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Brian C. Black

Alternative Energy

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Alternative Energy

Brian C. Black and Richard Flarend

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Now that it is complete, Geneva, Chadric, Ben, and Sam, let's go find a corn maze!

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Introduction: Conceiving of Alternative Energy

"There are times in the history of our nation when our very way of life depends upon dispelling illusions and awakening to the challenge of a present danger." The middle-aged, white American male who is speaking pauses in what seems an intentional effort to elongate the surreal moment. He does not pause because of the moment's oddity—the fact that he stands as Al Gore, mere global citizen, not a candidate for any public office, let alone for U.S. President as he did in the 2000 election. All of that is odd; however, the moment becomes surreal, because, in fact, the world is listening to what he has to say. In fact, in an era when reality is fleeting and on an issue in which scientific truth is difficult to locate, his words are sage.

Thanks to the remarkable success of the film *Inconvenient Truth* and a shared 2007 Nobel Peace Prize, Gore has by this point in July 2008 become a figure of unparalleled international influence on issues related to climate change and the environment. It is a big stick that he swings selectively and with great care. Thus, his pause can only be explained by the fact that he truly does believe the human species, and particularly its American variation, is at a crossroads. In fact, similar to a gambler, he has taken his public capital as a forward-looking problem solver and placed the proverbial stack of chips all in on one issue.

After listing many sociological, climatic, and weather issues facing the nation, he arrives at the crux of what has brought him before the world community: "If we grab hold of that common thread and pull it hard, all of these complex problems begin to unravel and we will find that we're holding the answer to all of them right in our hand. The answer is to end our reliance on carbon-based fuels."

Gore has learned to use a scientist's specificity when discussing such issues. Therefore, his address made his purpose very clear when he continued:

> That's why I'm proposing today a strategic initiative designed to free us from the crises that are holding us down and to regain control of our own destiny. It's not the only thing we need to do. But this strategic challenge is the lynchpin of a bold new strategy needed to re-power America.
>
> Today I challenge our nation to commit to producing 100 percent of our electricity from renewable energy and truly clean carbon-free sources within 10 years.
>
> This goal is achievable, affordable, and transformative. It represents a challenge to all Americans—in every walk of life: to our political leaders, entrepreneurs, innovators, engineers, and to every citizen.
>
> A few years ago, it would not have been possible to issue such a challenge. But here's what's changed: the sharp cost reductions now beginning to take place in solar, wind, and geothermal power—coupled with the recent dramatic price increases for oil and coal—have radically changed the economics of energy. (Appendix 4)

Before he had even left the stage/bully pulpit, a significant portion of the media was already dubbing him an alarmist whose plans would cost the United States billions. In the balance, they argued, was America's standing in the world: an economic place largely built on the transformative effect of burning cheap fossil fuels during the last century. Gore and his advocates, though, say that the international standing of the United States is one of the primary reasons to shift to alternative power—before we are left behind by nations that do so.

How will history view Gore and his vision of the future? Only time will tell. The following pages, though, demonstrate that in July 2008 Gore's campaign became one of the most recent chapters in a critical debate over energy that has endured throughout the existence of the United States. How should Americans power their future? Are we poised at a transformative moment in energy use? What amount of economic cost and discomfort is reasonable to endure in such a transition?

Beavers build dams. Just as apple trees bud and flower as part of making their way to leafing and, eventually, bearing fruit, a beaver needs to control the waters that flow around the landscape in which it resides. In the colonial New England of the 1700s, among other locales, when hunters reduced the population noticeably, the beavers' absence was reflected by the region's rivers and streams, which were marked by intensified runoff and flooding. Beneath the Earth's crust, earthworms aerate dirt. The soil's health and its content of specific nutrients can be traced to the preponderance of earthworms. In bays and wetlands, oysters filter water. Their decline in brackish locales such as the Chesapeake Bay directly impacts the overall water quality of the estuary.

These are just a few examples of the dynamic interchange going on all around us, between humans and the natural environment in which we reside.

As humans, we often hope that we are exempt from such patterns and the restraints that they can demand. We have spent generations seeking to prove the exceptional quality of our species. By using technological innovation, humans have been able to overcome many natural constraints. Particularly in the United States, we have even been able to employ fabulous examples of engineering innovation to mitigate one of the most dramatic changes in human life over the last few centuries: population growth.

Particularly in the American system of capitalism, accommodating population growth has gone hand in hand with economic development. For some, the outcome of such effort has been great profit. For most, the outcome has been a stable, middle-class existence at a remarkably high standard of living (relative to other nations). An overarching priority in this society was on *doing things.* We realized that if we concentrated our technologies on achieving things, such as making cars or electricity, the market would allow consumers to eventually reap the benefits as well.

Today, a host of issues and complexities demand that we focus our spirit even more minutely not just on doing things, but on creating innovations that help us to *do things well.* What, though, does it mean to do something well? Ultimately, this book will suggest that the response must be one that takes into consideration the constraints of nature. We must not forget that the beavers, earthworms, and oysters do not forget their role in larger patterns and systems. They neither exceed their duties nor forget to carry them out. Therefore, our approach to comprehending this transition in American life begins with the reality that humans require energy—a necessity for accomplishing the things that we need to; however, this is not the end of our deliberations. The need to do these things well means that our question does not stop with just the necessary energy to complete the task. Instead, our line of inquiry must expand to include issues such as how to continue to create profit and development while also using methods that do little or no injury to humans, and that can be sustainably used in the future. Judged by such a standard, not all sources of energy are created equal.

Our contemporary search for improved sources of energy will be the subject of the latter chapters of this book. The earlier chapters, however, set the context for this consideration by telling the tale of development and expansion that has steered us down a different path for the last few centuries. This book begins with the initial premise faced by oysters, worms, beavers, and any member of Earth's ecosystem. As ecologist Aldo Leopold writes, "[That] man is, in fact, only a member of a biotic team is shown by an ecological interpretation of history. Many historical events, hitherto explained solely in terms of human enterprise, were actually biotic interactions between people and land" (Leopold, *A Sand County Almanac,* 78). Our inherent need for some energy is just such a biotic interaction.

Although humans have many innate and ingrained interactions with the natural environment, this volume is organized around just one: Humans use energy. As a species in our own right, humans can be studied, grouped, and categorized. No matter where they live, humans share certain traits and patterns. For the entire existence of the human species, we have used and participated in natural cycles of energy. There is clearly continuity in human living, simply in our own biological processes of breathing, producing waste, aging, and dying. Energy fits into this category, because all humans participate in natural energy cycles that exist all around us. However, energy use is not static or consistent. Variations in energy use among different human cultures and eras provide important and revealing distinctions. These have provided historians and scientists with one method for organizing the human past. A portion of this story is suggested by historical terminology, such as the Iron Age and the Stone Age.

Within these broader categories, of course, are smaller-scale variations that might be attributable to region, ethnicity, or nationality. Humans also acquire traits, and adapt and change over time. These might be minute forms of culture, such as hair length or music, but it might also take larger, macro forms such as modes of travel and reproduction. In short, there are certain things that humans do—some of them we must do (such as to breath) and others we choose to do (such as to hit a tennis ball with a racquet). The latter choices are always an indication of our culture, which is considerably influenced by the time period in which we live.

In certain cases, a basic detail of human life, such as energy use, might be significantly influenced by its surrounding culture. Some of these cultural details, however, become so pervasive in our lives that we cannot imagine a life without them. Still, they remain traits added to the human species by a certain time and certain expectations of a standard of living. The use of energy is just such a trait of human life in the 21st century. In fact, just as spokesman Gore reported above, many indications suggest that humans at the dawn of the 21st century are at a critical energy crossroads. One can glimpse this juncture from a host of overlooks involved in bringing us the energy supply we demand.

For instance, few sites seem more unnatural than an open-pit coalmine. A massive, man-made valley, the mine is most identifiable by the corkscrew-like roads that spiral down its perimeter in order to connect the Earth's surface with the bottom of the man-made hole, where the coal is being extracted. There is a cartoon-like quality to such a scene, because each detail appears magnified beyond anything seen in our everyday life on the Earth's surface:

dump trucks with tires as tall as a four-story building and shovels with a scoop seemingly able to contain an entire city block at once. This coal, of course, is brought to sites all over the world in railroad hopper cars or the holds of ships to endure a very simple but oh-so-magical transformation: to be burned at power plants and, thereby, to force each chunk of coal to release its vaunted power, gathered over centuries. A remarkable technology of circuits, transformers, and wires then moves the coal's energy into every nook and cranny of our lives.

Belying these unnatural, industrial beginnings, the later portions of the energy's lifecycle, of course, seem entirely natural to us: electricity so flexible that we can use it to toast a Pop Tart, move the waving arm of a decorative Santa on our lawn at Christmas, or keep frozen a pizza that we can have ready at a moment's notice. Although each use of energy is familiar, it is also artificial—a component of the lifestyle we have constructed using cheap energy. For the purposes of this book, we must begin from the basic assumption that all of our uses for energy—whether for the colossal engine that drives the great digger that rips the coal from the bowels of the Earth, or for the rechargeable battery that, once filled, fuels your electric toothbrush—are part of nature. No matter how unnatural they might seem.

The Earth had energy before it had humans. There has been life on Earth for at least three and a half billion years, and over this time, there have been significant changes in the way energy is used. At the basic levels of life, living things likely obtained energy from organic molecules that had accumulated in their environment. The real energy transactions, though, began with photosynthetic autotrophs that eventually evolved the capability to capture energy from sunlight. These beings slowly gained the ability to escape the limited niches in which they lived. Their complexity increased, and autotrophs made a place for heterotrophs, which use energy already captured by autotrophs. This energy system continues to organize and, indeed, to power the natural environment. In a basic sense, systems of energy organize each of the occupants of the world around us.

Therefore, as consumers of energy, humans have found their existence to be organized by these patterns throughout history. This can seem a vague notion, because energy is not an object that can be picked up and held—it does not occupy space. Instead of being defined in terms of what it is, energy is defined in terms of the work it can do. The scientific definition of energy is the capacity to do work and transfer heat. Work can be boiling water or sawing a log; however, energy is also the heat that flows automatically from a hot object to a cold one when they come in contact.

In its use by humans, energy-harvesting methods have taken many forms, beginning with the use of fire and the plants grown by the Sun's energy.

Although many observers do not categorize it as energy use, of course, agriculture is the conversion of the Sun's energy into food that humans can eat. The process of converting this energy is referred to as photosynthesis. Over 99% of the energy used to heat the Earth and all our buildings come from the Sun. Photosynthesis began with small plants absorbing its energy. Based on fossil records, scientists believe blue-green algae first employed the two-stage process that was eventually handed down to green plants. Photosynthesis has a simple outcome: carbon dioxide reacts with water through energy from light, fixing carbon, and releasing oxygen; and a portion of the energy remains captive as long as the carbon and the oxygen remain apart. Plants release this energy through their various metabolic processes (Starr and Taggart, 1987). The following pages tell the story of humans' relationship with energy production, starting with these most basic of natural principles.

Chapter 1 will discuss the basic laws and structures of the Earth's supply of energy. Most important, though, is that the amount of available energy can't increase. The systems and cultures using the various forms of energy adjust over millennia, finding energy overlooked previously; however, new energy can never be created. During the Earth's geological history, the impact of photosynthesis broadened as more and more plant life took advantage of the Sun's energy. In addition, energy supplies grew as stockpiles in living matter. These energy stockpiles were then stored when carbon from once-living matter was buried, in ever-so-tiny increments, under the surface of the earth—in deposits that became the fossil fuels coal, petroleum, and natural gas, as well as in sedimentary rocks containing calcium and magnesium carbonates derived from shells. These carbon-based, fossil-fuel resources lay dormant until humans found a method for harvesting them and converting their potential energy into kinetic forms, primarily heat.

Of all the carbon that has played a part in Earth's various life processes, very little has been separated out and held apart in this way; therefore, over the course of millions and millions of years, the stores grew massive. More and more carbon wound up under the ground, with a greater and greater amount of oxygen in the earth's atmosphere. This separation of carbon and oxygen from a primeval atmosphere in which carbon dioxide and water were relatively abundant represents a vast accumulation of solar energy from the past. This savings account would benefit humans during the industrial era to an unprecedented degree.

It was the harvest of these energy-producing beings—whether plants or animals—that first involved humans intimately in the Earth's energy cycle. During the hunter-gatherer phase, and even after that of the agricultural revolution, humans had a limited impact on the Earth's biological systems. In short, there is every indication that humans could very likely have continued to live in this fashion in perpetuity. But the human population changed significantly after the 1700s, both in number and in its prevailing living patterns. Energy use provided the lifeblood of this new way of life.

We live in the human era defined by its industrialization. During this era, the human relationship with energy became expansive. Prior to this era, virtually all energy was renewable energy—a recurring, inexhaustible power source. In many cases, these sources of energy were transformed into relatively complex forms of work in their application by humans to many activities. These societies were defined by what they asked of the sources of power that they knew. Historian John R. McNeil refers to this structuring characteristic of human life as each society's "energy regime." McNeil defines such a regime as "the collection of, arrangements whereby energy is harvested from the Sun (or uranium atoms), directed, stored, bought, sold, used for work or wasted, and ultimately dissipated" (McNeill, 2001, 298).

Such choices about which resources to utilize and in what fashion to use them are controlled by ethics, which are often cultural characteristics held throughout a specific society. A society's choices about energy reveal a great deal about it. In his recent book *The Hydrogen Economy,* Jeremy Rifkin writes:

> Energy is the elemental force and the medium upon which all human culture is built. And, yes, human history shows a marked increase in both the flow of energy and the complexity of social institutions needed to accommodate that flow. (Rifken, 2003, 42)

As societies then attempt to facilitate and integrate specific regimes, we move from the systematic level and begin to see the ground-level stories of human culture—the ways that energy ethics influence consumers—us—in our everyday lives.

Particularly in examples such as the United States, the ethics with which we use nature have broad implications. Historian David Nye writes that the energy systems a society adopts create the structures that:

> . . . underlie personal expectations and assumptions about what is normal and possible. . . . Each person lives within an envelope of such "natural" assumptions about how fast and far one can [go] in a day, about how much work one can do, about what tools are available, about how work fits into the community. (Nye, 1999, 7)

By themselves, these decisions and the machines that they inspire, adds Nye, do not make history. He argues against technological determinism, instead suggesting that consumers can play a prominent role in managing, and even to some extent guiding, what he calls the "technological momentum" of a specific era. "Energy choices are social constructions that often appear to be inevitable once they acquire technological momentum," he writes (176).

Today, our lives have been witness to such an era—when fossil fuels dropped in price and grew in availability to the extent that we could apply cheap energy to nearly every facet of our life—from brushing our teeth to making our dessert Twinkies, one of the highest-energy foods created in man's history. We are creatures of a high-energy lifestyle never seen before in human history.

The phenomenal growth during the 20th century was largely made possible by energy harvested from one-time, non-renewable sources. Historian Al Crosby described our approach to energy management from a macroscopic level, in *Children of the Sun,* in this fashion:

> In the past two centuries we have been burning immense, almost immeasurable, quantities of fossilized biomass from ages long before our species appeared. Today, as ever, we couldn't be more creatures of the sun if we went about with solar panels on our backs. (Crosby, 2006, 5)

Our unsustainable lifestyle has become clear to more consumers than at any other time in American history. In the estimation of Crosby, Gore, and many others, our energy binge is nearing an end. It being impossible to say when the end of this high-energy life will come, we are, instead, left to use a flexible, general term for where we live: an "energy transition."

This transition means that, once again, the basic ways that we do things are in play—available for change. Similar to eras seen in the 1820s, 1870s, and again in the late 1890s, energy transitions occur when a society, much like a business, seeks to re-mode itself to take advantage of improved, cost-effective, or more practical ways of doing things. Interestingly, at this moment in history, Americans are returning to energy sources that pre-date cheap fossil fuels, like sunshine, wind, water, and plants. Only now, new technology allows us to use these raw energy sources in ways that were never before imagined. In fact, as soon as one begins to administer energy under the guise of sustainability and *doing things well,* the topic must turn to alternative energy.

This volume looks at one specific segment of this transition: alternative forms of energy. Many experts believe these methods for harvesting energy promise the most likely paradigm for future development. Or, at least, they represent a segment of our energy use that must slowly—and strategically—expand and incrementally replace our use of fossil fuels. As one begins to forecast the future of alternative fuels, he or she can't help but also cast a look backward to the history of such energy sources. With even a passing glance backward, it becomes obvious that there is a long and complex history related to the emergence of alternative energy. Often, these are very old technologies used in a new fashion. Most important, contained within the very terminology of the name of these sources of power is their basic reality: To what are these energy sources an alternative?

Fossil fuels, which currently supply about 85 percent of our energy, are all concentrated in locations that are out of view of the general public. The environmental impact of extracting these energy sources goes unseen, not to mention that most waste emissions are dumped into the atmosphere and rivers in invisible amounts—but not with invisible harm. The economic and environmental costs of these emissions, not to mention the societal impact of this extraction of energy, is not factored into the consumer cost of electricity or gasoline. Therefore, the chain of connectivity between the extraction and supply of energy to society and the resulting negative impact on society is broken. Many scholars have sought to create a more complete accounting of energy production. In short, to prove the point, a single place must currently absorb or suffer from much of the cumulative environmental or social effects caused by the extraction of energy. This out-of-sight-out-of-mind pattern misleads the public, particularly when that impact is exerted mostly upon regions distant from the populations that reap the benefits of the energy created.

New ideas in energy accounting take these impacts into consideration and, thereby, provide even more substantiation to alternative methods of creating power. Finally, the pollution or end product of each method has also begun to be used as a quantifiable entity. Many experts believe that using carbon accounting to add these costs to fossil fuels will make alternative sources even more competitive in the energy marketplace. Many are now promoting the idea of knowing what you eat by being familiar with where and how the food you eat is grown or produced. Similarly, the public needs to be aware of where their energy comes from and what impact the entire fuel chain has on land use, the environment, and the unintended impacts upon human health.

In this volume, we will demonstrate how such an accounting process can make alternative energy much more viable and cost-effective than those sources on which we now rely. However, we also must factor in that most renewable sources would require the construction of infrastructure in addition to that already built and maintained in order to take advantage of the flexibility found in hydrocarbon-based power.

By contrast, most renewable resources are spatially concentrated and immobile. This lack of flexibility has contributed to the public resistance that such development has encountered at various sites. Renewable resources are presently confronted with systemic limitations that are very similar to those that befell other resources earlier in their usage. In the case of fossil fuels, we found technical solutions to their problems with location and use; now we must do so with alternatives as well.

Although many societies in the world still depend heavily on renewable energy, the ideal of development during the 20th century came to embody a vision of progress based on non-renewable sources of power. Our intention in this volume is to provide some basic information about why the 21st century demands a different paradigm. We will do that by also providing historical context to help us understand the formation of our high-energy existence.

Will Al Gore's call for Americans to cease their use of fossil fuels within 10 years be viewed as the turning point in our energy transition? It is possible. On the other hand, we believe it is certain that American consumers will have a great deal to do with any such transition. This volume is meant to help each of you make more-informed decisions about your energy choices.

1

Human Society's Need for Energy

Energy and fresh water are the most fundamental natural resources that any society requires. Everybody needs water and energy to survive. The need for water is obvious: without water, the human body will die within a few days. The need for energy may not be so obvious. In this chapter, we investigate the science behind our need for energy and the technology we use to find and exploit this energy.

ENERGY'S MANY FORMS

Although cars and lightbulbs are nice, we need energy in a much more fundamental way. Energy comes in many forms, from the gasoline to fuel your car, to the electricity used to light up the room in which you are sitting, to the sunshine needed to grow the grain eaten by the cow that provided the milk for your breakfast. So without any energy, our bodies would slowly shut down and we would starve. We also need energy for heat, appliances, transportation, consumer goods, and virtually everything that makes up a technologically advanced society.

Energy costs money, and lately it seems that the price has gotten quite high. So while we may be sad that money doesn't grow on trees, energy does, in a sense. Energy comes from the sun, which can then be absorbed by plants as they grow. So while you won't find a tree growing gallons of gasoline on its branches, gasoline does come from living organisms that got their energy from the sun millions of years ago. Today, we can use a plant's energy, absorbed from the sun, by converting it into ethanol, which is essentially equivalent to gasoline. In fact, all forms of energy, except for nuclear and tidal energy, ultimately come from the sun.

Fossil fuels such as coal, oil, and natural gas come from living plants, tiny organisms such as phytoplankton and tiny marine life such as zooplankton, which died hundreds of millions of years ago and were buried deep in sediment. Once buried in this sediment, the pressure and heat from the earth then chemically converted this organic stew into the various fossil fuels we use today.

Fossil fuels are not considered to be renewable fuels, even though the earth is constantly making new supplies. This is because it takes millions of years to make a barrel of oil, and yet that barrel of oil can then be consumed in a single day of driving. Worldwide, we are now using fossil fuels at a much faster rate than they were deposited so long ago. Today, in just one year, Americans will use the equivalent of several hundred years' worth of organic material that was deposited millions of years ago. Clearly, this rate of energy usage is not sustainable, and fossil fuels will become extinct. To be a renewable energy, the energy must be created as fast as it is used up on either a daily or annual basis, or perhaps even on a century-long timescale for some renewables. Renewable energy, such as solar, wind, and hydroelectric, as well as biofuels such as ethanol, have this quality. For example, ethanol is created from plants that grow during the summer. During the fall, those plants are harvested and stored. During the coming year, the stored grain is converted into ethanol. The whole process repeats each year. (Each type of renewable energy will be discussed in chapter 5).

KNOWING OUR LIMITS

In the long term, it is impossible for more energy to be produced on the earth than the amount of sunlight absorbed by the earth (excluding nuclear and tidal energy). This is explained by the physical law of the Conservation of Energy, also called the First Law of Thermodynamics. It is impossible for anyone to invent a machine or to devise some method of simply making more energy. We just cannot exceed the amount of energy with which nature has provided us.

The world currently uses a total of 460 Quads of energy (one Quad is one quadrillion British Thermal Units). Fortunately, the average amount of sunlight striking the earth annually is about 2.6 million Quads, which is more than 5,000 times the amount of energy currently used by the planet. In fact, using standard solar panels produced today, it would be possible to provide all the energy used in the United States by covering a section of Arizona desert measuring 150 miles by 150 miles.

This would make it seem like energy should be cheap and abundant. But the problem is how to convert this sunlight into a usable form that meets all our needs. The First Law of Thermodynamics also says that we can't convert energy from one form (like sunlight) into another usable form (like electricity or gasoline) at any efficiency higher than 100 percent. In practice, the actual efficiencies achieved by nature or by human technologies tend to be low. For example, photovoltaic solar panels are currently about 15 to 20 percent efficient in turning sunlight into electricity. Plants are less efficient at collecting sunlight and storing its energy within the plants. Corn is less than 0.1 percent efficient. However, plants are very cheap and solar panels can be very expensive. So, just because solar panels are more efficient than plants doesn't mean that solar panels are the most economical choice for collecting the sun's energy.

