Future Energy: Opportunities and Challenges

Part I. Getting Started

Chapter 1. Introduction to the Energy Story

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1
Introduction to the Energy Story

1.1 The Energy Issues

Harnessing nature's bounty of energy has enabled humanity to exist in great numbers and to prosper. Throughout history, changes in energy production and use have occurred as technological innovations created new opportunities. However, it is now clear that continuing current practices and trends in energy production and use cannot continue unchanged.

The energy question revolves around two goals: providing enough sustainable energy to satisfy human requirements, and ensuring that supplying this energy does not result in unacceptable environmental consequences. Accomplishing these goals will require informed decisions about what to do and how to do it. Currently, opinions vary on the best path to follow.

1.2 Three Viewpoints

At one extreme of the energy debate are those who say that concerns about energy resource depletion and environmental effects are unfounded. They feel that energy will be available as needed and that environmental effects associated with using it are acceptable. They see no need to embark immediately on radical changes in energy production and use. Following the example of Deffeyes[1], I will call them cornucopians.

There are also those who say we must quickly and radically change our energy habits and policies because of fossil fuel depletion, environmental effects, cost, and achieving or maintaining world peace. They believe energy habits and policies from the twentieth century are unwise, unsustainable, and unnecessary. They are generally in favor of transforming to greater reliance on conservation and renewable energy to create a sustainable condition. I will call this group the transformarians.

A third, smaller group believes there will be a world-wide crisis caused by the unavailability of energy and by environmental degradation regardless of what we do[2]. This is the dystopian view of the future. I will call this group the futilitarians.

Proponents of each of these positions make detailed arguments for their stance. Basically they look at the same data and draw different conclusions. It may be argued that the proponents of each position are influenced by their political and philosophical persuasions as well as by their assessment of technical issues.

Many proponents of all three viewpoints remain convinced of the validity of their position. It is now clear that the cornucopian viewpoint is inconsistent with finiteness of resources, environmental effects, and the unlikely prospect of developing totally new energy technologies. The futilitarian approach is unacceptably defeatist. Transforming to a new era of energy supply and use is essential for America and the world.

In following the transformarian approach, it is important to make the correct transformations. To do so requires some familiarity with technical issues. Discussions about technology with individuals who are not familiar with the underlying science are difficult. Such is the case in discussions about energy. Non-specialists may even question whether they need to make an effort. If the lights come on, why ask about how electricity works? In the case of energy, there are very good reasons for the non-specialist to want to understand the science and technology. Technical and political decisions made by governments, businesses, and individuals will certainly influence our economy, our health, our comfort and convenience, and whether we suffer war or enjoy peace. Everyone has a stake in the energy game.

Every energy production means has undesirable side effects. Decisions about future implementations must consider the trade-offs between benefits and side effects.

1.3 Success Stories

In assessing what is possible in transforming energy use, it is helpful to examine serious efforts that have already taken place. Four countries are especially noteworthy for their efforts to reduce reliance on fossil fuels.

Brazil has eliminated the need for fuel imports by transforming from oil-based fuels to ethanol for transportation fuel. Brazil took advantage of its huge capability to grow sugar cane and built the infrastructure to manufacture ethanol and use it for transportation needs.

Iceland is another interesting case. Iceland has a small population, whose electrical and heating needs are largely supplied by ample hydroelectric and geothermal resources. Iceland is now converting from oil-based transportation fuel to hydrogen produced by the electrolysis of water using its cheap electric power.

France, with negligible domestic fossil fuel resources, has moved aggressively to nuclear power, which now satisfies over 80 percent of its electrical energy needs.

Portugal has no fossil fuels, but has ample hydroelectric, wind, and solar energy production capabilities. Through strong government action, Portugal increased its renewable electricity production from 17 percent in 2005 to 45 percent in 2010.

All four countries have successfully transformed their energy systems to reduce the use of fossil fuels. Each case is very different and extrapolation to applications in other countries where resources, requirements, and attitudes are different is inappropriate. Nevertheless, these cases show that huge transformations are possible where the will to act exists.

1.4 Getting Energy

The energy available in the thin husk of the earth where humanity lives and captures energy is almost all nuclear in origin. Nuclear fusion-generated energy from the sun heats the earth directly and can also be used to produce electricity with solar cells or solar thermal systems. Solar energy enables plants to grow and causes wind and precipitation. Radioactive decay of elements in the earth causes heating in the depths.

Modern society currently relies on fossil fuels for most of its energy. The energy in fossil fuels is the result of the capture of solar energy by plants that lived long ago. The remains of plants and animals (which were directly or indirectly dependent on plants for food) were buried under sediment. These materials underwent chemical changes when subjected to high pressures and temperatures that occurred when they were buried deep in the earth for millions of years. The result is fossil fuels: natural gas, coal, and oil. The use of fossil fuels releases solar energy that was stored in biomass long ago and also releases chemicals into the atmosphere that were previously trapped in the earth. The main concern is the conversion of trapped carbon into atmospheric carbon dioxide, which is thought to contribute to global warming.

