, because of growing consumption elsewhere, this will have little impact on total world energy requirements.

A major shift in the global energy consumption pattern started around 2000 when energy consumption in China began a rapid increase. Chinese energy consumption surpassed U.S. consumption in 2009. This book focuses on energy in the U.S., but China's increasing appetite for energy influences every country through its impact on fuel cost, resource availability, and climate change. Energy consumption in India is also expected to grow rapidly in the twenty-first century. The emergence of these countries as major energy consumers illustrates that energy is a global issue.

Oil production in the U.S. peaked around 1970, and a dependence on imports has evolved, leading to a huge transfer of wealth to exporters and vulnerability to supply curtailments. Now, even the future availability of foreign oil is uncertain. Analysts say the world has used one-third to one-half of the recoverable oil that was originally in the ground. The oil already withdrawn has satisfied the world's energy appetite for over 100 years. But, because of the exponential nature of demand growth, the remaining reserves will not last nearly as long. The era of cheap and plentiful oil will be over in decades rather than centuries.

Natural gas has evolved from a nuisance to be eliminated by burning to a treasured energy source. The change came about when pipelines were built to carry gas from wells to users. America's natural gas reserves include so-called unconventional deposits. These reserves are huge, but extraction requires the fracturing of underground, gas-bearing rocks. This is a complex process, with the potential for the release of harmful chemicals into the water and air. Nevertheless, unconventional gas already provides a significant portion of America's gas, and further increases are anticipated. It is not yet known whether environmental and health issues will limit the production of unconventional gas or require changes in drilling technology.

Coal, oil shale, and oil sands contain a very large quantity of recoverable energy. Coal use has several major drawbacks, including carbon dioxide release, pollution, and the undesirable consequences of mining operations. Producing fuel from oil shale or oil sands faces cost and environmental protection issues. Using its large reserves of coal and oil shale would help reduce U.S. dependence on foreign energy sources, but cost and environmental concerns may limit production. Canada faces similar issues with its reserves of oil sand.

There are still those who claim that either climate change is not occurring, or, if it is, it is a natural phenomenon that is unrelated to human activities. There is no uncertainty in the science that relates climate to atmospheric gases such as carbon dioxide and methane. There is also no doubt that human activities result in the release of these gases into the atmosphere. Finally, there is no doubt that atmospheric carbon dioxide and the earth's average temperature are increasing. The overwhelming consensus among climate scientists is that human activities are causing climate change, and curtailment of releases is necessary to prevent unacceptable consequences.

A transition to sustainable U.S. energy will require a huge shift in our energy infrastructure. The technologies that can (and almost certainly will) contribute to weaning America from fossil fuel dependence are solar heating, solar electricity, biofuels, wind energy, hydroenergy, geothermal energy, and nuclear energy.

Solar energy can be used either directly or indirectly, through other energy forms that derive their energy from sunlight. Biofuels, wind, and hydroenergy are all resources that get their energy from the sun.

Solar heating involves collecting solar energy and, in some cases, storing it for later use. Solar collection schemes range from architectural designs that optimize solar home heating in winter to solar collectors that are constructed to maximize energy capture.

Several methods exist for producing solar electricity. Since solar electricity systems can operate only when the sun is shining, provision must be made for providing energy by other means when solar energy is unavailable. Photoelectric devices can produce electricity in small-scale applications (such as private homes) or in large solar farms with thousands of square feet of collector surface. Photoelectric system use is growing. Costs are still high, but they are dropping. Solar heat engines can also serve as large-scale electricity producers. Solar energy may be used to boil a fluid that drives a turbine-generator or power a Stirling engine or (more speculatively) to heat air that rises through a tall chimney, driving a turbine-generator along the way.