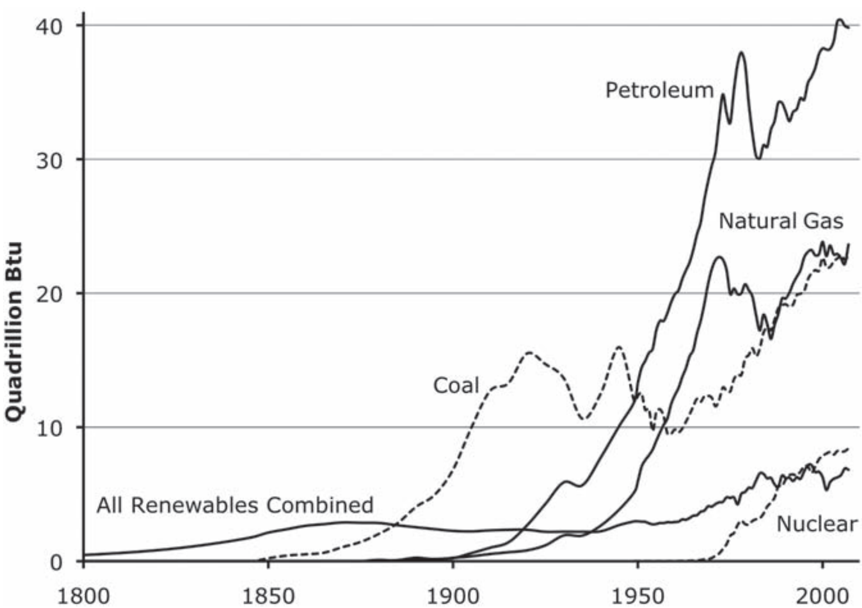
From an economical viewpoint, the cheapest form of energy has historically resulted from allowing trees and plants to grow naturally. These trees could then be harvested for firewood. However, starting in the 16th century, the harvesting of energy from the forests began to be done in a non-renewable manner due to the growing demands to produce iron for the industrial revolution (discussed in chapter 2). The trees were being cut faster than they could re-grow, leading to a shortage of wood and very high prices for wood in many regions. Thus, it became necessary to switch to less-desirable coal whenever possible. However, coal was dirty, and useful for only some energy needs, and could not be used to make iron to feed the blossoming industrial revolution. Thus, coal was used for other purposes by those who could not afford the more-expensive, more-useful firewood. Wood became so scarce in England that, by the mid-18th century, iron production actually decreased, despite increasing demand. When the coking method of using coal to produce iron was discovered in the early 18th century, coal then became used more extensively for iron making.

Another, similar example came with the invention of the lightbulb in the late 19th century. Of course, this innovation produced an immediate demand for electricity, as well as fundamental shifts in society. For example, with the invention of the lightbulb, children could finally be allowed to read at night without fear of fires caused by oil lamps. Following the invention of the lightbulb, libraries around the country suddenly saw a marked increase in readership. Homeowners began to demand electricity from utilities. In many cases, utilities began giving away electric appliances in order to increase demand for electricity and boost profits (Nye, 1992). It can be said that this was the beginning of consumer energy demand. Although this increasing demand will be discussed in later chapters, here is a short version of the progression.

As utilities built power plants, with power lines running into the city, they also tended to build electric trolley lines, which were the beginning of the development of suburban life. More energy was needed to transport workers between home and work in suburbia, and suburban homes tended to be much larger and to consume more energy per residential unit. This suburban distribution of population is one of several reasons why the United States uses more energy than other developed nations today. About the same time in the early 1900s, the first mass-produced automobiles were being sold, which also created a high demand for liquid fuel (petroleum) and tended to shift the population away from city centers. As automobiles became more popular, workers started to ride the more energy-efficient trolleys less and drive less-efficient personal cars more. In some cases, automobile manufactures conspired to put trolley lines out of business in order to increase car sales, and by the mid-1900s, most trolley companies were out of business.

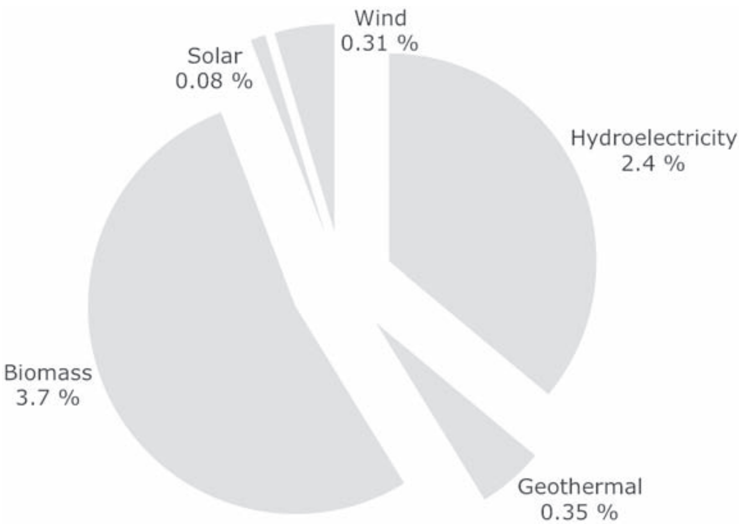
During the century following this, the United States continued to grow, become more prosperous, and increasingly using more and more energy. The main source of that raw energy changed from wood to coal and now to petroleum, as seen in Figure 1.1. There has also been the development of other new raw sources of energy, such as nuclear fission, wind, hydroelectric, and solar, as shown in Figure 1.2. However, these do not contribute nearly as much as

Figure 1.1
Raw Energy Used in America Since 1850



Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

Figure 1.2
Current Breakdown of Renewable Energy Sources and Their Contribution to the Annual Energy Consumed in the United States



Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

the three basic fossil fuels of petroleum, coal, and natural gas. Even all the renewables together do not provide as much energy as nuclear power, which still is used much less than any of the fossil fuels.

Energy is required for everything in society, not just for appliances and transportation. People also need food (an energy form in itself), electricity, and heat for our homes and workplaces. All the various things we buy or consume each day require a certain amount of energy to make. Considering raw materials only, almost everything we come into contact with each day is made of metal, wood, paper, plastic, glass, or ceramic, which all require energy. Some of these are very energy intensive, as seen in Table 1.1, while others are not.

Everything that we do with these raw materials also requires energy, either directly to transform the raw material into a final product or indirectly for the buildings and equipment used by the workers to do their jobs; for example, heating raw plastic or glass to form a finished bottle or powering the lights so that a worker can see to put the final touches on a toy requires energy. Thus, the modern economy is fundamentally reliant on a steady supply of energy. Throughout history, the economic strength of the United States or any other country could be measured by the amount of energy consumed. In order to have a growing economy, we have to have a growing supply of energy. Figure 1.3

Table 1.1
Energy Required per Pound to Produce Various Raw Materials, and the Amount of Energy Required to Produce the Same Material by Recycling

	Energy Required to Make 1 Pound (Btu)		
	From Raw Material	*From Recycled Material*	*Energy Savings (Btu)*
Aluminum	125,000	6,300	118,700 (95%)
Plastic bottles	55,700	6,700	49,000 (88%)
Steel	7,300	1,800	5,500 (75%)
Paper	8,500	3,400	5,100 (60%)
Glass	900	540	360 (40%)

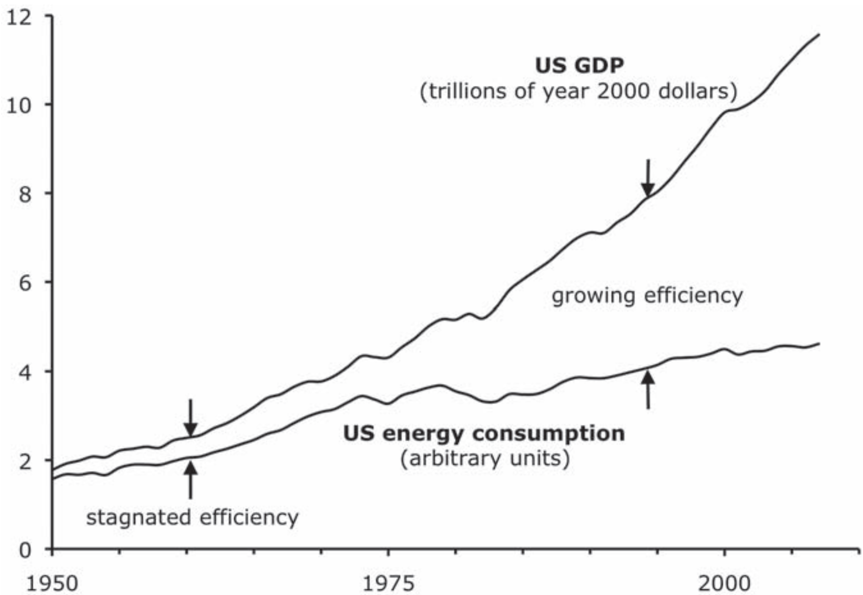
below shows that as the GDP increases, so does the energy consumed. Prior to the mid-1970s, both GDP and energy consumption showed the same exponential growth. However, since the mid-1970s, GDP has continued to grow exponentially, whereas the growth in energy consumption has dropped off. The efficient use of energy to produce economic growth has steadily improved since that time. The gap in Figure 1.3 illustrates the growing efficiency of energy use in the United States since the mid-1970s. Even if our economy does not grow on a per-capita basis, we still have to have a growing supply of energy because of population growth.

THE CRISIS OF EXPONENTIAL GROWTH

The economy of the United States has historically grown by about 3.5 percent per year above inflation. The population of the United States has also grown by about 1.2 percent per year. This percentage of growth that continues year after year is called an exponential growth. It is a fact that *no* exponential growth can ever be sustained forever! If nothing else, we will run out of shoulder room for everyone in the United States. But long before that, we will run out of basic resources such as water and food. As for the economy, since all societies and economies require energy, we will also run out of energy.

The same is true for the world as a whole. Although one nation can import resources from another nation, the earth as a whole can only sustain a certain number of people, based on the availability of water, food, soil, energy, and other resources. This carrying capacity of the earth is estimated to be somewhere between 4 and 16 billion people, by most estimates (World Population

Figure 1.3
Gross Domestic Product in Inflation-Adjusted Year-2000 Dollars; Energy Consumption

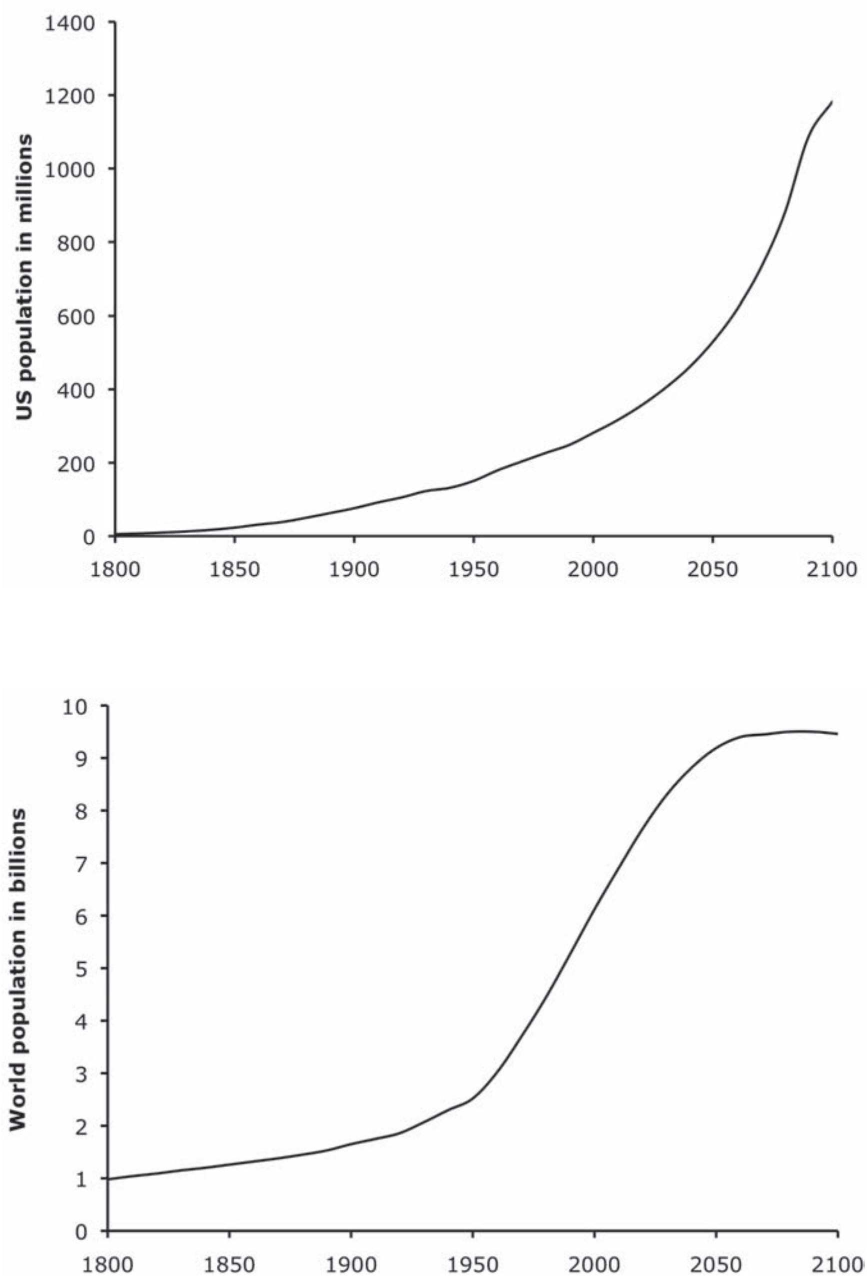


Top line—gross domestic product in inflation-adjusted year-2000 dollars. Bottom line—energy consumption. Note how an increased use of energy efficiency has allowed continued exponential growth in GDP while limiting the growth in energy consumption since the mid-1970s.
Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

Monitoring, 2001). The earth already has a population of 6.5 billion, and its population has doubled every 50 years in the past century.

As the world's population increases *and* as the U.S. economy and the economy of all the other nations in the world continue to grow (as seen in Figure 1.4), more energy will be required. This is particularly true of developing nations such as the Asian nations that are becoming more industrialized and are striving to be modern, developed nations like the United States and those in Europe. Thus, if the world's supply of energy is currently in a crisis situation, the crisis will become much worse in the coming decades as populations grow and the demand for energy continues to increase, both in developed and developing nations. For example, if everyone in the developing world were to use as much energy as the average person does in the developed world, global energy demand would increase by 300 percent. If one also included the estimated population growth of the world for the next 50 years, global energy demand would increase by 400 percent. Here lies the real energy crisis. Will

Figure 1.4
(a) U.S. Population and (b) World Population, with Predictions to 2100



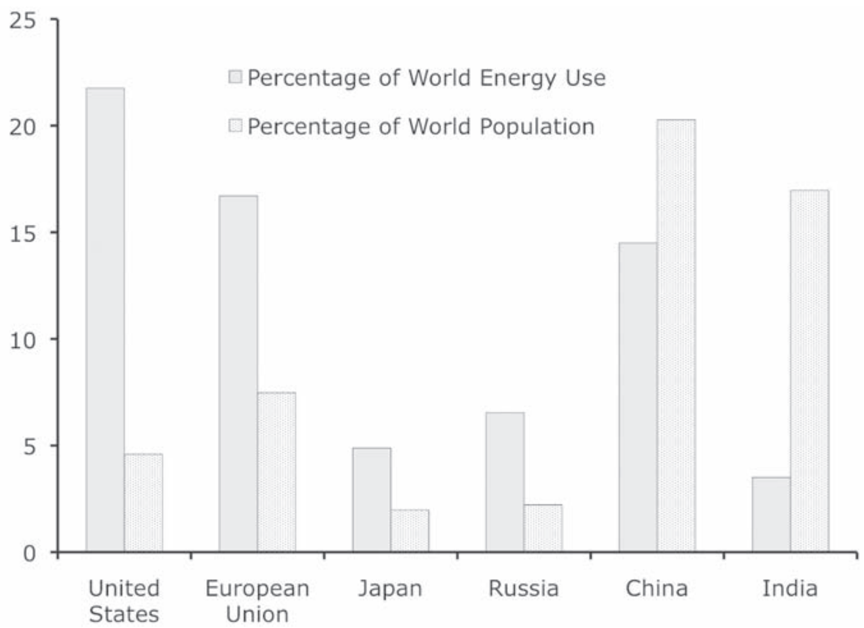
Source: U.S. Census and United Nations Division on Economic and Social Affairs.

humanity be able to meet this energy demand? Will developing nations be forever barred from transitioning into a technological society? Will something happen to substantially alter world population trends? Or will there be some dream-discovery of a clean, plentiful energy source?

WHERE DOES THE UNITED STATES FIT INTO WORLD ENERGY CONSUMPTION?

It is common for someone critical of the United States to say that the United States consumes far more than its share of energy, by giving the statistic that the United States has only 5 percent of the world's population and yet consumes 22 percent of the world's energy. While factually true (see Figure 1.5), this is somewhat misleading because it compares advanced, developed nations with undeveloped nations. Since economic development is what spurs the need for energy, a less developed nation doesn't require as much energy, nor do their citizens enjoy the same technological benefits.

Figure 1.5
Percentage of World Population and Energy Consumption for Selected Nations



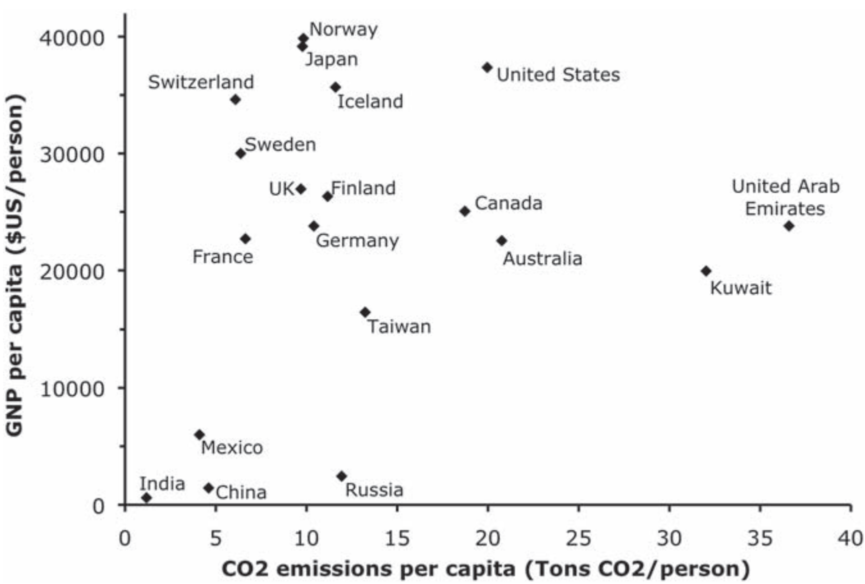
Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

An industrialized society will inherently consume more energy than a less advanced society. So, putting aside any issues regarding industrial nations versus developing nations, it is fairer to compare the energy consumption of the United States to that of other industrialized nations, such as Japan, Australia, Canada, and most of Europe. When this comparison is made, the United States still uses the lion's share of the world's energy resources, while having only 26 percent of the industrialized world's population and consuming 41 percent of the energy consumed by the industrialized world.

When comparing the energy consumption of different nations, the most obvious thing to notice is that both population and economic development increase the amount of energy consumed. Thus, a simple way to fairly compare energy use among different nations is to consider energy consumption per capita and GNP per capita. Figure 1.6 shows the energy per capita and the GNP per capita of various nations, both rich and poor.

While the United States uses more energy per person than do most other nations in the world, there are a few exceptions, for rather notable reasons. For example, the oil-producing nations of Kuwait and the United Arab Emirates use more energy per person than does the United States. However, these

Figure 1.6
Energy per Capita and GNP per Capita of Selected Nations



Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

are the nations that own much of the petroleum reserves of the world. Some of their energy is used to produce and refine this oil for export. But more importantly, energy is a natural resource that these countries have an overabundance of, and thus they use it much more freely than do other, less-endowed, nations. Other nations, such as Iceland or Norway, also use more energy per person; however, their climate is substantially colder than that of the United States and they also get a much larger amount of energy from renewable sources than does the United States.

DWINDLING SUPPLIES OF OIL AND GAS, AND EVENTUALLY COAL

Fossil fuels such as petroleum, natural gas, and coal take millions of years to form naturally. However, they will be completely used up in just a few centuries. In fact, most of those few centuries have already occurred. At this point in time, the resources of all three fossil fuels will be depleted within the next century. In order to understand the nature of fossil-fuel supplies, it is necessary to know the difference between *resources* and *proven reserves*.

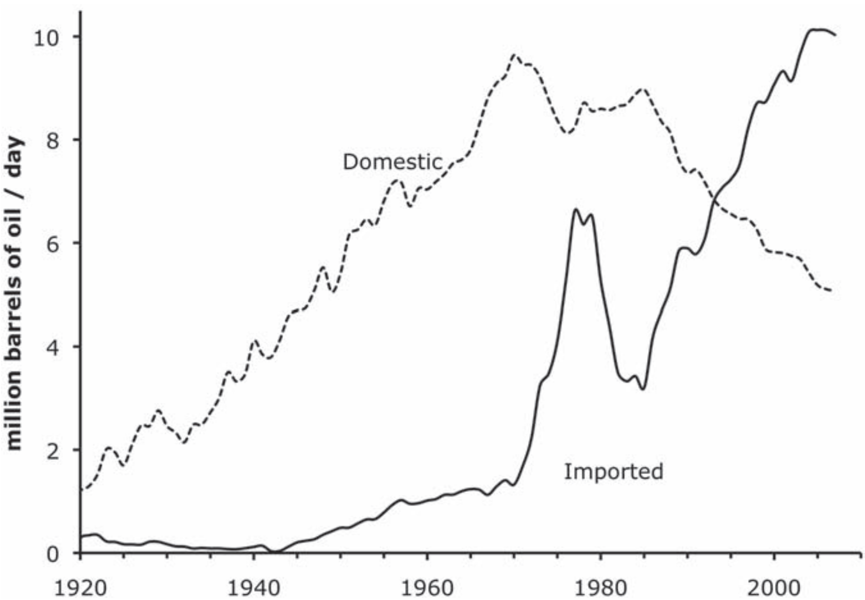
Resources are the total amount of a fossil fuel that is *believed* to exist. Most resources have not even been discovered yet. Even when discovered, resources are often impossible to extract using today's technology, or because of current economic conditions. Thus, resources is the term used when it is understood that future discoveries will be made, new technologies will be developed for future exploration, and prices will continue to rise to make all this futuristic thinking profitable.

Proven reserves is a much more down-to-earth term. Proven reserves have already been discovered and can be developed with known technology under current economic conditions. The quantity of proven reserves of oil and natural gas is much less than that of the estimated oil and natural-gas resources.

The two terms do not apply to coal. Coal is much easier to explore, discover, and exploit. The amount of coal in the United States, and in the world, is well known and is called the *demonstrated reserve base*. Of this amount, 50 to 55 percent can be extracted, which represents the *estimated recoverable reserves*.

At the current rate of use and without imports, the U.S. supply of coal will satisfy its needs for 240 years, and the proven reserves of oil and natural gas will last 3.2 years and 8.9 years, respectively. From these scientific facts, it is easy to see why we import most of our oil today, as seen in Figure 1.7. It is also clear why energy companies are continuously exploring new sources of oil and gas. With the assumed continuation of these new discoveries, new drilling technologies, and at the current rate of consumption, total fossil-fuel resources will allow oil to last 30 years and natural gas 65 years, although prices will be considerably higher.

Figure 1.7
Domestic and Imported Supplies of Oil in the United States



Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

The reality of supply makes it easy to see why coal must play a major role in the energy future of the United States. But coal won't really last 230 years! Coal has already started to replace the other fossil fuels for some uses, and the total use of fossil fuels is expected to grow for at least several decades, according to the U.S. Department of Energy. If all fossil fuels are considered exchangeable so that coal is used to replace oil and natural gas as they are depleted, the total U.S. resources of *all* fossil fuels will be depleted within 65 years if the current growth in energy consumption continues. These estimates are shown in Table 1.2, along with similar estimates for the entire planet.