We have come to depend heavily on fossil fuels because of their convenience of use in applications related to modern living. But the energy stored in biomass long ago and now contained in fossil fuels is a finite resource that is being depleted steadily. Of course, we use the cheapest, easiest-to-obtain materials first. As a resource becomes scarce, we accept the higher and higher costs associated with more difficult acquisition, but eventually these increased costs force us to consider other energy sources that were previously uneconomical, unknown, or inadequately developed.

The most recent major addition to our energy resources menu is nuclear fission in rare, heavy elements, such as uranium (naturally occurring) and plutonium (produced in nuclear reactors). Another potential nuclear energy source, nuclear fusion, produces energy by combining light elements at very high temperatures, but this source is not yet practical because of technical difficulties.

The next chapter in the energy story will involve a different mix of energy sources than we now use. Fossil fuels will see continued use, but will represent a decreasing fraction of total energy production. Nuclear systems are capable of contributing significantly, but their future is uncertain because of the impossibility of predicting the outcome of the controversy about nuclear safety vs. benefits of clean nuclear power from domestic resources. Candidates for increased implementation are biofuels, solar energy systems, wind turbines, hydroenergy systems, and geothermal energy systems. Most of the science underlying these energy sources is old and well-established. But knowing the science does not ensure that large-scale implementations are feasible, practical, or sustainable. Much remains to be done before new energy sources can make a major contribution to our energy supply.

Creating a sustainable energy future requires that we consider all available sources and implement use patterns that are sustainable in terms of continued energy availability and protection of the environment.

1.5 Energy and the Environment

The current use of energy technologies impacts our environment through the release of gases (most notably, carbon dioxide) and pollutants. Scientific evidence indicates that atmospheric carbon dioxide contributes significantly to global warming. Some contend that the manmade contribution to climate change is insignificant compared to naturally-occurring effects. As we shall see in Chapter 19, the informed consensus is that manmade emissions are a real problem and must be minimized.

1.6 Making the Transformation

Transforming to a sustainable energy future will require a move away from fossil fuel use and towards reliance on biofuels and on electricity from solar, wind, hydroenergy, geothermal, and nuclear sources. Transportation must increase its reliance on energy from electricity and biofuels. Heating applications must switch to greater use of electricity, direct solar heating, geothermal sources, and biofuels.

Bioenergy production is limited by the large requirement for land to grow dedicated energy crops or to provide agricultural scrap material for collection. Wind and solar systems can produce great quantities of electricity, but both will require massive construction projects. They will also require the commitment of large land areas, but the land requirements could be met with areas unsuitable for agriculture and in locations where coexistence with current use is possible.

Most suitable sites for large hydroelectric dams have already been used. Smaller dams and river diversions, river and ocean currents, waves, and tides are potential suppliers of significant future energy, but exploiting these sources depends on overcoming major technical and/or financing obstacles.

Geothermal resources, defined by hot rocks within about six miles of the earth's surface, are huge, but accessing the energy will require successful major implementation of new drilling and rock modification technology.

Nuclear power from fission reactors can provide electrical energy for many years, especially if breeder reactors are employed. The reserve of uranium needed for fission reactors is large, but this too is a finite resource. Fusion reactors are theoretically capable of supplying huge quantities of energy, but development of practical designs remains a challenge. The nuclear safety issue (including reactor safety and nuclear waste handling) will be a factor in determining the extent of nuclear energy use in the future.

Overall, it is certain that providing adequate energy in the future will be difficult, in the near term (decades) and the long term (centuries), and that no single technology will be sufficient.

Now consider energy consumption. Highly developed societies currently have huge energy appetites. For example, the U.S., with less than 5 percent of the world's population, consumes about 20 percent of the world's energy. Increasing world population and increasing demands from countries that move from underdeveloped conditions to fully developed conditions will increase world energy demand and competition for resources. Reducing per capita consumption by improving the efficiency of energy use can ease the strain on resources somewhat but cannot eliminate the inevitable need for more energy.

1.7 Preparing for the Energy Future

Energy is the key to achieving and maintaining modern societies. At one extreme, sufficient energy enables comfort and prosperity for large populations. At the other extreme, insufficient energy limits the possibilities for peace and survival. Failure to prepare for tomorrow's energy needs is hugely irresponsible. Subsequent chapters will provide the essential information needed to make informed decisions about our energy future.

In these chapters, data are presented for energy production and consumption. The purpose of presenting these data is to provide a snapshot of how we now produce energy and how we use it. The data should be viewed as representative rather than absolute. Data often are not available for every year, and different sources often report slightly different values for the same quantities. Furthermore, production and consumption change as economic conditions change, as resource availability and cost change, and as new technology is implemented. Nevertheless, one must understand current conditions before addressing the future.

References

1. Deffeyes, K. S. Beyond Oil New York: Hill and Wang, 2005.

2. http://dieoff.org