Biofuels such as ethanol, butanol, and biodiesel are potentially important replacements for oil-based fuels. The major limits on biofuel production are determined by total suitable land availability, competition with land use for producing food, water usage for growing plants, and effects on soil fertility. Plants store chemical energy derived from solar energy during photosynthesis. It is quite simple to calculate the possible range of stored energy per acre of land used to grow plants. This type of calculation shows that biofuel can contribute significantly to future transportation fuel needs, but cannot yield as much energy as is currently obtained from oil-based fuel because of the acreage required. Satisfying transportation energy needs will require a major shift to electricity. Batteries or fuel cells can supply electricity for transportation by using grid electricity to create chemical energy that can be converted back into electricity when needed.

Wind possesses kinetic energy that can be captured by wind turbines. Like solar energy, wind energy is also intermittent. Huge turbines with electric power outputs as great as seven megawatts are being installed, usually in large wind farms. The best locations for wind farms in the U.S. are in Midwestern states and along some coastlines. For wind energy to achieve its full potential, new transmission lines must be built from producer regions to user regions. Building coastal installations (generally off-shore) depends on overcoming cost, durability, aesthetic, and environmental concerns.

Hydroenergy is the energy in moving or falling water. Hydroelectric dams exist throughout the U.S., but suitable sites for large hydroelectric systems have all been used. However, contributions to future electricity needs could be made using smaller dams, natural elevation changes in rivers, river current turbines, ocean current turbines, tidal energy converters, and wave energy converters.

Geothermal energy may be the dark horse in the race to sustainable energy. Enough energy to satisfy all human needs is contained in hot rocks located within six miles of the earth's surface. In some locations, hot rocks exist near the surface, and there is a natural source of water that picks up heat from these rocks. These formations, called hydrothermal sources, are already being used for producing electric energy in some locations. However, the energy in hot, dry rock is many times greater than the energy in hydrothermal formations. The trick to exploiting hot, dry rock is to fracture it (to permit fluid to flow through it) and to introduce a fluid (generally water) to carry heat to the surface. These geothermal systems are called enhanced geothermal sources or engineered geothermal sources. The problem of modifying huge volumes of underground rock and supplying adequate and controlled quantities of heat transfer fluid is daunting, but the potential reward is great.

Nuclear reactors that employ fission of heavy nuclei now produce about 20 percent of America's electricity. Reactors in the U.S. have operated safely for many years, and new designs have additional safety features. In 2011, just as a consensus seemed to be developing that nuclear reactors are safe, practical, and necessary, the catastrophic accident occurred at the Fukushima power plant in Japan. The Fukushima accident has rekindled concerns about reactor safety and casts doubt on a resurgence of the U.S. nuclear industry.

Fusion reactors, based on the fusion of light nuclei, are a potential huge energy source for the future. However, building a practical fusion reactor is a much larger challenge than building a fission reactor. Decades of research have provided a good understanding of the physics involved, but the design and construction of an operable reactor are yet to be done.

Energy transport is the movement of energy resources or energy carriers (such as electricity) from their source to the sites where they are used. Pipelines provide the most efficient means for transporting liquid and gaseous fuels. If biofuels and/or hydrogen become important, their transport by pipeline will require major new construction. Trains, trucks, and barges can be used for transporting coal, liquid fuels, and gaseous fuels within the U.S., but the use of trucks is much less energy efficient than the other options. Intercontinental transport of liquid and gaseous fuels requires special ships.

Expected increases in the use of electricity will require increasing the capacity of the electrical grid by new construction and by implementing Smart

Grid technology. Required grid capacity can be reduced by local electricity production, such as by solar or wind power systems, but overall it is clear that expanding the electrical grid, as well as the remainder of the energy transport system, will be expensive but necessary.

All the technologies mentioned above are likely to play a role in satisfying future energy needs. The relative importance of each technology remains uncertain. It is clear, however, that energy issues will result in major impacts on our personal habits, our business practices, and our government policies.

The story told in preceding chapters should make it clear that we face problems in supplying future energy, but we have the means to deal with these problems. What will be needed is commitment, informed decision-making, and hard work.