There is a total of 41,000 Quads of fossil-fuel resources in the world. At the current rate of consumption, these will be gone within 100 years. But when the growth in energy consumption, especially by the developing world, is considered, all of these fossil-fuel resources will be depleted in just 60 years. It is worth noting that even with the increased consumption by the developing world that has been assumed (EIA, 2007), the per-capita energy consumption of the developing world would still only be 30 percent of the per-capita energy consumption of the technologically developed world. If the developed

Table 1.2
Proven Reserves and Resources of Fossil Fuels Expressed as Years of Use at the Current Rate of Consumption

	At Current Rates of Consumption		*With Increased Consumption*[a]
	Proven Reserves[b]	*Resources*[c]	*Resources*
United States			
Coal[d]	230	230	
Oil	3	15	
Natural gas	10	35	
All fossil fuels			65
World			
Coal	130	130	
Oil	45	65	
Natural gas	60	120	
All fossil fuels			60

The last column assumes a growing rate of consumption consistent with predictions by the U.S. Department of Energy.

Note: Reserves and resources expressed as years of use at the current rate of consumption.

[a]This column assumes a growing rate of consumption consistent with predictions by the U.S. Department of Energy.

[b]Data from the U.S. EIA.

[c]Data from the U.S. Geological Survey.

[d]In the case of coal, proven reserves and ultimately recoverable resources are referred to as "estimated recoverable resources."

world were to use as much energy per person as the rest of the world, all fossil fuels could be gone in as little as 30 years!

The reader might assume that since most of these end-of-energy predictions are looking 60 years or more into the future, he or she will not be affected. But the supply of fossil-fuel energy will not simply keep flowing, and then one day be turned off. The supply of fossil-fuel energy will continue to increase for a number of years, peak, and then rapidly diminish. It is safe to assume that there will be at least some amount of each fossil fuel remaining 100, 200, or even 500 years from now. But there will be very few who will be able to afford this energy. Thus, from a practical viewpoint, most people will have to stop using these fossil fuels many years before they have actually run out.

This doesn't mean that society will be thrown into the Stone Age, although it is probably a good thing for people at least to be concerned about that.

That may indeed be what happens, if society doesn't properly prepare for a transition by changing wasteful consumption habits and creating new energy strategies that increase energy efficiency among consumers and producers of energy. With the proper use of renewable energy, and with the very efficient use, through technology, of fossil fuels, society can continue to prosper for the foreseeable future.

SOURCES AND SECTORS OF ENERGY USE

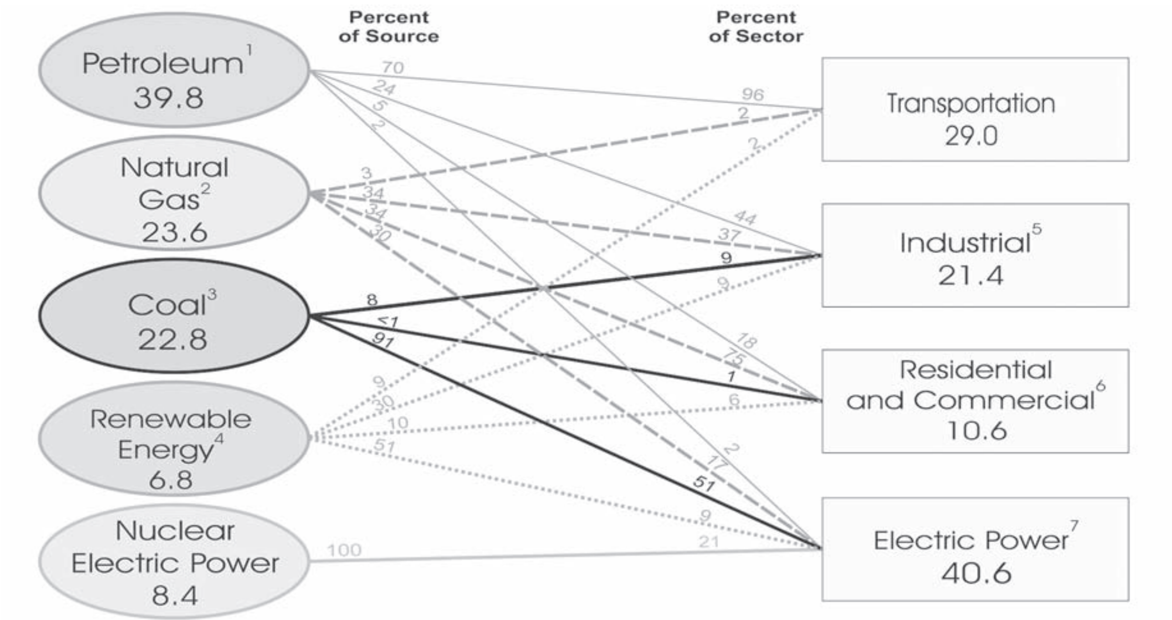
There are several main sources of energy. These include petroleum, coal, natural gas, nuclear fission, and various renewable energies (biomass, hydroelectric, wind, solar, and geothermal). The energy-using sectors fall into four broad categories: transportation, industrial, residential/commercial, and electric power. Electric power is available to each of the other three, although it is currently not used much for transportation.

As seen in Figure 1.8, some raw energy sources can only be used for certain purposes. Nuclear fission is the most obvious case, as it can only be used commercially for generating electricity. Petroleum is the most expensive form of raw energy, and is mostly used for transportation, due to the convenient portability of its liquid-fuel derivatives, gasoline and diesel. Despite common belief, petroleum is not used for generating electricity, except in a very few special circumstances. Coal is used mostly for generating electricity, but is also used in industrial settings for the smelting of metals and other industrial uses. Most renewable energies, except biomass, are also used only for electricity, although solar-thermal energy can also be used for space and water heating. In practice, the most flexible energy sources are natural gas and biomass. These are commonly used in nearly every consumer sector, for electricity, heating, transportation, and industrial uses. In theory, petroleum is also very flexible, yet due to its high cost and dependence on foreign sources, it is generally reserved only for transportation.

In an equilibrium situation, most sources of energy are priced approximately the same per energy unit. This is because it is usually possible for some, but not all, consumers to switch from one energy source to another source should the prices of two sources become unbalanced. In large commercial settings, these energy sources can be switched around rather quickly. In the past, there were quite a few industries that could switch between natural gas and petroleum, almost with the flick of a switch. Thus, the wholesale price of these two fuels has been approximately the same. However, now that petroleum has increased in price by so much, there are very few industries that use petroleum when natural gas, coal, or electricity would suffice.

What is missing in this discussion, however, is how the raw energy is delivered to the consumer for use. There is nearly always some intermediate

Figure 1.8
U.S. Primary Energy Consumption by Source and Sector, 2007, in Quads



[1]Does not include 0.6 quadrillion Btu of fuel ethanol, which is included in "Renewable Energy."
[2]Excludes supplemental gaseous fuels.
[3]Includes less than 0.1 quadrillion Btu of coal coke net imports.
[4]Conventional hydroelectric power, geothermal, solar/PV, wind, and biomass.
[5]Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[6]Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[7]Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

Note: Sum of components may not equal 100 percent due to independent rounding.
Sources: Energy Information Administration, *Annual Energy Review 2007*, Tables 1.3, 2.1b-2.1f and 10.3.

Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

step in which the raw energy is modified into some other form to be used by the consumer. This is partially indicated in Figure 1.8, showing the production of energy. Without the intermediate step, the raw energy is utterly useless. Just imagine driving up to the gas station and getting 10 gallons of crude oil. Your car would be ruined! Petroleum is used mostly for transportation, but it must first be refined into the appropriate intermediate products: gasoline, diesel, jet fuel, and so forth. But these products don't have to be made from petroleum; they can also be made from coal, natural gas, or biomass. Thus, if the price of petroleum gets to be too high, producers of gasoline can just switch to a different fuel source to make their gasoline, and save money in the process. This is precisely what has happened recently. Gasoline made from biomass is now competitive with gasoline made from petroleum.

Imagine trying to turn on your lights when all you had was a pile of coal in your cellar! Most residential energy is consumed from electricity, which in turn comes mostly from coal. But the typical homeowner doesn't really care where the energy comes from, as long as the lights turn on when the switch is flipped, the temperature of the house is comfortable, and everything works 99+ percent of the time without the need for costly repairs. Thus, while most electricity is generated from coal, the coal itself is useless. Coal is only of use after it has been converted to electricity. Furthermore, the homeowner would never know the difference if that electricity was generated from some other source of energy, such as natural gas, nuclear fission, wind, solar, or hydro. The same goes for a home's heating and cooling system.

INTERCHANGEABLE SOURCES OF ENERGY

Transportation fuels and electricity are the two main intermediate energy forms. Each can be produced from a variety of raw sources and then used in any consumer sector. The next section will break down each of these sectors and the prevalent sources of energy used by each.

Transportation Fuels

Transportation fuels such as gasoline and diesel can often come from multiple sources of raw energy, such as petroleum, biomass, coal, or natural gas. A petroleum refinery can make gasoline using less petroleum and more biomass (ethanol) if the price of the biomass is less than petroleum. Of course, this will then increase the demand for, and thus the price of, the biomass feedstock, which sends ripples through the rest of the economy. In the current case of ethanol, the biomass product is mostly corn. When the price of petroleum spiked to $100 per barrel and even higher, the demand for corn-based ethanol also spiked, since it was a cheaper alternative to petroleum.

This caused the corn demand and price to spike as well. The results were seen in higher prices not only for delicious sweet corn, but also for dairy and meat products (cows are fed corn), and all other grain-based foods, as other grain prices increased too.

Gasoline can also be made from coal, using a process known as coal-to-liquids (CTL) or liquefaction. CTL is an old technology developed by Germany during WWII to provide fuels when access to petroleum became difficult. Today this technology is profitable, as it is cheaper to make gasoline from coal than from petroleum when oil is over $100 per barrel. This technology is not being pursued in the United States, but has been in South Africa, where the equivalent of 60 million barrels of oil per year come from local coal. China is also pursuing CTL technology. Natural gas can be converted to into a liquid fuel, but this is less advantageous than CTL. Transportation can also be fueled with electric batteries, hydrogen fuel cells, and even compressed air, but each of these does require some form of raw energy.

Electric-Power Generation

Electric-power generation is the other major intermediate energy form. Electricity is also special, because it is the most useful form of energy and can be used to do just about anything with up to 100 percent efficiency. Electricity can even be used to leverage the generation of heat, so that one unit of electricity can generate three or four units of heat. Other sources of energy, particularly raw sources of energy, are usually much less efficient when actually applied in some situations. However, producing electricity is not without its drawbacks. Generating electricity from any raw energy source is usually very inefficient. Electricity can be generated by wind and solar at only 15 to 20 percent efficiency, by coal and nuclear fission at about 35 percent efficiency, and by natural gas at up to 65 percent efficiency. But efficiency is not the only criterion. The cost of the raw energy is important. Wind and sunlight are free, whereas natural gas is very expensive. Complicating this even more is the cost to build and maintain the power plant.

Since electricity can be produced from so many different raw energy sources, electric utilities are very prone to shopping around for the lowest price for wholesale electricity. If the price of natural gas rises, then utilities will purchase less electricity from that source and more from sources like coal, wind, and nuclear. During the 1990s and early 2000s, natural gas was particularly cheap. Prior to the turmoil of the 2008/2009 global recession, natural-gas rates had climbed so that the focus is now on electricity from sources such as wind and coal. Another example is that the expected movement toward some sort of carbon-trading system is pushing the economics of electricity production toward wind, solar, and nuclear, since it is assumed that coal will become more expensive to use. But regardless of what raw source of energy is used to generate electricity, a kilowatt-hour at the electrical receptacle is still a kilowatt-hour, no matter what the source.

WHAT IMPEDES COMPETITION AMONG RAW ENERGY SOURCES?

Although it is technically possible for any one raw source of energy to be substituted for any other source, this is not typically done for some consumption sectors. Two examples of this are transportation and commercial/residential heating. In the case of transportation, there is some flexibility, as discussed above, but to be completely flexible, we would need to be able to drive our cars, trucks, trains, ships, airplanes, and so forth on coal, nuclear, wind, solar or any raw energy source. And while this may be technically possible, it is very impractical. Nobody wants to drive a car that resembles a 1900 coal-burning steam locomotive, nor would we want a nuclear reactor in the trunk of our car.

Electricity is the key to making the many raw energy sources exchangeable. Electricity is the most flexible energy source and can be used very efficiently for just about any use. Electricity is already used as an intermediate energy for many devices, but transportation and commercial/residential heating are two exceptions in which electricity is not generally involved. Any raw energy source can be used to generate electricity. In most cases, generating electricity as an intermediate step before the energy is finally consumed is more efficient than using some raw energy source directly for consumption as seen in one example in Table 1.3.

Table 1.3
Overall Efficiency of Different Ways to Use Natural Gas

Natural gas used to generate electricity to run a heat pump for home heating	Natural gas used directly for home heating
1 energy unit of nautral gas	1 energy unit of natural gas
↓ Combined cycle power plant (60% efficient)	↓ Ultra efficient condensing furnace (95% efficient)
0.6 energy units of electricity generated	
↓ National electric grid (95% efficient)	
0.57 energy units of electricity delivered	
↓ Geothermal heat pump (3.5 C.O.P.)	
2.0 energy units of home heating	0.95 energy units of home heating

Note: Utilities can use natural gas to produce electricity, and the consumer can then use the generated electricity to produce heat. This is better than the more common approach of using a natural gas furnace to generate heat directly. C.O.P. represents the coefficient of performance, which is a measure of the efficiency of a heat-pump.

Very few homes or businesses in heating-dominated climates are heated with electricity. However, with today's prices for heating oil, natural gas, and propane, using technologies powered by electricity or solar is the cheapest and most efficient way to heat homes, businesses, and water. By using electricity or solar for this type of heating, the raw sources of natural gas and petroleum may also be changed to the raw sources of coal, nuclear, and various renewable sources. But it takes time to make these changes. We can't just wait until petroleum is gone and expect to flip a switch to make the necessary change. The technologies which must be employed are air-source heat pumps, ground-source heat pumps, and solar collection. Although these technologies will use less energy and have an overall lower cost over the long-term, they are also costly to install, and thus, many are reluctant to choose them. In fact, many consumers don't even know that these are the cheapest ways of heating a structure or that they can be used in practically any climate. Newer technologies also have fewer qualified technicians who can design, build, or install them. These factors combine to add a delay in the switch from one raw energy source to another, even when the newer energy source is more efficient and cheaper.

The delay is also true for the transportation sector. It takes time for newer technologies to break into the market. When gasoline prices hovered around three to four dollars per gallon in 2008, it would have been much cheaper to run vehicles on natural gas, electricity from a variety of raw sources, or even on liquefied coal fuels. It would take time, however, for such alternative-fueled vehicles to be designed, manufactured, and placed into service across the United States. For natural-gas powered vehicles, a large network of refueling stations would need to be built, in addition to the mass-production of the vehicles themselves. For electric vehicles to be a reality, the production of batteries needed for electric vehicles needs to be ramped up, but this type of sudden large-scale production is difficult for any emerging product. Lastly, the use of liquefied coal requires large production facilities to be built to convert solid coal into liquid fuels that can be refined into gasoline. All of these technologies are being pursued in other nations to a much larger degree than in the United States.

As certain fossil fuels are used up either locally or globally, the consumers of that raw energy will need to switch to some other raw energy source. This requires full competition between the various raw energy sources for all consumer sectors. In order for this to happen, it is necessary that all such sources feed into the same energy pool from which all the various energy consumers will draw. This is essentially the purpose of the national electric gird or alternatively a hydrogen-based economy.

In a hydrogen-based energy economy, then, some form of raw energy would need to be used to produce this hydrogen, which could then be piped around the country in a network of hydrogen pipelines (Rifkin, 2003). The main advantage of using hydrogen is that energy, in the form of hydrogen, can be stored during times of low demand and high production and then used during times of high demand and low production. An example of the benefit of storage is that solar energy could then be stored for use at night. The shortcomings of a hydrogen-based energy economy is that hydrogen is currently much too expensive to produce, store, and convert back into useful energy.

If the national electric grid were significantly updated to have a much larger capacity, this would also provide the infrastructure for all the raw energy sources to compete with each other. The infrastructure for an electricity-based energy economy is much closer to the currently existing infrastructure than is the infrastructure for a hydrogen-based energy economy. Thus the cost of an expanded electric grid is modest. Such large electricity-based networks would also increase the impact of renewable energies like wind and solar, because it is likely that the wind would be blowing somewhere in the country at any given time, producing energy that would be available to someone anywhere in the country. It also allows solar energy to be collected in regions with plentiful sunshine and then consumed in regions with less sunshine. The shortcomings of an expanded electric grid is that it does not offer any inherent energy storage.

Shifting infrastructure for use by other resources is extremely costly and difficult. One difficulty is that of unintended consequences. Consider coal-to-liquid (CTL) technology, which allows coal to compete with petroleum in the transportation sector. When the price for petroleum exceeds $100 per barrel, making synthetic gasoline from coal (CTL) becomes cheaper than making gasoline from petroleum. But to use CTL technology, a huge investment must first be made to build one or many CTL plants at a cost of billions of dollars. In the energy industry, this type of investment is not unheard of, and many energy companies can readily fund this type of investment when they choose to do so. However, it will take years for the investment to pay off with the profits of the synthetic gasoline. When a CTL plant is built, the overall supply of gasoline will increase, and thus by simple supply and demand economics, the price of petroleum will decrease. This in turn decreases the price of traditional gasoline. At the same time, the CTL plant will also increase the demand for coal, causing the price of coal, and therefore the price of synthetic gasoline, to rise. These two factors together make the CTL technology less competitive with petroleum. In fact, if the price swings are large enough, they can cause the CTL plant to lose money and go bankrupt, even though it was viable before it started production.

Such a case, of new, competing technologies going bankrupt, is not just a theoretical scenario. Many alternative energy companies went bankrupt because of this situation, and in fact, there are concerns that many of the ethanol plants that sprang up in the early 21st century will go bankrupt, due to the increased price of biomass feedstock and the falling price of petroleum in late 2008.

RAW ENERGY ON THE INTERNATIONAL MARKET

All fossil fuels can be exported and imported on the international market. But petroleum is by far the fuel that is traded the most. This is because the qualities that make petroleum an ideal transportation fuel on land also make it an ideal fuel to transport via ship. Being a liquid, petroleum can easily be loaded and unloaded on a ship with pumps, and it is a very energy-dense fuel. Although coal can also be loaded and unloaded, it is not quite as easy to do, and coal is not nearly as energy-dense as petroleum. It would take a much larger ship to transport the same amount of energy in the form of coal as in the form of petroleum.

Natural gas can also be imported via ship, but it is expensive. The natural gas must be cooled to cryogenic temperatures and carefully loaded and unloaded. There are relatively few locations that have the ability to handle imports or exports of natural gas. But due to the high demand for this relatively clean fuel, the international market for natural gas is increasing.

The United States currently imports about 30 percent of its total raw energy. Nearly all of that is crude oil, and a small but growing amount is natural gas. The United States cannot produce enough petroleum for its own needs, and it never will be able to supply its own needs, even if there were a massive expansion of domestic drilling. The reason for these imports is that oil is the raw energy source that is the hardest to replace with some other energy source, due to transportation's need for gasoline. If transportation could be fueled by some other energy source, like electricity, then the vast quantity of this imported oil would no longer be needed.

There is also the volatility of energy prices that we have come to know all too well. Energy prices routinely go up and down. This is caused not only by supply and demand, but also by external factors such as economic strength and weather. The internal effects of supply and demand tend to be long-term effects, and are very substantial when global demand nears peak global supply. From the demand side, as prices go up, consumers will change their energy consumption habits. This may be by purchasing a more fuel-efficient vehicle, driving less, carpooling, adding insulation to their home, buying more-efficient appliances, and so forth. Not everyone will do this, but enough people will, so that the nation's demand for energy will decrease, and therefore energy prices will decrease as well, or at least not increase as much.

There is always a delay between the prices going up and the demand going down, because it takes time for enough individuals to change their consumption. There was a fine example of this during the spring and summer of 2008: as gasoline prices escalated, the sales of small cars went up, the sales of trucks went down, and the actual consumption of gasoline decreased. In the fall of 2008, the external effect of world economic strength took over, and prices plummeted due to lower energy demand caused by the global recession.

From the supply side, when prices are high, new technologies for producing renewable energy or for tapping harder-to-reach fossil fuels are suddenly profitable and worthwhile. But it takes some time to get these new sources of energy into the market. Once in the market, the supply of energy will increase and the price will fall, all other things being equal (like zero inflation and zero-demand growth). A very serious problem arises as a result of this. If the price falls too much, then some of those new technologies will no longer be profitable, and the companies involved could face ruin if too much money had been invested. Because of this, many new technologies are not pursued until they are very profitable, not just barely profitable.

The external effects on energy prices include weather, strength of the United States and global economies, and the strength of the U.S. dollar and investment markets. Weather may be unusually warm or cold, which has a temporary impact on the demand for natural gas needed to produce electricity for air-conditioning or heating, and on the demand for petroleum for home heating oil. Severe weather, particularly in the Gulf of Mexico, can have an impact on the supply of natural gas and petroleum from that region, as well as on refining petroleum into gasoline and home heating oil. Weather effects will usually not impact prices for longer than a few months.

The major external influence on the price of energy is the strength of the regional and global economy. The first reason for this is that when the economy of the United States, or the world, is strong and growing rapidly, lots of energy will be needed in order to produce the products that make up the expanding GDP of the nation or world. Thus, the demand for energy will be high whenever the economy is prospering, and the demand will likewise be low whenever the economy is weak or even in recession. This has happened in the fall of 2008 to a very large degree. The largest and fastest drop in oil prices resulted from the sudden slowdown of the global economy.

Closely related to this is the fact that worldwide, petroleum is priced in U.S. dollars and is traded upon the open market. Because it is priced in U.S. dollars, whenever the U.S. economy is weak compared to the rest of the world, the value of the U.S. dollar will fall in currency exchanges. This makes the price of petroleum and other globally traded energy sources to rise, due just to the value of the U.S. dollar. In essence, it becomes easier for other nations to buy petroleum and harder for the United States to buy petroleum whenever the U.S. dollar is low.

One last externality on the price of energy, particularly petroleum, is that it is considered a commodity. Investors are constantly looking for the right combination of the safest place to invest their money and get the greatest yield on their investment. Whenever the investment markets (stocks, bonds, real estate) look weak, investors may move funds out of these markets and put them into the commodity markets (gold, metals, food, petroleum, and so forth). Just like anything else, when the investment demand for commodities is high, their prices will also be high, regardless of whether there is consumer demand for the same commodity.

HOW DO THE ISSUES OF POLLUTION AND GLOBAL CLIMATE CHANGE INFLUENCE ENERGY CHOICES?

Energy production requires the use of natural resources, and this inherently leads to pollution. The amount of pollution is not the same for all energy sources, or even for the same energy source in different situations. For example, it is possible to burn coal with very low emissions of pollutants, or as is usually the case, with relatively high emissions. Even renewable energy sources like wind and solar require the production and installation of wind turbines or solar panels. The energy generated may be pollution-free, but the production and installation of the equipment requires an initial use of fossil fuels and thus causes some one-time emission of pollutants.

Water pollution can be a concern, especially with coal mining, dumping of coal ash residue, and, to a lesser extent, oil and gas drilling. Water pollution is usually a localized effect, except for acid rain. Air pollution is a broad concern relating to the production of energy. Common air pollutants are sulfur dioxides (SO_x), Nitrous Oxides (NO_x), fine particulate matter (PM_{10}), volatile organic compounds (VOC), heavy metals, and carbon dioxide (CO_2). Until recently, carbon dioxide was not legally considered a pollutant susceptible to EPA regulations; however, that changed in 2007, and it now has the same legal status as other pollutants, although the regulations concerning allowable emission have not yet been determined. Listed below are the major sources of these pollutants.

Each type of pollution tends to have its own environmental and health impact. Heavy metals are emitted mostly from the burning of coal. Such heavy metals include mercury, lead, arsenic, and even radioactive uranium and thorium. In fact, there is a greater emission into the environment of radioactive uranium from the normal operation of coal-fired power plants than from nuclear-power plants. Mercury is of particular concern, since it is easily absorbed into the human body. After the mercury is emitted into the air, it then precipitates down and contaminates rivers, streams, and lakes. Fish then naturally concentrate this mercury, so that they become too toxic to eat.

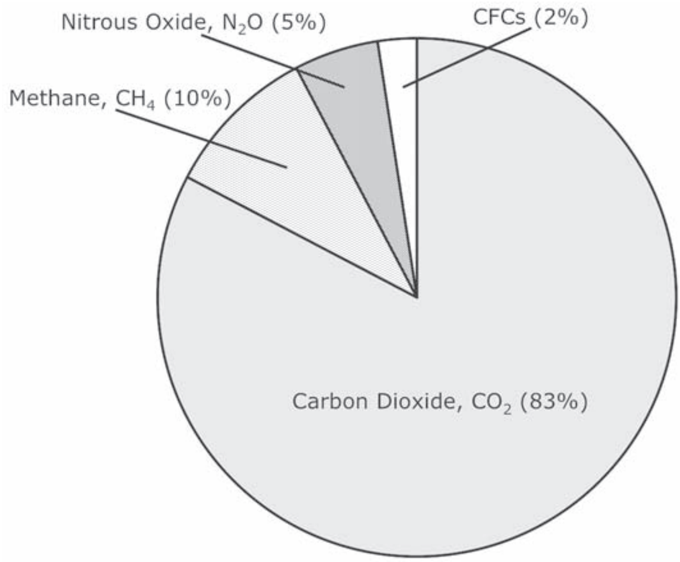
Photochemical smog and ground-level ozone are mostly problems in cities, where they are made worse by warm weather. Smog is a combination of smoke and fog in which the solid particulates in smoke are suspended in the fog. Ground-level ozone is the result of a series of chemical reactions that occur in the atmosphere, starting with the emission of VOCs and NO_x, particularly from vehicles. This ground-level ozone is bad, and very different from the good stratospheric ozone that is needed to protect the Earth from harmful ultraviolet radiation. Ground-level ozone is a significant health problem and is responsible for thousands of deaths in the United States each year from asthma, bronchitis, and COPD.

Sulfur dioxides (SO_x) react with air and water vapor to form sulfuric acid, which then is washed out of the atmosphere by precipitation. This is the cause of acid rain. Acid rain and particulate matter (PM_{10}) are responsible for most of the health problems related to electric-power generation. It is estimated that 20,000 to 30,000 Americans die each year from electric-power plant pollution, mostly due to coal-burning power plants. Such deaths may be heart attacks, lung cancer, asthma, and so forth, and of course it is impossible to know exactly who these 20,000 to 30,000 people are, from among the millions of Americans who die each year.

Carbon dioxide is only of concern as a greenhouse gas causing global climate change. Other major greenhouse gases are methane, nitrous oxides, and chlorofluorocarbons (CFCs) (see Figure 1.9). Although CFCs are a far more powerful greenhouse gas on a per-molecule basis than CO_2, CO_2 is still more important, because there is far more CO_2 produced by humans than CFCs. All fossil fuels release CO_2 when they are burned, and unless this CO_2 is captured and sequestered, it will increase the greenhouse effect and cause global climate change. Carbon dioxide does not pose the same immediate threat as other pollutants (e.g., killing 25,000 people per year) but it does pose a more severe long-term threat with global climate change. Global climate change is usually expressed as the temperature change the earth will see, based on global yearly average temperatures. According to the latest UN IPCC prediction, the earth will be about 2–4.5°C (4–8°F) warmer within the next 100 years. The range depends mainly upon how much and how fast the world is able to curb the emission of carbon dioxide, and upon the uncertainty of climate modeling.

This average temperature is not the main problem with climate change. More significant effects of global climate change include changing weather patterns, such as extreme summer and winter temperatures, the timing of growing seasons, rising sea levels, episodes of severe weather, and, more im-

Figure 1.9
Contribution to Global Climate Change from Greenhouse Gases Emitted by Human Activities



Source: U.S. Energy Information Administration. Annual Energy Review, 2007.

portantly, annual precipitation patterns. These climatic changes are expected to lead to worldwide mass extinctions.

It is known with great certainty that precipitation patterns around the world will change, but it is not certain exactly how they will change. Some places that currently receive enough rain for crop production will become so arid that crops can no longer be sustained. Other places will receive more rain, enabling more crops to be grown, but will also be at risk of flooding. In both cases, there will be economic turmoil because centuries' worth of farming infrastructure will need to be relocated, and in many cases moved to other nations or continents.

Mass extinctions will occur all over the planet as weather and temperature patterns change too quickly for species to adapt. Under normal circumstances, animal species can move relatively quickly to keep up with changing and moving climate patterns. But in many cases, forest fragmentation will prevent this. Some species, such as malaria-carrying mosquitoes, will be pushed into currently malaria-free, populated regions. This will increase the occurrence of many diseases. Equally important, the plant species with which the animals have evolved to coexist with are much slower to move. It is easy to conceive how an animal can migrate many miles in one day, or even cross an entire continent in just one year. However, a tree can't just pull up its roots and start walking. A tree migrates by having its seeds spread relatively short distances in random directions. Those seeds then have to wait a decade or more to grow into a mature tree to repeat the process. In this manner, a tree cannot migrate the necessary hundreds or even thousands of miles per century. Thus, without the required plant species, an animal that has moved with the changing weather patterns will not be able to thrive. It is estimated that up to 75 percent of all species on earth will go extinct with global climate change. This mass extinction will seriously decrease the biodiversity of the planet, which is what provides the backbone of life's resiliency on this rock we call Earth.

Thus, while global climate change may not cause thousands of human deaths per year now, it is quite possible that it will become a leading cause of death over the next century, in the form of starvation, malnourishment, displacement resulting from coastal flooding, and diseases of all types. Thus, the annual death rate due to global climate change could easily dwarf that which is due to all of the classic forms of air pollution.

CAN POLLUTION CONTROLS AND CARBON SEQUESTRATION HELP?

Most pollution can be reduced using technology, but doing so is costly and can even reduce the net amount of energy produced. In the case of coal-burning electric-power plants, the emissions that need to be controlled are particulates (PM), SO_x, NO_x, and CO_2. It is a fairly simple process to eliminate larger particulate matter (over 100 microns in size) using a cyclone filter. But the smaller and more dangerous particulate matter under 10 microns in size requires the use of electrostatic precipitators. In order to remove the SO_x, wet and dry flue scrubbers can be used. To remove NO_x, selective catalytic reactors are required. All this pollution-control technology can be expensive, especially to install in existing power plants. To bring the pollution controls of an old power plant up to modern, best technological standards costs about $1 billion per unit.

One billion dollars seems like an awfully large burden to impose on a power plant, until this number is put into perspective. For a typical power plant unit, this amounts to an increase of about one cent per kilowatt-hour of electricity generated, compared to the average retail price of 12 cents per kilowatt-hour of electricity. Thus, consumers would see only an extra 10 percent charge for electricity. To put this in different terms, the $1 billion cost of pollution controls will be passed on to consumers. But the consumers will also benefit from the cleaner environment and will be the beneficiaries of about $3 billion in healthcare savings. Thus, the societal investment in pollution controls is well worth the expense.

It is also possible to reduce the amount of pollution at a coal-fired power plant by burning the coal in a very different way. Old furnaces can be converted into advanced pulverized furnaces, fluidized-bed furnaces, or even integrated-gasification combined-cycle (IGCC) turbines. Updating the way the coal is burned has the advantage not only of helping to reduce pollution before it is even created, but also of increasing the overall efficiency of the power plant. The most advanced of these IGCC turbines is also being considered as a candidate plant design in which to test the carbon-sequestration technology discussed below.

It is also possible to reduce the amount of carbon dioxide that is emitted into the air using carbon capture and sequestration. The technologies for doing so are much less evolved than for other pollutants. It is fundamentally impossible to extract energy from fossil fuels without creating carbon dioxide. Thus, the only solution that reduces CO_2 emissions is capturing the CO_2 and then doing something to keep it out of the earth's atmosphere.

There are currently no full-scale working examples of carbon capture and sequestration in the U.S. energy industry. However, there is much research in this area, and there are a few full-scale test projects that are set to begin construction soon. In addition, there are plenty of long-standing examples of CO_2 being pumped into the ground to enhance the production of oil and gas from old wells. But these projects have always been about how to pump more oil and gas out of the ground, and not about putting as much CO_2 into the ground as possible and keeping it there.

There is a variety of carbon sequestration ideas that are being developed. Most methods involve geologic storage of pressurized CO_2. Carbon dioxide can be stored in depleted oil and gas wells, salt domes, un-mineable coal beds, deep aquifers, dissolved in the ocean, and even a pool of liquid CO_2 can be created along deep seabeds. Early Department of Energy estimates are that carbon sequestration will add an extra two to five cents per kilowatt-hour to the cost of electricity. This would amount to an increase of about 15 to 30 percent on the retail rate of electricity. It is worth noting that early estimates of the cost of pollution-control equipment to reduce SO_x emissions turned out to be very inflated.

The cost of reducing pollution is related to the amount of pollution reduction that can be attained. Simple equipment can be small and cheap. But the best pollution-control equipment is usually very large, cumbersome, and expensive. This makes it ill-suited to the transportation sector, but well suited for the electric-power industry and other large industrial consumers. Power plants and other industrial plants do not have to move about on wheels, so adding several hundred tons of equipment doesn't matter. Furthermore, power and industrial plants generally operate for several decades. Thus, expensive equipment that can be financed over a long period of time makes sense for this sector. This does not make sense in the transportation sector, where the purchase price of a vehicle is only financed over five years or less.

As with other pollution controls, carbon sequestration is best suited for the electric-power industry and other large industrial sectors. Carbon sequestration technology will probably be impossible to deploy in the transportation sector as long as fossil fuels are used directly in the vehicle. However, if a shift is made to electric-powered vehicles or hydrogen-powered vehicles, then carbon can be sequestered during the production of the electricity or hydrogen. Then the vehicles can be driven with no carbon emissions.

None of these sequestration methods has been tested on a large scale, so it is impossible to compare the cost, effectiveness, or environmental impact of each sequestration method.

ARE WE IN AN ENERGY CRISIS?

What is the definition of an energy crisis? Is such an energy crisis defined by rising prices, increased worldwide demand, diminishing supplies, or reliance on foreign energy? Perhaps it is a combination of all of these. These factors have all had a growing importance in our society, and it is expected that they will become even more pressing issues in the coming years.

Energy transitions grow out of a crisis or the demand for change. Thus it appears that we are on the verge of a new energy transition. No one knows what this energy transition will yield, but one thing does appear certain: society's current use of energy cannot continue without some transition.

2

The Industrial Revolution and Humans' High-Energy Existence

Although energy is always an integral part of human life, there have been clear separations between eras, depending on humans' uses and applications of power systems. Of these various shifts, most likely the most significant is the Industrial Revolution, which marked a fundamental shift in the way that humans did many things. Economic historians argue that it was profound because it remade methods of trade—goods moved between human communities with more regularity, increasing a whole set of diverse connections. Outcomes of these trade patterns, though, whether the Silk Road, the Atlantic System, the Panama Canal, or the Internet are indicators of a radical change in the human condition—particularly in the human use and application of energy.

At its basic level, the Industrial Revolution, which historians date to the mid-1700s, represented a dramatic and revolutionary expansion in the capabilities of human production. This production could only expand, though, with the input of raw materials and, most important, of energy. Thus, the fundamental shift in human life during the Industrial Revolution began with the effort to control and manipulate massive supplies of potential energy. In fact, the actual practices of the industrial era can be found in societies dating to the year 1000. The primary revolution of the period dating from 1750 through 1900, then, was, in the scope, on the scale of that which made the energy input possible.

In order to tell this story, this chapter must cover an extremely long sweep of time. Over the extent of human existence, many different methods and modes of energy have been put to use. Ironically, some of the earliest energy regimes fall into the category of what we today know as "alternatives." Humans have defined this terminology as they have determined what sources were primary. This terminology is, of course, a cultural construction, defined and adjusted by people at a specific juncture in time. Therefore, when wind was the prime mover for all milling in Europe during the 14th century, it was not known as an alternative source. Instead, it was a remarkable vehicle for human progress that evidenced a community's development and expansion.

In short, then, this chapter depicts the construction of an energy-intensive culture over many generations and cultures of the human species. Humans, living throughout the world, developed new methods for living. As some of these patterns became more prevalent, they shaped the expectations for all humans as a species. Plank by plank, this chapter depicts the shift in the human condition in which energy emerges as a most crucial component. By the close of the 20th century, the standard paradigm of energy use would derive from the burning of hydrocarbons. This way of harvesting power would be so accepted and normal that, by the end of the 20th century, other methods of obtaining energy—even if they had been used for thousands of years prior—would become classified as alternatives.

REORGANIZING HUMAN LIFE

Humans began the management and harvest of Earth's energy with their existence as hunter-gatherers. As their ability to manage and to manipulate the surrounding natural systems matured, humans passed through what historians and archaeologists refer to as the Agricultural Revolution. This shift in human life occurred at different moments throughout the globe. Adapting to climatic variations, humans in different regions took control of the natural cycles of energy—primarily of the sun and photosynthesis—and learned to condition their behavior, resulting in a relatively consistent supply of food. Once food management had allowed humans to become more sedentary, they only had to make a slight adaptation to their living patterns in order to exploit and to develop practices that we refer to as early industry.

Some renewable energy technologies, including water and wind power, were closely related to agricultural undertakings. These power sources have been used in milling for centuries. For instance, mills to grind grain into flour have been powered by waterwheels since at least the first century. The Domesday Book survey of 1086 counted 5,624 mills in the south and east of England. Similar technology could be found throughout Europe and elsewhere and were used for milling or other tasks, including pressing oil or even making wire. Most often, each of these industrial establishments was an entirely local, limited endeavor. A few exceptions also grew, well beyond the typical village center. For instance, the Romans built a mill with 16 wheels and an output of over 40 horsepower near Arles in France. In each case, though, the energy was harvested and applied to a specific activity; it did not necessarily alter the way most humans lived their daily lives.

The organization and adaptation that historians refer to as the Industrial Revolution, though, came much later, when technical innovations grew to form dominant patterns in human life. First, however, these energy sources were utilized in areas where human and capital concentration made it more possible. Some of the earliest milling technology arrived in England through its use in religious communities, including monasteries.

Monasteries at this time were self-sufficient religious communities, producing their own food and other goods. Often they were referred to as estates, and they seem to have resembled diversified plantations. One of these enterprises had monks turning wool into various forms of cloth. The name of this process was "fulling." This process was revolutionized when the Cistercians at Quarr Abbey set up a mill that would full the wool by using waterpower. Although this was not the first fulling mill in England, historians credit it with initiating the enterprise on the Isle of Wight, which became world-renowned for its kerseys, a coarse cloth made on a narrow loom.

Previously, the cloth would be placed in a trough filled with the fulling liquor, and then it would be walked on with bare feet to complete the process. With access to a waterwheel, the monks created a series of large wooden mallets that would pound on the fabric while it was in the liquid, making the cleaning process much more rigorous and even. Perfecting these methods inadvertently allowed merchants to prepare for important technological shifts that took place in European history.

The wars during the Renaissance and Reformation proved to be a great boon for merchants and manufacturers supplying armed forces. Many of these new industries and systems of transportation would ultimately be put to peacetime uses as well. However, by most modern measures, the manufacturing taking place from the 1300s to the 1500s was on a very limited scale. Between 1500 and 1750, changes in manufacturing continued, but would not accelerate remarkably until after 1750.

During this early era of manufacturing, most enterprises garnered energy from passive means, including from rivers and the wind. Each source of power proved extremely limited in energy and reliability. Of course, this meant that manufacturing, also, could not be reliable, and could only expand to a limited degree.

The manufacturing that did develop was most often based on technologies that European merchants brought from other regions, particularly from Asia. For instance, Europeans perfected the art of making porcelain imitations of Chinese crafts. And from India, Europeans imported methods for manufacturing silk and textiles. While perfecting these technologies, European business leaders also linked specialized, small-scale, craft production into larger-scale systems that began to move such small-batch production into the class of manufacturing.

The basis for this system of manufacturing was improved energy resources. Ultimately, the outcome was the large-scale shift in economic and social patterns in Europe that culminated with the formation of an entirely new social organization. These living patterns ultimately led up to and fostered the Industrial Revolution.

Early Examples of Alternative Energy

Milling with Wind

Most historians believe windmill technology was in used in the Middle East by at least the 10th century, followed shortly by its utilization in Europe. Over the following centuries, the uses of wind power included milling grain, pumping water, working metal, sawing, and crushing chalk or sugarcane.

Most early mills began in fairly remote locations, which were primarily selected for their access to the raw energy resource of choice. In some models of development, towns found access to energy sources near enough that the mill could be integrated into the community. Otherwise, towns developed around successful mills.

The wind's power was one of the first prime movers used for the production of grain in various parts of Asia. Europeans imported the technology to make horizontal or vertical—also known as post mills—wind turbines. Such devices use a paddle with sails attached to it, which in turn is attached to a wheel whose rotating vertical axis directly drives a grindstone.

By and large, Europeans adopted the vertical mill, on which the sails were vertical, revolving around a horizontal axle. The other end of this axle was attached to a wooden gear that attached to gear on a separate vertical axle to which the millstone was attached. The gear ratio was set to provide a reasonable grinding speed in a typical wind, but early mills did not operate with brakes or governors to control the speed of the millstone.

Most historians attribute the re-organized design of the post mill to European inventors entirely. It is seen to have occurred independently from the horizontal mill seen in a variety of locations. The post mill only functioned effectively if it faced the wind, which proved to be a severe limitation. To overcome this, the entire mill housing was raised from the ground and made mobile, rotating on a vertical axis. It was light enough to be easily turned by one man. In this way, it could be kept turned into the wind at all times.

The post mill could generate roughly two to eight horsepower (1½ to 6 kilowatts).

Milling with Tidal and River Flows

Tidal mills were a medieval invention that was first mentioned in the 12th century in both England and France. These mills were built in low-lying areas near the sea. Additionally, dams with swinging gates were built along shallow creeks so that as the tide came in, the gates swung open inwardly, away from the sea and water-filled area behind the dam. When the tide turned, the gates swung shut, forcing the water to flow seaward through the millrace of the tidal mill.

The obvious disadvantage to tidal mills was that the time of the tides shifted every day. Thus, the millers had no choice but to work hours dictated by the tides. These mills seem only to have been used to grind grain. There were never very many of them, compared to waterwheels and windmills.

Water-powered mills were placed along rivers with any of a number of wheel mechanisms to catch the water's flow. The energy of the current in either of these cases was used to push a series of gearing wheels that could be linked to various mechanisms to allow grinding, sawing, and other pursuits to take place.

Milling with Water Power

Water mills proved to be the most expansive application for manufacturing in the early industrial era. Typically, the primary device for capturing the river's motive power was a large wheel, known as a breast wheel. Water and gravity functioned to spin the wheels, and a close-fitting breast work steered the water into the wheel, which was most often designed so that the water entered below the level of the central shaft. These wheels were referred to as undershot wheels. Overshot wheels, in which the water hit above the shaft, would also come into eventual use.

Undershot wheels could be placed directly in a stream, which made them simpler to site but also more prone to flooding. Overshot wheels needed a regulated water supply and, therefore, involved the additional construction of flumes, ponds, and ducts.

Whichever type of wheel was used, the motive power was then transferred into a mill through the use of gears. Through the 18th century, wheels, gears, and shafts were most often made of wood. Afterward, the more durable iron would take over as the primary construction material for manufacturing hardware.

Throughout the 1600s, wheels remained limited to producing approximately four kilowatts. The only way to expand a manufacturing site's capabilities was to add wheels. For instance, by the late 1600s, one of the best-known industrial sites was the series of 14 large waterwheels on the Seine at Marly that were built to pump water for the Versailles fountains of Louis XIV. Each wheel could muster only four to seven kilowatts.

URBANIZATION AND MANUFACTURING

Technological innovations carry with them social and cultural implications of great import. For instance, industry brought new importance by allowing people to settle and live in clustered communities. Even limited energy development, such as the waterwheels, has spurred urbanization in human history. Changes in manufacturing from 1300 to 1650 brought with them major alterations to the economic organization of European society, as well as greater availability of goods and services. In addition, though, patterns such as urbanization helped to foster other factors that helped a singular innovation move into the realm of industrial development.

For instance, the growth of urban areas brought profound changes in banking and in the technology that supported manufacturing. A class of big businessmen arose, and, in connection with it, an urban working class, often referred to as the proletariat. For this new urban society, new types of legal institutions and property tenure had to be devised. A mercantile law, or law merchant, grew up to settle cases arising from trade disputes. Property holding was set free from the complex network of relationships and obligations that had burdened it, and it became possible for city dwellers to hold property outright. This liberation and flexibility of capital was critical to later economic developments.

One of the most distinctive characteristics of urban life was new freedom that had not been seen in the feudal countryside. Towns grew and flourished; trade, banking, and manufacturing became established on a new scale; more and more persons achieved the legal status of free men. To accommodate these changes, vast tracts of land, which had been uninhabitable forest or swamp, were cleaned, drained, and subjected to cultivation. A new order and urgency came to the landscape of production that ushered in the scale and scope of industry.

Rapidly, these early industries made flexibility a valuable commodity and increased the potential of undertakings that did not rely on geographical features such as wind, tidal flow, and river power. For instance, early industries began to quickly impact Europe's supply of wood. During this early period of industry, Western Europe's forests largely disappeared as they provided the raw material for shipbuilding and metallurgy. This shortage led English ironmasters, however, to utilize a new source of energy that would greatly multiply the scale and scope of industrial potential. The English use of coal and, more specifically, of coke, revolutionized the scale and scope of the manufacturing that followed throughout the world.

Although Western Europe had abundant supplies of ordinary coal, it had proven useless for smelting ore. Its chemical impurities, such as phosphorus, prohibited its ability to produce strong iron. For this reason, smelting was fired with charcoal, which was made from wood.

Western Europe's lack of wood made it lag behind other regions during these decades. However, in approximately 1709, Abraham Darby discovered that he could purify coal by partly burning it. The resulting coke could then be used as a smelting fuel for making iron. Darby released this knowledge for public use in 1750. This process proved to be a launching point for the reliance on fossil fuels that would power the Industrial Revolution.

The Intellectual Underpinnings of the Machine

The period introduced above, which lasted from 1500 to 1750, can best be described as one containing great technological developments but no genuine revolution in industrial expansion. In an era in which scientific and technological innovations were frowned upon and when energies and monetary support were focused on exploring the globe, it is relatively remarkable that any developments occurred at all. Simply put, the society of the Reformation was not conducive to new technological developments. The pressure to conform in this era slowed technological change and kept the implications of energy development fairly limited and confined.

Social changes did occur, however, that had a significant impact on later uses of technology. Industry began to move outside of cities. The nation-states that began to develop slowly became somewhat supportive of select technologies. In particular, technologies and machines that might be used in battle, including fortifications design, cannon casting, and improvements to naval fighting ships.

But more important to most members of society, during the 18th century, a series of inventions transformed the manufacture of cotton in England and gave rise to a new mode of production that became known as the factory system. Based on a series of related innovations, the new factory-based society that took shape made machines part of nearly every worker's life.

During these years, other branches of industry stimulated comparable advances, and all these together, mutually reinforcing one another, made possible an entire era, grown, at least partly, on the back of technological gains. The age would be organized around the substitution of machines for human skill and effort. Heat made from inanimate objects took over for animals and human muscle. Furthermore, this shift enhanced the amount—the scale and scope—of the work that could be undertaken.

After 1750, of course, the steam engine and related developments generated a bona fide industrial revolution. As Joel Mokyr has written, "If European technology had stopped dead in its tracks—as Islam's had done around 1200, China's by 1450, and Japan's by 1600—a global equilibrium would have settled in that would have left the status quo intact" (52–53). Instead, of course, in the next two centuries human life changed more than it had in its previous 7,000 years. At the root of this change lay machines and an entrepreneurial society committed to applying new technologies to everyday life. Each one relied on new, flexible, and expandable sources of energy.

ENERGY SOURCES FUEL THE INDUSTRIAL TRANSITION

What historians of technology refer to as the "great transition" is not necessarily the emergence of the Industrial Revolution in the mid-1700s. In order to reach that revolution, a great transition was necessary in intellectual thought, as was discussed above, and in the availability of energy resources. Biomass fuels such as wood and charcoal had been in use for centuries, but they did not necessarily support an entirely new infrastructure of machines. Coal, on the other hand, emerged as a prime mover during the 1600s and did exactly that.

After England experienced serious shortages of wood in the 1500s, domestic coal extraction became the obvious alternative. Most of the existing coalfields in England were opened between 1540 and 1640. By 1650, the annual coal output exceeded two million tons. It would rise to 10 million tons by the end of the 1700s. Mining technology, of course, needed to be quickly developed to provide the fuel to power this new era. In the new energy resource of coal, industrialists found potential power that far exceeded any sources then in use. Thus, new industrial capabilities became possible. Primary among these was the steam engine.

The basic idea of the steam engine grew from the exploration of some of the revolutionary intellects of this new era in human history. Scientific minds were becoming increasingly free to openly explore innovations that might significantly alter human life. For instance, the idea of the piston, which was the basis of the engine, only came about after the realization of the existence of Earth's atmosphere. Although other societies had thought about the concept of an atmosphere and pressure holding things to Earth, it was Europeans who began to contemplate the possibilities of replicating this effect in miniature.

In the mid-1600s, English engineers began contemplating a machine that utilized condensation, in order to create a repeating vacuum to yield a source of power. The first model of such a device is attributed to Denis Papin who, in 1691, created a prototype piston that was moved within a cylinder using steam. This device remained unreliable for use, though, because the temperature could not be controlled.

In 1712, Thomas Newcomen used atmospheric pressure in a machine that he alternatively heated and cooled in order to create the condensation pressure necessary to generate force. Additionally, Newcomen's engine was fairly simple to replicate by English craftsmen. Employed to pump out wells and for other suction purposes, the Newcomen engine spread to Belgium, France, Germany, Spain, Hungary, and Sweden by 1730. Although it lacked efficiency and could not generate large-scale power, the Newcomen engine was a vision of the future. It marked the first economically viable machine to transfer thermal energy into kinetic energy. This concept, powered by a variety of energy sources, was the flexible, primary mover that would lead the Industrial Revolution.

The need for energy sources and the trade networks forming in the Atlantic provided another portion of the raw material required to spread industry. Linked by ships, European powers sought necessary resources in other regions. Soon, this led the mercantilist nations to establish colonies. In North America, settlement grew from agriculture; however, as the United States developed, it emphasized industries—using technologies perfected in Europe, and new ones that blazed important new paths. The key connecting each undertaking was that energy was the raw material necessary for developing the young nation.

CASE STUDY OF AN EARLY ALTERNATIVE: WATERPOWER IN THE EARLY REPUBLIC

Throughout much of the 1700s, the American colonies had defined themselves as the suppliers of raw materials to industrial Europe. By the late 18th century, efforts abounded to keep the profits made from American raw materials by creating the country's own industrial infrastructure. One of the first examples of such planning arrived in the 1790s, with Alexander Hamilton's effort to develop Paterson, New Jersey. Fearing that it would lose its technological edge, England passed laws forbidding the export of machinery or the emigration of those who could operate it.

Despite these laws, one of the world's first brain drains occurred when laborers in the British textile industry secretly immigrated to the United States. Samuel Slater, who was born in England, became involved in the textile industry at 14 years of age, when he was apprenticed to Jedediah Strutt, a partner of Richard Arkwright and the owner of one of the first cotton mills in Belper. Slater spent eight years with Strutt before he rose to oversee Strutt's mill. In this management position, Slater gained a comprehensive understanding of Arkwright's machines.

Believing that the textile industry in England had reached its peak, Slater posed as a farm laborer in order to immigrate secretly to America in 1789. While others with textile manufacturing experience had emigrated before him, Slater was the first who knew how to build, as well as operate, textile machines. Slater, with funding from Providence investors and assistance from skilled local artisans, built the first successful water-powered textile mill in Pawtucket in 1793. Slater's Mill was staffed primarily with children from 7 to 12 years of age, and with women. The laborers worked with machines to spin yarn, which local weavers then turned into cloth. Slater added housing in order to attract poorer families to work in the mills. His plan concentrated the workforce within easy walking distance of the mills. Slater also established company stores and paid the workers in credit that could only be used at those stores. Slater also established nearby churches and schools for his workers. He had created a template for early industrial development in the United States.

The millwrights and textile workers who trained under Slater contributed to the rapid proliferation of textile mills throughout New England in the early 19th century. The "Rhode Island System" of small, rural spinning mills set the tone for early industrialization in the United States. By 1800, Slater's Mill employed more than 100 workers. A decade later, 61 cotton mills turning more than 31,000 spindles were operating in the United States, with Rhode Island and the Philadelphia region the main manufacturing centers. The textile industry was established, although factory operations were limited to carding and spinning. By the time other firms entered the industry, Slater's organizational methods had become the model for his successors in the Blackstone River Valley. Based on Slater's model, new models also quickly emerged on other American rivers.

The Merrimack River possessed enough raw power to surpass the Passaic and the Blackstone river valleys as an industrial center. Located just outside of Boston, the Merrimack became the next center of American industry when the businessman Francis Cabot Lowell used Slater's idea, but exploded the scale of manufacturing in order to create industrial communities entirely organized around turning the power of the river into textile cities and towns. The workable power loom and the integrated factory, in which all textile production steps took place under one roof, made Lowell the model for future American industry.

The city's brick mills and canal network were, however, signs of a new human domination of nature in America. Urban Lowell contrasted starkly with the farms and villages in which the vast majority of Americans lived and worked in the early 19th century. Farming represented humans' efforts to work with and accommodate natural patterns; Lowell followed more of a bulldozer approach—mill owners prospered by regimenting that world. For instance, they imposed a regularity on the workday that radically differed from the normal agricultural routine, which followed the seasons and sunlight. Mills ran an average of 12 hours per day, 6 days per week, for more than 300 days per year. Mill owners resisted seasonal rhythms in order to set their own schedule, operating the mills longer in summer, yet extending the winter workday with whale-oil lamps.

The power behind the factory began with the river. Simply damming the existing waterway did not create enough power to run the mills. Lowell's industrial life was sustained by naturally falling water. At Pawtucket Falls, just above the Merrimack's junction with the Concord, the river drops more than 30 feet in less than a mile—a continuous surge of kinetic energy from which the mills harnessed thousands of horsepower per day. Without the falls, Lowell's success would have been impossible. In addition, however, Lowell relied on the construction of canals to better position the Merrimack's water. To increase efficiency, mill owners dammed it, even ponding water overnight for use the next day. Anticipating seasonal dry spells, planners turned the river's watershed into a giant millpond. They were aggressive in purchasing water rights in New Hampshire, storing water in lakes in the spring and releasing it into the Merrimack in the summer and fall (Steinberg, 1991, 3–14).

The rise of Lowell in the second quarter of the 19th century prompted the rhetoric of poets and politicians, who hoped to make it a national model for development. Massachusetts Governor Edward Everett wrote that the city's tremendous growth "seems more the work of enchantment than the regular process of human agency" (Steinberg, 1991, 3–4). The poet John Greenleaf Whittier described Lowell as "a city springing up . . . like the enchanted palaces of the Arabian Tales, as it were in a single night-stretching far and wide its chaos of brick masonry. . . . [the observer] feels himself . . . thrust forward into a new century" (Steinberg, 1991, 14). The city became an obligatory stop for Europeans touring the United States.

Although each of these examples relied on the power systems devised during the Middle Ages, American industrialists had made important new changes in harnessing waterpower. Before human labor could go to work in the mills of Paterson, Rhode Island, or Lowell, the water's power needed to be harnessed. The tool for managing this natural resource was the waterwheel or turbine. Until the second half of the 19th century, waterpower was the major mechanical power source in the United States.

Lowell also marked an important moment in the large-scale manipulation of a river for industrial use. In this case, water was channeled out of the river at a certain height in a power canal. This canal led to a point from which the water would fall to a lower level. During its fall, it filled the buckets in a waterwheel, its weight driving the wheel around. The turbine was later substituted for the waterwheel. The first turbines were designed by Uriah Boyden and adapted by James B. Francis to power Lowell's mills. In this system, the water entered the wheel at its center and was directed outward by stationary vanes to turn another set of moving vanes. By 1858, Lowell employed 56 Boyden turbines, each rated at 35 to 650 horsepower. In both the waterwheel and turbine systems, the power was transferred by wooden or metal gears and leather belts to the mill's main power shaft or drive pulley (Steinberg, 1991, 143).

CASE STUDY OF AN EARLY ALTERNATIVE: MAKING IRON IN THE EARLY REPUBLIC

Just as iron manufacturing marked one of Europe's early industries, settlers also brought the undertaking to the New World. Iron plantations were one of the first inland industries introduced to North America. Americans began to expand iron making in the early 1700s. Many of these bloomeries, fineries, and furnaces were soon built west and north of Philadelphia. In each case, the industry was powered by wood, a renewable biofuel.

Often, British immigrants established these furnaces with the know-how they brought with them from industry abroad. Many of the blast furnaces were on plantations, which were largely self-sufficient communities with large landholdings to supply fuel, ore, and flux for running the furnaces. The process revolved around heating raw ore in order to create a more pure, pig or bar iron. Usually, charcoal provided the best fuel. Therefore, other sites on the plantation would burn the felled lumber to convert it into charcoal (Gordon and Malone, 1994).

The wood was hauled to the coaling areas and made into charcoal during the spring, summer, and fall by skilled colliers. This was done by slowly charring it in pits, a careful process carried out to expel the tar, moisture, and other substances from the wood without consuming the wood itself. Once the process was complete, the charcoal was raked out, cooled, and taken by wagon to the furnace, where it was stored in the charcoal house (Bining, 1973).

Historians Gordon and Malone explain:

> An acre of woodland in sustained production on a twenty-year rotation in the Middle Atlantic region yielded between 500 and 1200 bushels of charcoal. The largest annual consumption of charcoal among the New Jersey ironworks listed in 1850 was 200,000 bushels a year; so between 167 and 385 acres would have been cut each year, and between 3,300 and 7,700 would have sufficed for sustained operation. (Gordon and Malone, 1994, 76)

This ethic, of course, helped to make iron manufacturing a temporary mining industry.

The early iron industry stimulated the development of related industries, including small rail lines to move raw materials around a confined site. Some of these would combine with additional technological advances to make such furnaces obsolete by 1850. The primary reason, though, was the dramatic shift in energy sources.

COAL SPREADS A NEW INDUSTRIAL ERA

The America of the early 1800s still relied on energy technologies that would be considered sustainable alternatives to fossil fuels. The transition, though, had begun, as industrialists extended the use of charcoal, which created an infrastructure that could be expanded to include additional energy sources. Some of these resources, however, were complicated to harvest and manage. Their acquisition demanded entirely separate technological innovations, as well as shifts in the accepted patterns of human life.

In the early 1800s, timber or charcoal (made from wood) filled most Americans' heating and energy-production needs. This changed rather suddenly during the War of 1812, which pitted the United States against Great Britain in a conflict over trade. The war started in 1812 and ended in stalemate in 1815. The root of the conflict was the rights of American sailors, who were being impressed to serve in the British Navy. The major military initiative of Britain during the war, though, was related more to trade: the British blockade of ports such as Philadelphia nearly crumbled the economy of the young republic.

The blockades of the War of 1812, though, became instrumental in moving the United States more swiftly toward its industrial future. Depleting fuelwood supplies combined with the British blockade to create domestic interest in using anthracite or hard coal, particularly around Philadelphia. Historian Martin Melosi writes, "When war broke out . . . [Philadelphia] faced a critical fuel shortage. Residents in the anthracite region of northeastern Pennsylvania had used local hard coal before the war, but Philadelphia depended on bituminous coal from Virginia and Great Britain" (1985, 130). Coal prices soared by over 200 percent by April 1813. Philadelphia's artisans and craftsmen responded by establishing the Mutual Assistance Coal Company to seek other sources. Anthracite soon arrived from the Wilkes Barre area of Pennsylvania. After the war, the industrial use of hard coal continued to increase slowly until 1830. Between 1830 and 1850, the use of anthracite coal increased by 1,000 percent (Melosi, 1985).

This massive increase in the use of anthracite demonstrates how the Industrial Revolution, in a larger sense, represented a transitional period, with animate, muscular energy being almost entirely replaced by inanimate, hydraulics-based energy. Steam engines converted coal's energy into mechanical motion, but still remained very limited in application. Building on the early work of Newcomen and others, James Watt created an engine in 1769 that did not require cooling, which then allowed for the spread of use of steam. Ultimately, then, during this same era, water-powered milling was replaced by inanimate, fossil fuel-based energy in the form of steam power.

As the Industrial Revolution swept from Europe into other parts of the world in the early to mid-1800s, the nations most susceptible to its influence were rich in raw materials and committed to freedom of economic development. In these terms, the United States led the world. Thanks to the American interest in free enterprise and the astounding supplies of raw materials, including coal, and later, petroleum, the United States became the industrial leader of the world by the early 1900s—after only four or five decades fully committed to industrialization. Economic prosperity, massive fortunes for a few, and employment for nearly everyone who wanted to work were a few of the outcomes of American industry. Another outcome, though, from the intense use of the natural environment exerted by industrialization, was environmental degradation.

In the industrial era that stretched from 1850 to 1960, many industrialists were willing to create long-term environmental problems and messes in the interest of short-term gain. Some of these gains came in the form of unparalleled personal fortunes. Other benefits included long-standing economic development for communities and regions around the United States. However, this economic strategy took shape on back of the harvest, manipulation, and exploitation of natural resources. This ethic of extraction was felt to some degree in any industrial community, but possibly it was most pronounced in mining areas, particularly those areas mining for energy resources such as coal and petroleum (Black, 2000b).

As American society committed to a primary course of development that was powered by fossil fuels, much of the evidence of extraction and production was viewed as a symbol of progress. Few checks and balances existed to demand care and conservation. Chapter 3 will discuss the evolution of an alternative ethical paradigm with which Americans administered natural resources. In the 19th century; however, the environmental consequences of mining for these hydrocarbon resources buried deep in the earth was of little concern. Most often, industries were viewed almost solely for the economic development that they made possible.

MINING OUR HYDROCARBON PAST

In terms of energy production, the Industrial Revolution marked the moment when humans turned to the flexible, concentrated power contained within minerals such as coal. Created from the remains of plants that lived and died about 100 to 400 million years ago, when parts of the Earth were covered with huge, swampy forests, coal had been mined by humans since the time of ancient Rome. Formed over millennia, though, coal can't replenish itself. Therefore, coal is classified as a nonrenewable energy source. The energy we get from coal and petroleum today derives from the energy that plants absorbed from the sun millions of years ago. Plants, just like all living things, store energy from the sun. In plants, this process is known as photosynthesis. After the plants die, this energy is released as the plants decay.

Under conditions favorable to coal formation, however, the decay process is interrupted. The plants' energy is not lost, and the material retains its stored solar energy. Most often, geologists believe this occurred as the dead plant matter fell into the swampy water and over the years, forming a thick layer of dead plants decaying at the bottom of the swamps. Over time, the surface and climate of the earth changed, and more water and dirt washed in, halting the decay process. The weight of the top layers of water and dirt packed down the lower layers of plant matter. Under heat and pressure, this plant matter underwent chemical and physical changes, pushing out oxygen and leaving rich hydrocarbon deposits. What once had been plants gradually turned into coal. This coal was then compacted into pockets below the Earth's surface.

Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—represent thousands of years of plant growth. One important seven-foot-thick coal seam, which is known as the Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam is estimated to contain about 14,000 tons of coal, which is enough to supply the electric power needs of 4,500 American homes for one year (Buckley, 2004).

Although petroleum would become a vital cog in portions of the industrial era, coal was the prime mover that achieved most of the work. Of course, coal deposits are scattered throughout the globe; however, northeastern Pennsylvania holds a 500-square-mile region that is uniquely different from any other. When coal was formed over a million years ago, northeastern Pennsylvania accelerated the process with a violent upheaval known as the Appalachian Revolution. Geologists speculated that the mountains literally folded over and exerted extra pressure on the subterranean resources. In northeastern Pennsylvania, this process created a supply of coal that was purer, harder, and of higher carbon content than any other variety. The first to be named using the adjective "hard," this coal eventually became known as anthracite. Geologists estimate that 95 percent of the supply of this hard coal in the western hemisphere comes from this portion of northeastern Pennsylvania.

This supply defined life in the state during the late 1800s. Thousands of families of many different ethnic backgrounds moved to mining towns to support themselves by laboring after coal. In other areas, mills and factories were built that relied on the coal as a power source. In between, the railroad employed thousands of workers to carry coal and raw materials to the mills and finished products away from them.

Coal would alter every American's life through the work it made possible. Although coal was found in a few Mid-Atlantic states, Pennsylvania possessed the most significant supplies and, therefore, became ground zero of the coal culture that would influence the nature of work and workers' lives in the United States. The roughhewn coal communities that sprouted up during the anthracite era reflected the severe organization that defined labor in the coalfields. An elite class of coal owners and operators often lived in magnificent Victorian mansions while their immigrant laborers lived in overcrowded, company-owned "patch towns." The class disparity was perpetuated by a steady change in which ethnic groups provided labor. Waves of European families arrived to live and work in the company towns found throughout the Appalachian Mountains. The original miners from Germany and Wales were soon followed by the Irish, and later, the Italians, Poles, and Lithuanians.

Despite difficult living conditions and ethnic discrimination from more-established groups, these diverse ethnic groups ultimately created vibrant enclaves. In each patch town, they built churches, formed clubs, and helped others from their nation of origin in getting a start in the coalfields.

RELATED PURSUITS: RAILROADS

In addition to stimulating the development of mining in places such as Pennsylvania, industrial development contributed to and even fed the development of related, ancillary undertakings. More and more industries became essential to everyday American lives. Throughout American history, transportation was one of the most important applications of energy. In the case of coal, the use of the railroads made coal supplies accessible, while also using coal's energy for innumerable other activities during the 1800s.

The planning and construction of railroads in the United States progressed rapidly during the 19th century. Some historians say it occurred too rapidly. With little direction and supervision from the state governments that were granting charters for construction, railroad companies constructed lines where they were able to take possession of land, or on ground that required the least amount of alteration. The first step to any such development was to complete a survey of possible passages.

Before 1840, most surveys were made for short passenger lines, which proved to be financially unprofitable. Under stiff competition from canal companies, many lines were begun, only to be abandoned when they were partially completed. The first real success came when the Boston and Lowell Railroad diverted traffic from the Middlesex Canal in the 1830s. After the first few successful companies demonstrated the economic feasibility of transporting commodities via rail, others followed throughout the northeastern United States.

The process of constructing railroads began reconstructing humans' view of the landscape. Issues such as grade, elevation, and passages between mountains became part of a new way of mapping the United States. Typically, early railroad surveys and their subsequent construction were financed by private investors. When shorter lines proved successful, investors began talking about grander schemes. These expansive applications of the railroad provided the infrastructure for remarkable commercial growth in the United States, expanding the impact of the Industrial Revolution (Stilgoe, 1983, 3–8).

By the 1850s, though, the most glaring example of this change was coal-powered railroads. The expanding network of rails allowed the nation to expand commercially. Most important, coal-powered railroads knitted together the sprawling United States into a cohesive social and commercial network. Although this could be seen in concentrated examples, including cities such as Pittsburgh and Chicago to which railroads brought together the raw materials for industrial processes such as steelmaking, on the larger scale, railroads allowed American settlement to extend into the western territories. Functioning as a commercial infrastructure for the entire region, the railroad tied raw materials from distant corners to central processing centers such as Omaha and Chicago (Stilgoe, 1983).

It was a cruel irony that the industrial era that evolved in the late 1800s relied intrinsically on transportation. Long, slender mountains stretched diagonally across Appalachian regions such as Pennsylvania, creating an extremely inhospitable terrain for transporting raw materials. Opening up isolated and mountainous regions required the efforts of a generation of capitalists and politicians, who used their resources and influence to create a transportation network that made the coal revolution possible. Canals were the first step in unlocking the great potential of the coalfields. Soon, though, industrialists focused on a more flexible transportation system that could be placed almost anywhere. Railroads quickly became the infrastructure of the industrial era. Knitting together the raw materials for making iron, steel, and other commodities, railroads were both the process and product of industrialization (Cronon, 1991b).

The iron rails produced in anthracite-fueled furnaces extended transportation routes throughout the nation. This revolution in transportation led to corresponding revolutions in the fueling of industries and the heating of urban residences, which in turn required more and more miners and laborers.

Although each of these social and cultural impacts of the railroad altered American life, it was, after all, primarily an economic enterprise. Primitive as it was, the antebellum railroad entirely remade American commerce. Americans needed to entirely remake ideas of prices and costs. Previously, prices had factored in the length of time involved in transporting goods via turnpikes, steamboats, and canals. From the start, railroad rates were significantly cheaper than wagon rates. The increasing systemization of the railroad process made low costs even more possible (Cronon, 1991b).

The possibility of railroads connecting the Atlantic and Pacific coasts was soon discussed in Congress, and this initiated federal efforts to map and survey the western United States. A series of surveys showed that a railroad could follow any one of a number of different routes. The least expensive, though, appeared to be the 32nd-parallel route. The Southern Pacific Railroad was subsequently built along this parallel. Of course this decision was highly political, and southern routes were objectionable to northern politicians and the northern routes were objectionable to southern politicians (Cronon, 1991b).

Although the issue remained politically charged, the Railroad Act of 1862 put the support of the federal government behind the transcontinental railroad. This act helped to create the Union Pacific Railroad, which subsequently joined with the Central Pacific at Promontory, Utah, on May 10, 1869, and signaled the linking of the continent.

Railroading became a dominant force in American life in the late 19th century, and the landscape that took shape was one of its most noticeable consequences. Following 1880, the railroad industry reshaped the American-built environment, and reoriented American thinking away from a horse-drawn past and toward a future with the iron horse.

RELATED PURSUITS: THE MANUFACTURE OF STEEL

Railroads and the reliance on fossil-fuels enabled the implementation of complex industrial undertakings with a scope and on a scale never seen before. Although iron manufacturing increased in scale with the more intense model of industrialization after 1850, steel is possibly the best example of this new era's capabilities. Using railroads as its linking device, Andrew Carnegie perfected the process of steel manufacturing and created one of the greatest fortunes in history (Opie, 1998).

Into one pound of steel, observed Carnegie, went two pounds of iron ore brought 1,000 miles from Minnesota, 1.3 pounds of coal shipped 50 miles to Pittsburgh, and one-third of a pound of limestone brought 150 miles from Pittsburgh. Rivers and railroads brought the material to the Carnegie Steel Works along Pittsburgh's Monongahela River, where Bessemer blast furnaces fused the materials into steel. One of the greatest reasons for the rapid rise of

American industry was its flexibility, compared to that of other nations. Railroading could be integrated immediately into various industries in the United States, which, for instance, allowed American industry to immediately embrace the new Bessemer steel-making technology. Other nations, such as Britain, needed to shift from previous methods.

One innovation contributed to the next in the late industrial era. Inexpensive energy made it feasible to gather the disparate materials that were necessary to make steel. Steel was stronger and more malleable than iron, which made possible new forms of building. Carbon levels make the bulk of the distinction between the two metals. Experiments with removing the oxygen content of pig iron required more heat than ordinary furnaces could muster. The Bessemer invention created a "Bessemer blow," which included a violent explosion to separate out additional carbon and produce the 0.4 percent oxygen level that was desirable for steel.

New tasks, such as running the Bessemer furnace, created specialized but also very dangerous jobs. Working in the steel mill created a new hierarchy in factory towns. In the case of steel-making, hot or dangerous jobs such working around the Bessemer furnace eventually fell to African American workers (Opie, 1998).

RELATED PURSUITS: ELECTRICITY AND THE EVOLUTION OF THE ENERGY INDUSTRY

Industrial applications of energy shaped the industrial era; however, later in the 1800s, coal, in the form of electricity, was also remaking the everyday lives of many Americans. On the whole, new energy made from fossil fuels altered almost every American's life by 1900. In 1860, there were fewer than a million and a half factory workers in the country; by 1920 there were 8.5 million. In 1860, there were about thirty-one thousand miles of railroad in the United States; by 1915, there were nearly two hundred and fifty thousand miles. The energy moving through such infrastructure would not remain limited to the workplace.

In the 19th century, energy defined industry and work in America, but did not necessarily impact everyday cultural life. This would change dramatically by the end of the 1800s with the development of technology to create, distribute, and put to use electricity. Although electricity is the basis for a major U.S. energy industry, it is not an energy source. It is mostly generated from fossil fuel (coal, oil, and natural gas), waterpower (hydroelectricity), and nuclear power. The electric utilities industry includes a large and complex distribution system and, as such, is divided into transmission and distribution industries.

Following experiments in Europe, the United States' electrical future owed itself to the mind of Thomas Edison, one of the nation's great inventors. In

1878, Joseph Swan, a British scientist, invented the incandescent filament lamp, and within 12 months Edison made a similar discovery in America. Edison used his DC generator to provide electricity to light his laboratory, and later to illuminate the first New York street to be lit by electric lamps, in September 1882. At this point, George Westinghouse patented a motor for generating alternating current (AC). Thus, starting with the general invention of Edison, society became convinced that its future lay with electricity in general and AC generation, specifically. This, of course, required a level of infrastructure development that would enable the utility industry to have a dominant role in American life.

Once again, this need for infrastructure development also created a great business opportunity. George Insull went straight to the source of electric technology and ascertained the business connections that would be necessary for its development. In 1870, Insull became a secretary for George A. Gourand, one of Thomas Edison's agents in England. Then, he came to the United States in 1881 at age 22 to be Edison's personal secretary (Hughes, 1989, 226–30).

By 1889, Insull became vice president of Edison General Electric Company in Schenectady, New York. When financier J. P. Morgan took over Edison's power companies in 1892, Insull was sent west to Chicago to become president of the struggling Chicago Edison Company. Under Insull's direction, Chicago Edison bought out all its competitors for a modest amount after the Panic of 1893. He then constructed a large central power plant along the Chicago River at Harrison Street. The modest steam-powered, electricity-generating operation would serve as Insull's springboard to a vast industrial power base.

By 1908, Insull's Commonwealth Edison Company made and distributed all of Chicago's power. Insull connected electricity with the concept of energy, and also diversified into supplying gas, derived from a variety of sources. Then he pioneered the construction of systems for dispersing these energy sources into the countryside. The energy grid was born. It would prove to be the infrastructure behind every American's life in the 20th century. Through the application of this new technology, humans now could defy the limits of the sun and season (Hughes, 1989, 234–40). The greatest application of this—and a symbol of humans' increased reliance on fossil-fueled power—is the lightbulb.

For decades, inventors and businessmen had been trying to invent a source of light that would be powered by electricity. Primarily, their experiments emphasized positioning a filament in a vacuum. The electric current, was then sent through in hopes of making the filament glow. The filaments consistently failed, though, disintegrating as soon as the current reached them (Hughes, 1989, 39–40).

In 1878, Edison decided to concentrate his inventive resources on perfecting the lightbulb. Instead of making his filament from carbon, Edison switched to platinum, which was a more resilient material. In 1879, he obtained an improved vacuum pump called the Sprengel vacuum, and it proved to be the catalyst for a breakthrough. Using the new pump, Edison switched back to the less-expensive carbon filaments. Using a carbonized piece of sewing thread as a filament in late October, Edison's lamp lit and continued to burn for 13.5 hours. Edison later changed to a horseshoe-shaped filament, which burned for over 100 hours. Edison had invented a practical lightbulb; but, more important, he cleared the path for the establishment of the electrical power system that would revolutionize human existence.

It was this power system that became Edison's real achievement and created the market that would beget a huge new industry destined to affect the lives of every American. The nature of everyday life became defined by activities made possible by electric lighting, as well as the seemingly endless arrival of other electrically powered items. The lightbulb was a critical innovation in the electrification of America; however, it also helped to create the market that stimulated efforts to perfect the power generation industry (Nye, 1999, 138–42).

At the root of power generation, of course, was the dynamo. The dynamo was the device that turned mechanical energy of any type into electrical power (Nye, 1999, 144–8). When Edison started working on the lightbulb, the most effective dynamo produced electricity at approximately 40 percent of the possible efficiency. He developed a dynamo that raised this efficiency to 82 percent.

Together, these technological developments made it possible for Edison to start providing electricity commercially to New York City. By September of 1882, he had opened a central station on Pearl Street in Manhattan and was eventually supplying electricity to a one-mile square section of New York. These areas became futuristic symbols for the growing nation.

A NEW SCALE AND SCOPE FOR ENERGY: BLACK GOLD

Coal provided the basic infrastructure for the Industrial Revolution. Through its impact on the factory system, American life changed radically. But a similar dependence derived from the primary energy resource that followed in the wake of coal: petroleum. The involvement of petroleum to American life in the 1990s would have shocked 19th-century users of "Pennsylvania rock oil." Most farmers who knew about oil in the early 1800s knew seeping crude as a nuisance to agriculture and water supplies. These observers were not the first people to consider the usefulness of petroleum, which had been a part of human society for thousands of years. Its value grew only when European-Americans exploited the resource with their commodity-making skills.

As the oil's reputation grew, settlers to the region gathered oil from springs on their property by constructing dams of loose stones to confine the floating oil for collection. In the mid-1840s, one entrepreneur noticed the similarity between the oil prescribed to his ill wife and the annoying substance that was invading the salt wells on his family's property outside Pittsburgh, Pennsylvania. He began bottling the waste substance in 1849 and marketed it as a mysterious cure-all throughout the northeastern United States. Although he still acquired the oil only by surface skimming, Samuel Kier's supply quickly exceeded demand, because there was a constant flow of the oil from the salt wells. With the excess, he began the first experiments with using the substance as an illuminant, or substance that gives off light. The culture of expansion and development was beginning to focus on petroleum (Black, 2000b).

From this point forward, petroleum's emergence became the product of entrepreneurs—except for one important character: Edwin L. Drake of the New Haven Railroad. In 1857, the company sent Drake to Pennsylvania to attempt to drill the first well intended for oil. The novelty of the project soon had worn off for Drake and his assistant Billy Smith. The townspeople irreverently heckled the endeavor of a lunatic. During the late summer of 1859, Drake ran out of funds and wired to New Haven, Connecticut, for more money. He was told that he would be given money only for a trip home—that the Seneca Oil Company, as the group was now called, was done supporting him in this folly. Drake took out a personal line of credit to continue, and a few days later, on August 29, 1859, Drake and his assistant discovered oozing oil.

Throughout its history, petroleum has exhibited wide fluctuations in price and output. The boom-and-bust cycle was even underwritten by the courts in the case of *Brown v. Vandergrift* (1875), which established the laissez-faire development policy that became known as "the rule of capture." The oil could be owned by whoever first pulled it from the ground—that is, captured it. The rush to newly opened areas became a race to be the first to sink the wells that would bring the most oil up from its geological pockets (Black, 2000b).

After the American Civil War, the industry consistently moved toward the streamlined state that would allow it to grow into the world's major source of energy and lubrication during the 20th century.

During the 19th century, petroleum's most significant impact may have been on business culture. The culture of the industry that took shape would change land use and ideas about energy management throughout the world. John D. Rockefeller and Standard Oil first demonstrated the possible domination available to those who controlled the flow of crude oil. Rockefeller's system of refineries grew so great at the close of the 19th century that he could demand lower rates and eventually even kickbacks from rail companies. One by one, he put his competitors out of business, and his own corporation grew into what observers in the late 1800s called a trust (what, today, is called a monopoly). Standard's reach extended throughout the world, and it became a symbol of the Gilded Age, when businesses were allowed to grow too large and to benefit only a few wealthy people. Reformers vowed things would change (Chernow, 1998).

The laissez-faire era of government regulation of businesses, particularly energy companies such as Standard, came to an end when Progressive reformers took a different view of the government's role in American life. President Theodore Roosevelt, who took office in 1901, led the Progressive interest in involving the federal government in monitoring the business sector. In the late 1890s, muckraking journalists had written articles and books that exposed unfair and hazardous business practices. Ida Tarbell, an editor at *McClure's,* who had grown up the daughter of a barrel maker in Titusville, took aim at Rockefeller. Her *History of the Standard Oil Company* produced a national furor over unfair trading practices. Roosevelt used her information to enforce antitrust laws that would result in Standard's dissolution in 1911. Rockefeller's company had become so large that when broken into subsidiaries, the pieces would grow to be Mobil, Exxon, Chevron, Amoco, Conoco, and Atlantic, among others (Tarbell, 2003).

Even after Standard's dissolution in 1911, the image of its dominance continued. Standard had led the way into international oil exploration, suggesting that national borders need not limit the oil-controlling entity. Throughout the 20th century, large multinational corporations or singular wealthy businessmen attempted to develop supplies and bring them to market. Their efforts combined with consumer desire to make petroleum the defining energy resource of the 20th century. Similar to coal, though, the real revolution in consumption required basic changes in the supply of petroleum—in scale and scope.

CHEAP OIL SETS THE TONE FOR OUR HIGH-ENERGY EXISTENCE

The revolution in the supply of petroleum began with international expansion; however, it was a domestic source that truly defined petroleum's role in Americans' high-energy existence. Although new drilling technologies helped to increase supply, entire new regions needed to be developed. By 1900, companies such as Standard Oil sought to develop new fields all over the world. In terms of the domestic supply of crude, though, the most significant breakthrough came in Texas. With one 1901 strike, the limited supply of crude oil became a thing of America's past. It is no coincidence, then, that the century that followed was powered by petroleum.

This important moment came in East Texas where, without warning, the level plains near Beaumont abruptly give way to lone, rounded hills before returning to flatness. Geologists call these abrupt rises in the land "domes," because hollow caverns lie beneath. Over time, layers of rock rise to a common apex and create a spacious reservoir underneath. Often, salt forms in these empty, geological bubbles, creating a salt dome. Over millions of years, water or other material might fill the reservoir. At least, that was Patillo Higgins's idea in eastern Texas during the 1890s.

Higgins and very few others imagined such caverns as natural treasure houses. Higgins's fascination with one dome-shaped hill in southeast Texas grew. Known as Spindletop, this salt dome—with Higgins's help—would change human existence.

Texas had not yet been identified as an oil producer. Well-known oil country lay in the eastern United States, particularly western Pennsylvania. Titusville, Pennsylvania introduced Americans to massive amounts of crude oil for the first time in 1859. By the 1890s, petroleum-derived kerosene had become the world's most popular fuel for lighting. Thomas Edison's experiments with electric lighting placed petroleum's future in doubt; however, petroleum still stimulated economic booms wherever it was found. But in Texas? Every geologist who inspected the Big Hill at Spindletop told Higgins that he was a fool.

With growing frustration, Higgins placed a magazine advertisement requesting someone to drill on the Big Hill. The only response came from Captain Anthony F. Lucas, who had prospected domes in Texas for salt and sulfur. On January 10, 1901, Lucas's drilling crew, known as "roughnecks" because of the hard physical labor of drilling pipe deep into earth, found mud bubbling in their drill hole. A sound like a cannon increased to a roar, and suddenly oil spurted out of the hole. The Lucas geyser, found at a depth of 1,139 feet, blew a stream of oil over 100 feet high until it was capped nine days later. During this period, the well flowed at an estimated rate of 100,000 barrels per day—well beyond any flows previously witnessed. Lucas finally gained control of the geyser on January 19. By that point, a huge pool of oil surrounded it. Throngs of oilmen, speculators, and onlookers came and transformed the city of Beaumont into Texas's first oil boomtown.

The flow from this well, named Lucas 1, was unlike anything witnessed before in the petroleum industry: 75,000 barrels per day. As news of the gusher reached around the world, the Texas oil boom was on. Land sold for wildly inflated prices. After a few months, over 200 wells had been sunk on the Big Hill. By the end of 1901, an estimated $235 million had been invested in oil in Texas. This was the new frontier of oil; however, the industry's scale had changed completely at Spindletop. Unimaginable amounts of petroleum—and the raw energy that it contained—were now available at a low enough price to affect every American's life.

It was the businessmen who then took over after Higgins and other petroleum wildcatters. Rockefeller's Standard Oil and other oil executives had managed to export petroleum technology, and had exploited supplies worldwide. The modern-day oil company became a version of the joint stock companies that had been created by European royalty to explore the world during the mercantilist period of the 1600s. Now, though, behemoth oil companies were transnational corporations, largely unregulated and seeking one thing: crude oil. Wherever "black gold" was found, oil tycoons set the wheels of development in motion. Boomtowns modeled after those in the Pennsylvania oil fields would suddenly pop up in Azerbaijan, Borneo, or Sumatra (Yergin, 1993, 117–19).

As East Texas gushers created uncontrollable lakes of crude, no one considered shortages or conservation. Even the idea of importing oil was a foreign concept. California and Texas flooded the market with more than enough crude oil, and then from nowhere, Oklahoma emerged in 1905 to become the nation's greatest oil producer. However, what was to be done with this abundant, inexpensive source of energy now?

MAKING BLACK GOLD FROM TAR

The second key to petroleum's expansion was for it to become essential. This required that petroleum's basic utility become transportation. Unlike coal, Americans formed a very personal, cultural relationship with petroleum during the 20th century. Commodities such as petroleum are culturally constructed: a market must first place a value on them before they are worthwhile. In the earliest years of petroleum, it was refined into kerosene, an illuminant to replace whale oil. This value or importance diminished after 1900, when electricity became the source of most lighting. Within a brief time, petroleum's greatest value derived from transportation, mainly the automobile.

First developed in Europe in the late 1800s, the automobile was marketed successfully beginning in 1894. Inconvenience from a lack of roads and infrastructure precluded Americans from rapidly accepting the new "horseless carriage." Through the technological developments of independent inventors, mass production in the automobile industry was introduced in 1901 by Ransom E. Olds, a pioneer experimenter since 1886. His company manufactured more than 400 Oldsmobiles in that first year. Each car sold for only

$650. Henry M. Leland and Henry Ford further developed mass production methods during the early 1900s. It remained unclear, though, who actually owned this evolving technology. Through court battles that stretched into the 1910s, aspiring automobile manufacturers debated who owned the patents for the basic technologies of the automobile industry, ranging from the internal combustion engine to the mass production process itself. Partly as a result of this litigation, the Ford Motor Company was organized in 1903, the General Motors Corporation in 1908, and the Chrysler Corporation in 1925 (McShane, 1994).

The manufacturing and marketing efforts of Henry Ford and others changed the American attitude toward the automobile by 1913, when there was one motor vehicle to every eight Americans. Ford's model of mass production made sure that by the 1920s the car had become no longer a luxury, but a necessity, of American middle-class life. The need for additional infrastructure—roads and bridges—was growing, but it was unclear who would pay to develop it (Brinkley, 2003).

Using mass production, the first Model T Ford was made in 1908. More than 15 million were to be sold in the next 20 years. The Model T, nicknamed the "flivver" and the "tin lizzie," was probably more responsible for the development of large-scale motoring than was any other car in automotive history. During World War I, the manufacture of automobiles for civilian uses was virtually halted as the industry was mobilized to produce vehicles, motors, and other war matériel for the armed forces. The automobile assumed a significant new role in the American way of life immediately after World War I.

No longer an extravagant novelty, the motorcar was rapidly becoming a necessity rather than a luxury for many American families. By the early 1920s, most of the basic mechanical problems of automotive engineering had been solved. Manufacturers then concentrated their efforts on making motorcars safer, more stylish, and more comfortable.

In 1929, about 90 percent of new purchases were drawn from a few original models. By the mid-1920s, Henry Ford had decided to abandon the three-pedaled Model T and to replace it with the Model A, which was to be equipped with a conventional gearshift. The last Model T was produced in May 1927, and the first Model A rolled off the assembly line in October 1927. An enthusiastic public was soon buying thousands (Brinkley, 2003).

Rising numbers of autos required organized development of the landscape on which they would be driven. Federal, state, and local governments began using taxpayer funds to construct roads after the Federal Road Act of 1916. This process of road building began what some historians have called the "largest construction feat of human history," and the American road system unfolded throughout the early 20th century. Beginning in the 1920s, legislation created a Bureau of Public Roads to plan a highway network to connect all cities of 50,000 or more inhabitants. Some states adopted gasoline taxes to help finance the new roads. These developments were supplemented in the 1950s when President Dwight D. Eisenhower included a national system of roads in his preparedness plans for nuclear attack. This development cleared the way for the Interstate Highway Act to build a national system of roads unrivaled by any nation (Jackson, 1985).

In the United States, roads initiated related social trends that added to Americans' dependence on petroleum. Most important, between 1945 and 1954, nine million people moved to suburbs. The majority of the suburbs were connected to urban access by only the automobile. Between 1950 and 1976, the population of city centers grew by only 10 million, while suburban growth was 85 million. Clearly, the United States was becoming a nation of suburbs. Housing developments and the shopping/strip mall culture that accompanied decentralization of the population made the automobile a virtual necessity. Shopping malls, suburbs, and fast-food restaurants became the American norm through the end of the 20th century, making American reliance on petroleum complete. Americans now were entirely wedded to their automobiles, which allowed prices of petroleum to impact American life more than any other nation (Lewis, 1997). Other details of this high-energy existence will be discussed in chapter 3.

CONCLUSION: THE HIGH-ENERGY LIFE

The high-energy lifestyle that humans adopted during the 20th century has enabled staggering accomplishments and advancements. The extensive use of fossil fuels has also come with its share of serious impacts, some of which we are just learning about in the 21st century. This chapter began with humans living during the agriculture revolution, living within the natural cycles of energy that begin with the sun. The Industrial Revolution made such natural forms of energy less desirable (alternatives) to the more desirable, primary use of energy made from burning fossil fuels. Particularly in the United States, we made cheap energy part of our lives and threw caution to the wind. The 20th century became a binge on cheap energy and all that it made possible.

At the dawn of the 21st century, Americans have come to recognize that the great energy resources of the industrial era were exhaustible: that the supplies of coal, petroleum, and natural gas were finite. Throughout the 20th century, though, amidst the frenzy of its energy decadence and its associated economic and social development, a growing chorus alerted consumers and politicians to the temporality of reliance on hydrocarbon-derived energy.

As one might imagine, the call for the use of alternative modes of power often went against the grain of basic ideas of American progress and success. By the end of World War II, the emergence of the United States as the global economic, military, and cultural leader was largely predicated on an existence of cheap energy. The infrastructure that emerged to support this society made certain that power from hydrocarbons involved some of the greatest economic, political, and social players of the century. To fight against such imbedded interests might have seemed folly; however, the persistence and innovation of such minority voices has largely set the stage for a new era of energy use in the 21st century. Alternative energy ideas used as early as the 1100s would rise again as the most sensible and sustainable ways of creating power.

3

Against the American Grain: Paths Taken, Paths Declined

How do culture-wide aspirations take form? How are they disseminated? The answer, of course, is complex and difficult to fully track, especially when the cultural practice you wish to comprehend is an intrinsic, basic part of human life such as energy usage. In the case of our high-energy existence, cheap fossil fuels brought us a higher standard of living with easier travel. Particularly in post-World War II America, this lifestyle was just what we desired. But how did Americans find out what they wished for? How did these tastes take shape?

In the case of the high-energy lifestyle, we might simply look at the utopian visions that preceded World War II. For one snapshot of our high-energy aspirations, historians point to the 1939 World's Fair in New York City. The scene created by designers at the 1939 Futurama exhibit is almost eerie in its accuracy. The future scene depicts a high-energy society in which, similar to strings on a marionette, the sources of energy are unseen. Futurama was a ride included in the General Motors Pavilion, which stimulated some of the greatest interest at the Fair. Long lines of people waited to glimpse the future scene of 1960.

In particular, GM's Futurama depicted a world linked by easy, clean, and simple personal transportation. Although such vehicles were only one use of energy, the imagined landscape was filled with models of the skyscrapers that had begun to emerge in American cities in the 20th century. GM's ride presented a utopia forged by urban planning. Sophisticated highways ran through rural farmland and eventually moved into carefully ordered, futuristic cities. What the Futurama ride was really selling was a transportation infrastructure—a taxpayer-funded highway system.

Behind the veil of this infrastructure and, in fact, all of Futurama, a network of affordable energy made the futuristic life go. In that fashion, the reality of 20th-century life was very accurately foreshadowed by the exhibit. Americans who began with what today we refer to as alternative fuels emerged from the Industrial Revolution of the 1800s in a society in transition: from the scattered, industrial use of fossil fuels for industry, innovators now devised methods such as electricity and the internal combustion engine to domesticate the application of such energy. Overall, the reliance on mined, artificial supplies of energy spanned nearly two centuries. During this time, new technologies and aggressive corporate development brought consumers the cheapest energy supplies ever seen in human history. In many parts of the United States, these supplies of energy resources were distributed widely, and their availability significantly impacted the everyday lives of consumers. However, alternatives never entirely went away.

For any observer well schooled in the natural laws governing energy, there was no doubt that alternative fuels would eventually be important again. In short, the energy resources such as coal and petroleum that were widely used during the 19th and 20th centuries were finite. They would not grow back at a rate to satisfy the demands of human life. Despite this reality, many Western societies (particularly in the United States) used energy without thought of managing supply and conserving potential energy. This high-energy existence was ironic, of course: it expedited the diminishment of the finite energy resources, thereby forcing the eventual need for alternatives to emerge earlier than they might have otherwise. Clearly, the high-energy existence was more a cultural paradigm than anything else. Similar to the scene of the Futurama, Americans' ability to grow unimpeded and unlimited became the defining ideal of the 20th century—alternatives, and the responsible resource management that they entailed, waited until they were needed.

Thanks to plentiful supplies of coal and petroleum, the 20th century was defined by inexpensive energy. Shaped by these primary energy suppliers, other sources of energy became more and more clearly defined as alternatives. Even though in most cases their use preceded those of fossil fuels, the adoption and development of alternatives required a change in the predominant culture and the ethic with which Americans viewed energy use. Most 20th-century Americans accepted the false reality of cheap energy because it made life easy and simple. Later in the 20th century, though, an alternative ethic emerged, which will be discussed in chapter 4.

This chapter will investigate the emergence of the high-energy juggernaut in American life by, conversely, discussing the ongoing and continued efforts to develop alternative systems of energy before 1970. Most important, this chapter discusses energy use as an expression of ethics and preferences. As such, any consideration of alternative energy required an *alternative* ethic to the approach governing the lives of most 20th-century Americans and even our dreams, such as Futurama. The cultural tradition for this alternative ethic is normally considered a part of the environmental movement: restraint, otherwise known as conservation.

THE AMERICAN CONSERVATION ETHIC

As most Americans focused on expansion and development as the overriding strategy for national development during the industrial revolution of the 1800s, a few intellectuals begged to differ. Interestingly, their call for an alternative approach reverberated in American society for decades and ultimately inspired many people to consider options to a severe emphasis on economic development. In this fashion, the early conservation thinkers played a crucial role in creating a culture that could, more than a century later, be receptive to the need for ways of generating power that were contrary to the accepted burning of fossil fuels.

During their lifetimes, romantic philosophers, including Ralph Waldo Emerson and Henry David Thoreau, stood against the calls for westward expansion and blind confidence in progress through industrial development. Instead, they stressed the need for other paradigms for approaching natural resources. In addition to serving as raw material for development, natural resources might serve other human needs, including a context for thoughtful repose.

When these thinkers began voicing their views early in the 19th century, the aesthetic appreciation of nature had little intellectual foundation in American history. After the 1820s, though, writers and intellectuals began knitting together ideas and influences from other parts of the world with sensibilities such as those of visual beauty expressed by the painter Thomas Coles. The literary and intellectual movement that grew out of this increased interest in nature was referred to as transcendentalism. This realm of belief became a part of American Romanticism, ultimately combining spirituality and religion (Nash, 1982, 85–86).

Writers and reformers, including Emerson, Thoreau, Margaret Fuller, and Amos Bronson Alcott, developed this line of thinking in New England between 1830 and 1850. Their actions helped to transform transcendentalism—at least partly—into an intellectual protest movement; however, it continued to carry with it a new appreciation for nature. Most often, transcendentalists connected to the ideas of philosophical idealism that derived from German thought, either directly or through the British writers Samuel Taylor Coleridge and Thomas Carlyle.

Emerson emerged as the intellectual leader of this group when he connected romanticism with Unitarianism. By 1825, Unitarianism had many followers in Massachusetts, where they openly attacked the orthodoxy of the Puritans who dominated New England. In place of Puritan thinking, the Unitarians offered a liberal theology that stressed the human capability for good. Four years after resigning as pastor at Boston's Second Church, Emerson published *Nature* in 1836. Emerson directly challenged the materialism of the age and his writing was adopted as the centerpiece of transcendentalism (Nash, 1982, 86–89).

In the Boston area, the Transcendental Club began to meet in order to refine and disseminate the ideas that Emerson had voiced in his writing. This group of intellectuals also created the famous Brook Farm experiment in communal living (1840–1847), in West Roxbury, Massachusetts. Young Henry David Thoreau became active with the Club and began working with its publication, the *Dial*. Thoreau's writing emphasized the role of nature in Americans' lives. Thoreau published his greatest work, *Walden*, in 1854. This book was Thoreau's account of transcendentalism's ideal existence of simplicity, independence, and proximity to nature. In *Walden*, Thoreau extended Emerson's ideas of replacing the religion of early 19th-century America with the divine spirit. In this paradigm, the natural surroundings took on spiritual significance. More than ever, Thoreau created a model of transcendentalist thought connected to nature.

Thoreau's message from Walden Pond urged Americans to escape from mechanical and commercial civilization in order to be immersed in nature, even if only for a short time. Although few Americans in 1850 either read *Walden* or immediately came to see nature differently, Thoreau and other transcendentalists laid the foundation for a new way of viewing the natural environment. No longer was raw material simply for industrial development; nature possessed aesthetic or even spiritual value.

Transcendentalists, writers, poets, and artists argued that America was nature's nation. The symbolic meaning of the United States was not necessarily found in the manicured beauty of the manicured French and British gardens. It lay also in the raw wilderness not found in Europe. In April 1851, Thoreau lectured at Concord Lyceum in Massachusetts. After beginning by saying that he "wished to speak a word for nature," he answered proponents of development and civilization. Finally, he shared a timeless insight when he stated, "In Wildness is the preservation of the world" (Nash, 1982, 84).

With that statement, Thoreau forged a connection between the intellectual approach of transcendentalism to the wilderness and to American ideals of democracy, independence, and beauty. The attraction of nature would eventually also include an interest in primitivism—one interpretation of

Thoreau's term, "wildness." As society became more industrialized, developed, and urban, a contrary impulse attracted some Americans to seek innocence in raw nature. This basic plank of Conservation thought helped to form an alternative paradigm for thinking about many issues in the United States over the next century.

In some intellectual circles, the conservation impulse took form in the admiration of natural beauty. An important component of this intellectual movement came from the Hudson River School. The first internationally recognized art genre to be initiated in the United States, it grew between the 1820s and the late 19th century. Initially, their paintings were scenes of the Hudson River Valley and the adjoining mountains of New York and Vermont. Eventually, as a view of nature and not a region was identified as the primary organizational device for the genre, Hudson River School artists would paint natural wonders from all over the world (Novak, 1980, 18–20).

Through the efforts of these writers and painters, among others, a new paradigm became part of American culture. In this new mindset, nature was granted worth in its own right, particularly for its aesthetic beauty. Although the majority of Americans maintained a utilitarian view of nature, the intellectual construction of what would develop into a conservation ethic in the later 1800s had begun. By the 1860s, this sensibility of restraint had taken physical form in a few cities.

With the completion of Central Park in 1862, America could finally boast of a grand park to compete with those of Paris and London. It was, of course, a complete luxury to set land apart from development and then to spend resources on its preparation for recreation and enjoying its aesthetic beauty. Although many Americans deemed it a waste to use 700 acres of what would eventually become the center of Manhattan, the park's architects, Frederick Law Olmsted and Calvert Vaux, sought to create a pastoral landscape in the English Romantic tradition. Completed in stages during the early 1860s, Olmsted and Vaux's Greensward plan revolutionized the American view of its landscape and represented a new relationship between Americans and the natural environment. Its building required more than 20,000 workers, 3 million cubic yards of soil, and more than 270,000 trees and shrubs. By 1865, there were more than seven million visitors every year. Through Olmsted, the ethic introduced by Emerson and Thoreau had found a physical form that specifically appealed to American ideals. Although such planning introduced an ethic of restraint to urban expansion, it did not yet affect parts of life such as energy management.

Taking on the concept of industrial development, of course, went against American trust in free enterprise. By the end of the century, early conservation thought had clearly begun to take on this basic American idea. One of the first views questioning it came from the Vermont Statesmen George Perkins Marsh.

While acknowledging the need for human use of the natural environment, Marsh used his 1864 book *Man and Nature* to take Americans to task for their misuse and mismanagement of their national bounty. Marsh writes:

Nature, left undisturbed, so fashions her territory as to give it almost unchanging permanence of form, outline, and proportion, except when shattered by geologic convulsions. . . . In countries untrodden by man, the proportions and relative positions of land and water . . . are subject to change only from geological influences so slow in their operation that they geographical conditions may be regarded as constant and immutable. Man has too long forgotten that the earth was given to him for usufruct alone, not for consumption, still less for profligate waste. . . . But she has left it within the power of man irreparably to derange the combinations of inorganic matter and of organic life. . . . man is everywhere a disturbing agent. Wherever he plants his foot, the harmonies of nature are turned to discords. . . . Of all organic beings, man alone is to be regarded as essentially a destructive power. (Marsh, 1965, 29–37)

In this passage, Marsh foreshadows the words of historian William Cronon, who would observe over a century later that "ecological abundance and economic prodigality went hand in hand: the people of plenty were a people of waste" (Cronon, 1991a, 146).

In addition to offering a new paradigm with which to perceive human development in 1864, Marsh also foreshadows the fascinating twist that the 19th century offers environmental history: just when it appeared that Americans would reap every resource available in North America with reckless abandon, they learned restraint. Voices such as Marsh's resulted in a reactionary movement that unfolded in the late 19th century. With little science at their disposal, early environmentalists called for restraint and conservation—management—of resources, largely because it seemed to be the logical thing to do (Lowenthal, 2000). Ultimately, this conservation ethic would have important implications for helping Americans overcome the expansive reliance on cheap energy that came to dominate it; however, in the late 1800s, the conservation ethic was only in its infancy.

The American movement for conservation took a variety of forms during its formative period. One of the earliest, though, applied to forests, which, by the late 1800s, were used more for construction than for energy. Separate parties interested in conservation and their supporting cultural elements coalesced in the early 20th century to form a revolutionary new mandate for federal activity in regard to natural resources use. The Progressive period energized many Americans to identify social ills and to use the government to correct them. The impulse to end the pollution and waste of resources, both physical and spiritual, of American communities rapidly became an expression of Americans' unique connection to the land.

The leadership of President Theodore Roosevelt and his Chief of Forestry, Gifford Pinchot, galvanized the upper class's interest in national policies. The aesthetic appreciation of wealthy urbanites grew into progressive initiatives to create national forests and national parks, with a unifying philosophy for each (Fox, 1986, 19–25). While Roosevelt possessed preservationist convictions, his main advisor on land management, Pinchot, argued otherwise for the good of the nation. Pinchot, who became one of the national politicians most identified with the Progressive era and served as Governor of Pennsylvania, is generally regarded first and foremost as the father of American conservation. Largely through his efforts, Americans gained a clearer understanding of the finite supply of many natural resources and the capacity of Americans to better manage their use. In his writings, Pinchot argued for an ethic of managed usage that became identified with the term "conservation."

Although this terminology and ethic could be applied to any resources, Pinchot began his work on trees. Pursuing a graduate degree in forestry required that Pinchot study in Europe. After one year of school in France, he returned to work as the nation's first professional forester. He worked as a resident forester for Vanderbilt's Biltmore Forest Estate for three years. In 1898, Pinchot was named chief of the U.S. Division of Forestry. Shortly thereafter, his close friend Theodore Roosevelt replaced the assassinated President William McKinley. The stage was set for the most formative period in American conservation history. In this important moment, the federal government became a primary tool for forcing an alternative ethic on the large corporate interests who administered much of the United States' supply of natural resources. In 1905, Roosevelt restructured the federal government to transfer responsibility for managing the forest reserves from the Department of the Interior to the Department of Agriculture and the new Forest Service. With Pinchot in charge of the new Forest Service, he professionalized the management of the national forests and increased their size and number. In 1905, the forest reserves numbered 60 units covering 56 million acres; in 1910, there were 150 national forests covering 172 million acres.

Conservationists were buoyed by Roosevelt's vociferous and active ideas. In 1908, he stated some of these points in the nation's first Conference of Governors for Conservation:

> The wise use of all of our natural resources, which are our national resources as well, is the great material question of today. I have asked you to come together now because the enormous consumption of these resources, and the threat of imminent exhaustion of some of them, due to reckless and wasteful use . . . calls for common effort, common action. (Nash, 1981, 156)

During the early 1900s, each of these cultural and political details became part of the land-use known as conservation. As a method of applying practical management principles to natural resources, conservation would influence the American use of forests, rivers, wildlife, and fish by the end of the first decade of the 1900s. Soon, this same attitude would influence some people's views on the use of energy resources. Clearly, though, the overwhelming norm for American attitudes toward energy remained the opposite of conservation well into the 21st century. However, this did not necessarily mean that there was no place for alternative power-generation methods. These might also become a tool for applying the conservation mindset.

GENERATING POWER AT NIAGARA

By the late 19th century, it was becoming increasingly obvious that the mainstay of Americans' high-energy existence would be electricity, primarily created from burning coal. Nevertheless, some alternative energy sources continued to make good sense, particularly given the conservation ethic. In a unique blend of modern technology and conservation planning and design, waterpower moved into the era of hydroelectricity at the end of the 1800s.

Although the conservation ethic evolved among a small group of Americans during the 19th century, the overwhelming majority of Americans clearly believed inexpensive energy marked the essential element for economic growth. By the late 1800s, these contrary impulses converged in a few choice locations. The most important was Niagara Falls, which obviously represented a vast potential source of alternative power; it became symbolically important to competing sides of the argument. A single site could force Americans to measure and define their commitment to viewing nature as an instrument for their use and economic growth or, instead, as an exceptional place, protected from change and development. In the 1890s, idealism slowly gained ground by virtue of the practicality with which many Americans viewed their natural surroundings.

Niagara Falls began the century as the young nation's primary tourist attraction—a dramatic example of the sublime nature. But the relentless spirit of industrialization had also permeated Niagara. By the 1880s, the motive power was not only attracting milling interests; in 1889 the Cataract Construction Corporation announced plans to make the falls the dynamo for an entire industrial region.

Involving sponsorship from the Edison Electric Company and Westinghouse (among others), the Company in 1893 committed its resources to making the falls the hub for alternating current electricity in the region. As construction moved forward, Niagara's tourists failed to see the irony. Its role as an electric mecca made the falls even more attractive as a tourist destination. As historian William Irwin writes, "Confident that the New Niagara did not usurp nature, tourist promoters and power developers alike championed the engineer's additions to the Niagara landscape" (1996, 114).

The main focus of this interest was an enormous power tunnel that was 6,700 feet long and 21 feet high. The tunnel re-routed a portion of the water through turbines and dropped it out just below the base of the falls. The tunnel's outlet soon became a stop on the tours carried by the *Maid of the Mist* tour boats. At the other end of the tunnel, of course, was the powerhouse. Built to be a monument comparable to the falls, the powerhouse was designed and built by the famous architectural firm McKim, Mead & White. Inside, the powerhouse held the state-of-the-art technology of the age: the electric dynamo.

A symbol of technological success in the popular imagination, the New Niagara became the backdrop for futuristic visions, including H. G. Wells' science fiction, Buck Rogers' adventures, and many others. The electricity, of course, also attracted cutting-edge manufacturing, including the model factory of the Shredded Wheat Company. Referred to as the Natural Food Company or the Natural Food Conservatory, the cereal factory attracted more than 100,000 visitors per year. The use of the term "natural" was meant to denote the healthfulness of the product. However, it certainly contributed to the image that the power of the factory came from the mighty, natural forces of Niagara.

THE GO-GO ERA OF PROGRESSIVE HYDRO DEVELOPMENT

Historian Sam Hays writes of the social changes connected with the conservation ethic in this fashion:

> The broader significance of the conservation movement stemmed from the role it played in the transformation of a decentralized, nontechnical, loosely organized society, where waste and inefficiency ran rampant, into a highly organized, technical and centrally planned and directed social organization which could meet a complex world with efficiency and purpose. (1999, 265)

The largest example of this planning related to alternative energy was the use of rivers to generate electricity.

Growing from the Niagara model, planners began to believe that modern technology allowed them to tame any river into a productive anchor of regional development. These aspirations knew no bounds; in fact, during the early 1900s, planners set out to use their know-how to fix and reclaim for human settlement the dry areas of the American West.

As the technology emerged to hydraulically manage rivers and water supplies, it became clear that the effort to manipulate the water supply of these states would require vast sums of capital. Although specific states would benefit most, one could clearly argue that, much like the railroad, the entire nation would gain valuable resources from such development in western states. Therefore, as a major part of the Progressive era of the early 1900s, lawmakers debated the extent to which federal funds should be used for dam building and water management in the West.

By the second decade of the 1900s, federal money would be channeled into revolutionary projects to aid in making the western lands more easily inhabitable by settlers. The Corps of Engineers typically used river conservation plans to assist or maintain existing human communities. With the Newlands or Reclamation Act of 1902, river engineering was connected to a federal effort to overcome the rainfall deficiencies of the American West and allow it to be reclaimed for human development. The new Bureau of Reclamation focused on water and irrigation needs, but also used each dam as an opportunity to develop inexpensive power through the use of hydroelectricity. Although these intrusive projects significantly manipulated western environments, they are typically considered a form of conservation because they necessitated the management and maintenance of natural resources.

Originally, the Bureau of Reclamation came to the field of hydropower simply to create revenue while achieving its larger goal of managing the water resources in the arid west. Government planners realized that Reclamation dams could provide inexpensive electricity, which might also stimulate regional growth. Reclamation's first hydroelectric power plant was built to aid construction of the Theodore Roosevelt Dam. Even prior to fully constructing the dam, the bureau installed small hydroelectric generators to manufacture energy for building the dam and running equipment. Surplus power was sold to the community, which helped citizens to quickly fall in line to support expansion of the dam's hydroelectric capacity.

In 1909, the Theodore Roosevelt Powerplant became one of the first large power facilities constructed by the federal government. Initially, the plant provided the Phoenix area with 4,500 kilowatts before being expanded to over 36,000 kilowatts. Its power, first developed for building Theodore Roosevelt Dam and for pumping irrigation water, also helped pay for construction, enhanced the lives of farmers and city dwellers, and attracted new industry to the Phoenix area (Reisner, 1993, 84–89).

By the early 1900s, hydroelectric power accounted for more than 40 percent of the United States' supply of electricity. In the 1940s, hydropower provided about 75 percent of all the electricity consumed in the west and Pacific Northwest, about one third of the United States' total electrical energy. The new era of hydroelectric development in the West received its greatest symbol in 1935, when the Hoover Dam was completed.

The large dam and the completeness with which it turned the unruly river to human good sent shockwaves around the world. In fact, Hoover Dam served as a symbol of the efficiency of modern technology in general—not just hydroelectric development. The dam, which has long since repaid its $165 million construction cost, is a National Historic Landmark and has been rated by the American Society of Civil Engineers as one of America's Seven Modern Civil Engineering Wonders. The structure contains over four million cubic yards of concrete, which if placed in a monument 100 feet square would reach 2.5 miles high—higher than the Empire State Building.

As proposed in the 1910s, the mammoth Boulder Dam (as it was first referred to) served as the linchpin of a western land-use policy designed to reclaim dry, barren regions by applying human ingenuity. This ingenuity would be applied to the region's few existing waterways, including the Colorado River. Most of the flow, including the electricity made at Hoover Dam, would be managed by the Six Companies contractors to power development over 300 miles away in Southern California. Today, the majority of Hoover Dam's power is passed over wires to Los Angeles.

The symbolic significance of this immense structure became obvious immediately, which led developers to name it after President Herbert Hoover (an engineer who had been a great supporter of the project). Upon its completion in 1935, Hoover Dam became a symbol of America's technological prowess, firmly placing the United States among the great civilizations in world history. More importantly, however, conservationists had adopted a policy that included scientific management based in ecological understanding. This perspective viewed technology, such as dams, as a tool of conservation through the creation of energy from alternative means.

THE TVA AND REGIONAL PLANNING

Throughout the United States, many regional and state groups used the advice of the Corps of Engineers as they built their own dams to assist in generating at least small amounts of electricity. Normally, these small dams simply added electricity to the overall grid; however, at least one example deserves special consideration.

When Franklin D. Roosevelt (FDR) took office in 1933, he sought the advice of modern-thinking experts in many fields. FDR took intellectuals from colleges and universities and inserted them immediately into the emergency of the Great Depression. Both he and the American people expected results. With a long-term interest in the science of forestry and resource management, FDR was particularly struck by the waste of American natural resources at a time of great need. In his inaugural address, FDR stated: "Nature still offers her bounty, and human efforts have multiplied it. Plenty is at our doorstep, but a generous use of it languishes in the very sight of the supply." His initiatives sought to intelligently utilize these resources while creating jobs for out-of-work Americans (Henderson, 2004, 35).

Although the economic collapse of 1929 left millions of Americans incapable of making a living, many New Deal conservation projects used job creation as only an initial rationale. In addition, many of these initiatives became opportunities to apply new scientific ideas for planning. This was also apparent in New Deal river projects, particularly the Tennessee Valley Authority. The entire watershed of the Tennessee River contributed to flooding problems on its banks and along the Mississippi River before 1933. In this year, Franklin Delano Roosevelt created the TVA to manage the entire watershed through a system of dams and other structures. The land management system, based in concepts of ecology, would restore lost topsoil, prevent floods, stabilize transportation possibilities, and create the opportunity for recreation and economic development (Henderson, 2004, 182–4).

The TVA Act of 1933 called for the U.S. government to finance, plan, and carry out the revitalization of a depleted region by constructing a series of dams along the Tennessee River to harness the river's potential for generating power, while also tempering its flow to prevent flooding. The first TVA project, Norris Dam, cost $34 million to erect. During the 1930s, the United States invested $300 million in TVA projects, creating eight dams along the Tennessee River. By 1945, TVA would double the number of dams and in the process put thousands of people to work. Such planning was based on the conservation ethics of efficiency and functionality, but especially on limiting waste. In his inaugural address, Franklin Delano Roosevelt revealed the forces that would drive many of his New Deal policies when he said: "Nature still offers her bounty and human efforts have multiplied it. Plenty is at our doorstep, but a generous use of it languishes in the very sight of the supply." The wealth was available, he suggested, if the management of such resources were conducted with more care.

Electricity made from turbines within the dams was considered integral to modernizing the region. The Electric Home and Farm Authority, for instance, facilitated the purchase of low-cost appliances that could be powered by TVA electricity. Before the TVA, 97 percent of those living in the area had no electricity. TVA dams were neither planned as landmarks nor intended to dominate the natural environment; instead, they were part of an integrated system of managed nature that would conserve the resources of the entire river valley. They were a cog in the machine of conservation.

For the first time, conservation could be envisioned clearly as a distinct scientific act of planning, followed by action that led to improved natural resources. Energy production through alternative means was a critical part of the process.

These systems of recovery, development, and conservation proved revolutionary in American land use. However, the idea of a national system of regional planning authorities dissolved in the shadow of TVA experience. The legal fights that befell the TVA in the late 1930s crystallized the American discomfort with the blurring of the line between government and private economic development (these cases essentially involved the right of the federal agency to seize private property in order to build facilities such as dams and power plants). However, a few other river projects, particularly the Columbia in Washington, followed the TVA's model. There can be no doubt that alternative power options had not been allowed to die, even though the high-energy existence dominated the lives of most Americans. In fact, entirely new alternatives lay just on the horizon.

NUCLEAR ENERGY BEGINS AS A WEAPON

Readers will note that in this volume we defined alternatives as those sources outside the more acceptable fossil fuels. We did not, necessarily, define alternatives as renewable energy sources—those sources, such as the sun, that do not diminish. Given this definition, we must discus the history of one significant alternative for electricity generation that emerged just after World War II: nuclear power. As an alternative to the fossil fuel paradigm, nuclear power only became identified as a source of power generation after it had first served a critical role in American history.

By the late 1930s, World War II threatened the globe. Leaders of every nation searched for any edge that would defeat the enemy forces. Scientists in America and Germany actively experimented with atomic reactions. In Germany, leaders felt such technology might prove a decisive force in the war effort. In reaction, American scientists enlisted Albert Einstein to write a letter about their research to President Franklin D. Roosevelt. In this letter, he stressed the technology's potential—particularly if it were developed by the enemy. In October 1939, Roosevelt authorized government funding for atomic research.

Eventually, science and the military would be linked in a way never before seen. However, first scientists needed to demonstrate the viability of an atomic reaction. Of course, today the concept of force generated by separating atomic particles is fairly well known; however, in 1940, such ideas smacked of science fiction. In 1940, Enrico Fermi and Leo Szilard received a government contract to construct a reactor at Columbia University. Other reactor experiments took place in a laboratory under the west grandstands at the Stagg Field stadium of the University of Chicago. In December 1942, Fermi achieved what the scientists considered the first self-sustained nuclear reaction. It was time to take the reaction outdoors, and this process would greatly increase the scope and scale of the experiment.

Under the leadership of General Leslie Groves in February 1943, the U.S. military acquired 500,000 acres of land near Hanford, Washington. This served as one of the three primary locations of Project Trinity, which was assigned parts of the job to produce useful atomic technology. The coordinated activity of these three sites under the auspices of the U.S. military became a path-breaking illustration of the planning and strategy that would define many modern corporations. Hanford used waterpower to separate plutonium and produce the grade necessary for weapons use. Oak Ridge in Tennessee coordinated the production of uranium. These production facilities then fueled the heart of the undertaking, at Los Alamos, New Mexico, under the direction of J. Robert Oppenheimer.

By 1944, World War II had wrought a terrible price on the world. The European theater of military operations would soon close after Germany's surrender. While Germany's pursuit of atomic weapons technology had fueled the efforts of American scientists, the surrender did not end the project. The Pacific front remained active, and Japan did not accept offers to surrender. Project Trinity moved forward, and it would involve Japanese cities, Hiroshima, and Nagasaki as the test laboratories of the initial atomic bomb explosions. The *Enola Gay* released a uranium bomb on the city of Hiroshima on August 6, and *Bock's Car* released a plutonium bomb on Nagasaki on August 9. Death tolls varied between estimates of 300,000 and 500,000, and most were Japanese civilians. The atomic age, and life with the bomb, had begun.

Historian Paul Boyer writes, "along with the shock waves of fear, one also finds exalted prophecies of the bright promise of atomic energy" (1994, 109). Many of the scientists involved believed that atomic technology required controls unlike any previous innovation. Shortly after the bombings, a movement began to establish a global board of scientists who would administer the technology with no political affiliation. Wresting this new tool for global influence from the American military proved impossible. The Atomic Energy Commission (AEC), formed in 1946, would place the U.S. military and governmental authority in control of the weapons technology and other uses to which it might be put. With its nuclear trump card, the United States catapulted to the top of global leadership.

DEVELOPING U.S. NUCLEAR POWER

In the 1950s, scientists turned their attention to taking the nuclear reaction and applying it to peaceful purposes, notably power generation. The reaction was a fairly simple process. Similar to fossil-fuel powered generators, nuclear plants use the heat of thermal energy to turn turbines that generate electricity. The thermal energy comes from nuclear fission, which is made when a neutron emitted by a uranium nucleus strikes another uranium nucleus, which emits more neutrons and heat as it breaks apart. If the new neutrons strike other nuclei, a chain reaction takes place. These chain reactions are the source of nuclear energy, which then heats water to power the turbines.

Soon, the AEC seized this concept as the foundation for plans for domesticating the atom. It was quite a leap, though, to make the American public comfortable with the most destructive technology ever known. The AEC and others sponsored a barrage of popular articles concerning a future in which roads would be created through the use of atomic bombs and radiation employed to cure cancer.

The atomic future in the media included images of atomic-powered agriculture and automobiles. In one book published during this wave of technological optimism, the writer speculates that “no baseball game will be called off on account of rain in the Era of Atomic Energy.” After continuing this litany of activities no longer to be influenced by climate or nature, the author sums up the argument: “For the first time in the history of the world man will have at his disposal energy in amounts sufficient to cope with the forces of Mother Nature” (Boyer, 1994, 109–15). For many Americans, this new technology meant control of everyday life. For the Eisenhower Administration, the technology meant expansion of our economic and commercial capabilities.

As the Cold War took shape around nuclear weapons, in the 1950s the Eisenhower administration looked for ways to define a domestic role for nuclear power even as Soviet missiles threatened each American. Project Plowshares grew out of the administration’s effort to take the destructive weapon and make it a domestic power producer. The list of possible applications was awesome: laser-cut highways passing through mountains, nuclear-powered greenhouses built by federal funds in the Midwest to enhance crop production, and irradiating soils to simplify weed and pest management. Often, nuclear power veered more toward its mythic possibility than to the intimidating reality.

Energy production, however, was a unique aspect of the nuclear future. Lewis L. Strauss, chair of the AEC, proclaimed to the public that the production of nuclear power was “too cheap to meter.” This was especially true if the federal government helped to finance the construction, operation, and insurance of atomic power plants (Opie, 1998, 473–74).

In 1951, the first experimental reactor went on line near Idaho Falls, Idaho. Initially, it produced only enough power to light four 150-watt lightbulbs. The lessons learned in Idaho, though, led to the AEC-sponsored pilot project with Duquesne Light Co. in Shippingport, Pennsylvania. This 60-megawatt breeder reactor opened in 1957 in order to serve as a model for future projects. In addition, though, the Westinghouse-designed plant served as a model for the navy program to use nuclear power for submarine propulsion. Ultimately, the Shippingport reactor became the first licensed American commercial reactor.

During the ensuing decades, new reactors would be constructed throughout the United States. Although the AEC and the federal government offered assistance, these power plants were normally constructed by private utilities. The electricity that they generated was placed on the utility's grid and sold with power made from coal, hydro-turbines, and oil.

During the 1950s and 1960s, nuclear technology symbolized the stable future that could be ensured and maintained through technological innovation. This confidence, however, shielded Americans from a more serious line of questioning about nuclear technology and other innovations. Costs could be measured in many ways, and the accidents at nuclear plants such as Three Mile Island in Harrisburg, Pennsylvania, and Chernobyl in the Soviet Union began to sour the public's view on nuclear power. By the late 20th century, concerns had also been raised about the safe storage of the waste left behind by nuclear power plants. As Americans began to consider the broader implications of nuclear testing, the arms race, and energy production, the popularity of nuclear technology would plummet over the next decades. While other nations used it to create larger portions of their electric power, American interest waned.

THE ALTERNATIVE ERA IN PERSONAL TRANSPORTATION

Generating electricity is only part of the United States' need for energy. In addition, transportation is responsible for a very large segment of American power consumption. Did the same ethic for conservation inspire Americans to use alternative power for transportation in the 20th century? Of course not. Just as we saw in the last chapter, the emergence of personal transportation powered by the internal combustion engine was one of the most important parts of the high-energy existence that shaped the last century; however, a closer inspection of this story may surprise you. In fact, one quickly sees that the transportation sector's complex beginning actually very nearly marked the greatest triumph of alternative fuels.

Personal transportation, of course, entered the late 1800s powered with an alternative fuel source: the horse or other animal that transferred solar power into motive energy. In a sense, the same technology that expanded the transportation of this era—the horse and the sailing ship—held court until the mid-1800s. In terms of predominance, though, they remained the transportation technologies for Americans into the early 20th century. Even when urban areas such as New York implemented mass transportation by the end of the 1890s, they could not entirely delete the use of horsepower.

Although new methods of transportation were being developed at the close of the 19th century, in fact, industrialization increased the number of horses needed in urban areas. The 1870 Census enumerated more than eight million horses throughout the nation, with 1.5 million employed in cities. Census 1900, however, shows an increase in the number of horses to 21.2 million, with the urban population nearly three million (Black, 2006, 37). Many of these were employed in new efforts of mass transportation, known as omnibuses and horse cars.

Omnibuses operated in most cities throughout the last half of the 19th century and could run anywhere, without the use of rail lines. In 1850, for instance, Philadelphia operated 322 and New York 683. In New York, the omnibuses claimed to carry more than 100,000 passengers per day (McShane and Tarr, 2007, 35). Horse cars, on the other hand, used rail lines, which helped to increase suburbanization by regulating commutes. By 1890, 32.5 million passengers each year rode the horse cars operated by over 700 companies. In addition, horses pulled most delivery wagons and even offered their services as prime movers. In some mills and at various construction sites, horses were used to walk treadmills that were linked to gearage systems that turned other devices. According to the 1850 Census, horses provided more than half of the motive power used in American cities. The horse's life cycle became entirely anthropomorphized during this period, with its meaning defined by humans. Historians Clay McShane and Joel Tarr write:

> As one thinks about the horse not as an animal but rather as a living machine in an urbanizing society, its role in the process of commodification becomes clearer. Horses had value assigned to them from their very birth. In the 19th-century city, this value related primarily to their usefulness for work. . . . Even their manure was of value as fertilizer, while at death their hides and hair were transformed into useful products. (2007, 35)

Their labor, though, came with a price. In particular, the organic city of the 19th century contended with the waste products generated by work animals, specifically horses.

A working horse drops between 15 and 35 pounds of manure each day, and two gallons of urine (Black, 2006, 39). In cities such as New York, this amounted to up 3.25 million pounds of horse manure per day. In addition to the mess and stench, the manure brought flies and the possibility of outbreaks of typhoid, cholera, tuberculosis, or infantile diarrhea. For city reformers, planners, and residents, horses were most often considered part of the problem in late-19th-century cities. They were not willing to give up personal transportation, though. In fact, the sprawling nature of cities demanded more than ever before that modes of transportation be available to residents of a variety of economic classes.

In terms of individual personal transportation, bicycles—powered by human energy, of course—allowed some Americans to liberate themselves from horsepower when they were first commercially developed in the latter 1800s. After initial use of the large front wheel design, safety bicycles (with two similarly sized wheels) emerged around 1880. By 1899, approximately one million bicycles were produced each year. In fact, American cyclists helped to stir the initial push to construct and improve the nation's roadways. Similar to other alternative sources of power, the bicycle had undeniable limitations. The true liberation for personal transportation would come when the vehicle tapped reserves of energy that were tied neither to human nor animal power.

THE FIRST ENERGY TRANSITION IN TRANSPORTATION

From horses and bicycles, personal transportation devices shifted to battery-charged electric power. Electric or hybrid cars were introduced to the United States in 1905 when H. Piper applied for a patent on a vehicular powertrain that used electricity to augment a gasoline engine. Piper's technology actually followed the work of French inventors. From 1897 to 1907, the Compagnie Parisienne des Voitures Electriques (Paris Electric Car Company) built a series of electric and hybrid vehicles, including the fairly well known 1903 Krieger. Although these vehicles used electric power, some also ran on alcohol (Motavalli, 2001, 9–14).

In fact, there were many sites, particularly in urban areas, where it appeared that Americans had already determined to follow a future other than that of the internal combustion engine powered by gasoline. The description seems one from a futuristic novel:

> At that busy corner, Grand Street and the Bowery, there may be seen cars propelled by five different methods of propulsion—by steam, by cable, by underground trolley, by storage battery, and by horses. (*New York Sun*, 1898, quoted in Kirsch, 2000, 11)

There is no mention, of course, of the petroleum-powered vehicles that would singularly inhabit the streets of New York City at the dawn of the 21st century. Petroleum, even with its abundant supply following the strikes in Eastern Texas, remained primarily a lubricant and illuminant. An energy transition would change all of that. One hundred years ago, when there was not yet a clear leader in the race for the most viable method to propel an automobile, steam, electricity, and internal combustion all vied to power horseless carriages.

At this important juncture, alternative power sources seemed most likely for future travel. When Oliver Evans built the first motor vehicle in the United States in 1805, his prime mover of choice was steam. A combination dredge and flatboat, it operated on land and water. Richard Dudgeon's road engine of 1867, which resembled a farm tractor, could carry 10 passengers. By the late 1890s, nearly 100 manufacturers were marketing steam-driven automobiles. The most famous of these steam-car makers were Francis E. and Freelan O. Stanley of the United States—twin brothers who developed an automobile called the Stanley Steamer in 1897. Most of the models of steam cars burned kerosene to heat water in a tank that was contained on the car. The pressure of escaping steam activated the car's driving mechanism, which moved the vehicle. The popularity of the steam car declined at about the time of World War I, and production came to an end in 1929. This was not, however, due to a decline in interest in automobility. Instead, powerful interests had swayed Americans toward a new model of vehicle construction—and it was not the internal combustion engine.

ELECTRICITY AND A NEARLY ALTERNATIVE ERA IN TRANSPORTATION

In these early days, most European designers had opted for electrically powered vehicles. One of the first electrics in the United States was produced by William Morrison in 1891. About 54 United States manufacturers turned out almost 35,000 electric cars between 1896 and 1915—the period of their greatest popularity. The Columbia, the Baker, and the Riker were among the more famous makes. The electric car ran smoothly and was simple to operate. However, it did not run efficiently at speeds of more than 20 miles per hour and could not travel more than 50 miles without having its batteries recharged. Thus, it was limited to city use. Electric cars were built by dozens of manufacturers until the early 1920s. Their reputation for providing reliable, quiet, and efficient transportation made them attractive. One popular model was the Detroit Electric, made by the Anderson Carriage Company of Detroit. Available in several body styles, including an upright design often called a doctor's coupe, the brand had its best sales years in the late 1910s and early 1920s.

The primary difficulty with electric vehicles then (as now) was the battery's inability to retain a lasting charge. In the dawning age of electricity, batteries were a frontier technology that promised all kinds of liberation but, in fact, delivered very little. In most designs, a battery received a current of external electricity through its electrodes and passed it on to a series of lead strips that accumulated or collected, and then stored, the charge. Creating the accumulator, as a battery was often called, required as much as two years in order to properly prepare the lead strips. In the late 1800s, efforts to devise a more reliable battery technology centered in France (Black, 2006, 40–46). George Brush, an American businessman, brought the new designs to the United States in 1882. However, over the following decade, his undertaking was mired in litigation with French inventors.

Of transportation in the late 1800s, the journalist and historian Edwin Black writes:

> Batteries could make it all sensible, make it all possible. Battery power was, in fact, wireless power. But as much as everyone craved batteries to usher the world into the next century, batteries were synonymous with lying and deception, fraud and speculation, exaggeration and misrepresentation. Who could trust the battery—or any company that offered one? (2006, 51)

Even the world's most famous inventor weighed in when Thomas Edison in 1883 called the storage battery "a mechanism for swindling the public by stock companies" (2006, 51–52).

However, by the late 1800s, a few large suppliers had steered urban transit towards electric vehicles. EVs became the first systematic effort at a personal transit system, and they experienced a host of difficulties; many of the difficulties would have affected any transit system. These problems, though, became specifically attributed to electricity-powered vehicles. The Columbia and Electric Vehicle Company worked with smaller companies in most Northeastern cities to create regional interests that established cab fleets and central charging stations in 1899. In Boston, an inspector's report focused on two primary problems: the total absence of regular daily inspections of the mechanism of the cab, and the lack of precautions taken against normal wear and tear. His report suggested that the undertaking was considered less a business than the introduction of an oddity (Kirsch, 2000, 65). Improvements were made, and by the summer of 1900, the New England Electric Vehicle Company operated approximately 175 vehicles in Boston and Newport, Rhode Island. In the Boston area, the company began implementing its plan to construct charging stations within concentric circles from the city hub.

Similar developments were also seen in New Jersey's tourist cities, including Atlantic City and Cape May. In Philadelphia, the era of electric transportation began with Electrobat, a prototype cleared for a test drive on Broad Street in August 1894. The 4,000-plus-pound vehicle carried 1,600 pounds of lead batteries above a series of open benches on which passengers could sit. Similar to the design of a bicycle, a long chain connected the power source to the wheels and moved them forward or backward. Throughout 1894, the Electrobat frequented the boulevards of Philadelphia, particularly frequenting its high-culture Fairmount Park. In 1895, Electrobat II entered one of the era's many man-versus-machine races. It only required 160 pounds of battery power—after just a year, the vehicle required one-tenth that weight. Innovations moved quickly, and events such as the arranged races helped to spur improvements in technological capabilities.

In each case, the national EVC established local or regional branch companies to develop a specific market. Viewed on an entirely profit-generating basis, these regional undertakings were given a very brief period to succeed. By early 1901, the national EVC declared that it would not purchase additional vehicles for any of the projects outside the New York market. Writes historian David A. Kirsch: "By 1901, the major shareholders of the vehicle-operating companies were more concerned about preserving capital than with the ultimate success or failure of the electric cars themselves" (2000, 73). In New York, electric cabs, buses, and sightseeing coaches continued to operate in and around the city until 1912. New battery designs during this period were put directly to work, and allowed the range of a single charge to grow to approximately 20 miles. In this urban environment, Kirsch traces the specific landscape of the EV:

> The large station on the West Side continued to serve as the base of cab operations, although the company eventually acquired substations and standing privileges at a number of remote locations, including the Hotel Astor (on 44th Street), Café Martin (on 126th Street), and the 34th Street ferry terminal. (75)

Kirsch's findings make clear that after losing money until 1904, electrics became increasingly profitable in New York. However, just as they reached this point, a mechanics strike in 1906 was followed by a disastrous fire in 1907 that destroyed 200 cabs at the Central Station. Assessing the situation from a business standpoint, the company imported from France fifty new cabs for its fleet that were powered by gasoline. Profits increased and the EV's last bastion was gone by the early 1910s. "Far from taking advantage of its pioneering role in introducing electric vehicle service," writes Kirsch, "the cab company ended up paying a steep price for innovating" (82).

Other social dynamics were also significant in the determination of how to power personal transportation. Scholar Virginia Scharff argues, in fact, that due to the unique timing of the battle between modes of powering transportation, the struggle had relevance for another struggle of the day: that of women's rights. A manufacturer of bicycles and other transportation devices, Colonel Albert A. Pope famously argued against the internal combustion engine by saying, "you can't get people to sit over an explosion" (Scharf, 1991, 35). He felt that the noise and grime made gasoline-powered transportation uncivilized, and by 1897 his Pope Manufacturing Company based in Hartford, Connecticut had produced 500 electric cars. In a 1903 ad, Pope claimed, "electrics . . . will appeal to any one interested in an absolutely noiseless, odorless, clean and stylish rig that is always ready and that, mile for mile, can be operated at less cost than any other type of motor car." Behind the wheel in the ad's illustration was a female driver seated next to her female passenger; together, they embodied an independence foreign to many women of the era (36). Scharff notes that some women consumers followed the suggestion of Pope and others, and came to view gasoline vehicles as "powerful, complicated, fast, [and] dirty," while electrics tended to be "smaller and slower" and were most often enclosed vehicles, as opposed to the wide-open, gas-powered cars. Another manufacture advertised its EV as "a woman's car that any man is proud to drive." Other manufacturers claimed that the EV allowed a woman to better "preserve her toilet immaculate, her coiffure intact."

In April 1904, *Motor* magazine's society columnist made the following observation:

> Mrs. James G. Blaine has been spending the last few weeks with her parents at Washington, and has been seen almost daily riding about in an electric runabout. The latter appears to be the most popular form of automobile for women. Indeed, judging from the number of motors that one sees driven by women . . . , one would imagine that nearly every belle . . . owned a machine. (37)

Built into this movement for liberation was a twofold agenda: first, for women, personal transportation, of course, did offer a profoundly new frontier of autonomy. Second, though, and possibly of more importance, the market of urban females most likely performed within the technical constraints of the EV (slow speeds, short distances, etc.). In a transportation system based on a variety of modes, humans—whether manufacturers or consumers—demonstrated a clear willingness to partition different modes of transport (electric or gas-powered, for instance) for specific duties that made the most sense due to a variety of factors.

Well after gasoline had come to dominate the field of pleasure driving after 1910, many people continued to believe that commercial vehicles, particularly trucks, could best be powered by electricity. As a replacement for the horse-drawn wagon, the commercial vehicle had to be reliable for small trips. Unlike the pleasure vehicle, the delivery truck had to be run in all weather. One of the chief complaints about using gasoline-powered trucks derived from the owners' inability to control drivers. Speeding was considered a major problem that derived from the drivers' disrespect for the owners' investment. Some owners installed governors on their vehicles' engines; others opted for the slower, electricity-powered vehicles. Overall, though, the definition of spheres of service and the consideration of transportation alternatives represent a commercial application of the nascent area of business management inspired by Frederick Winslow Taylor and others.

For instance, in 1909, Chicago Edison produced a study concluding that an electric truck replacing a horse-drawn wagon increased operating costs per mile by 70 percent; however, by the time the average service mileage reached 27 miles per day, the electric truck cost 5 percent less to operate. Other studies also demonstrated that within a 10-mile sphere of a city, the electric truck cost less than a gas-powered one to run (Kirsch, 2000, 148). Unfortunately for electrics, as businesses expanded in the 1910s, very few limited themselves to these spheres. Their preference, overall, became one of flexible transportation that could reach into whichever sphere was required.

EXPERIMENTING WITH BIOFUELS

Even though petroleum supplies were plentiful in the early 20th century, experiments with the use of biofuels in transportation began in the early days of personal transportation and continued for decades. In fact, the use of such oils for illumination and other work predated the discovery of petroleum in 1859. As early as the mid-1800s, many bio-materials were used for purposes such as making soap. Early feedstocks were corn oil, peanut oil, hemp oil, and tallow. These processes created alkyl esters from these materials. In addition, ethanol was in use prior to the Civil War. Mixed with turpentine, ethyl alcohol (ethanol), which was known as camphene, had become a popular illuminating oil by the second half of the 19th century.

In terms of personal transportation, biofuels were an alternative power option beginning with the first experiments at the close of the century. In fact, the first transportation device made by Henry Ford in 1896 was a quadricycle powered by ethanol. After his successful design of the Model T, in 1908 Ford made it capable of running on ethanol, gasoline, or a combination of the two.

Ford opened his own plant to make ethanol. Later, he worked with Standard Oil Company to distribute and sell the corn-based fuel at its service stations. Most of the ethanol was blended with gasoline. Ford continued to promote ethanol through the 1930s. But finally, in 1940, he was forced to close the ethanol plant due to stiff competition from lower-priced petroleum-based fuels.

Within the petroleum and automobile businesses, biofuels were seen as a necessary side-business—particularly with the ongoing uncertainty over the supply of petroleum in the early 1900s. Some developers intended to use such fuels as a substitute for gasoline, while others sought to boost octane levels by adding them to gasoline.

Quite famously, Alexander Graham Bell's 1917 *National Geographic* article predicts that alcohol will be the fuel of the future when the oil runs out: "[Alcohol] makes a beautiful, clean, and efficient fuel." Bell goes on to say "alcohol can be manufactured from corn stalks, and in fact from almost any vegetable matter capable of fermentation. We need never fear the exhaustion of our present fuel supplies so long as we can produce an annual crop of alcohol to any extent desired." (Black, 2006, 45)

For Charles Kettering and the research team at General Motors, alternative fuels like ethanol began as the ultimate fuel of the future. By the 1920s, though, the emphasis of their work had become adding ethyl to gasoline to improve engine performance. Of course, this also added lead to the gasoline and to the emissions that the engines produced, which will be discussed in chapter 4.

THE TRANSPORTATION CROSSROADS, 1910s

So, how did we get behind the wheels of gas-powered personal transportation devices?

It was the German auto designers who first emphasized an internal combustion engine powered by gasoline. Gottleib Daimler and Karl Benz created fuel-injected models that showed how such a design had the strengths of range, speed, and weight that placed it ahead of other prime movers. The obvious drawback was noise and smoke. Early innovators actually tried to turn this critique on its head. Charles Duryea argued that "the history of almost every invention of importance is that in its earlier stages it is met with some of the most unreasonable objections, and the objectors lived long enough to see their objections forced down their throats" (Black, 2006, 64). Clearly, for Duryea and others, what marked the drawbacks of burning gasoline to some of its critics were for him positive symbols. He continues by mockingly quoting a critic of gas-powered autos:

> Imagine a street full of such vehicles! Why, you could not live in the same town! . . . [But] it is also true that everybody rides behind locomotives which give out not only

the products of combustion of coal, but sulfuric gases arising from impurities in the fuel, cinders, and specks of soot and coal blown out by the forced draft. [Passengers] . . . do not revel in these objectionable features . . . but they patronize that method of travel and do not usually complain. (2006, 65)

In his final judgment, though, Duryea placed the decision squarely at the feet of American consumers when he writes: "If Americans were to refuse to ride until better accommodations were afforded, the accommodations would be forthcoming in short order." The passion for the autonomy of personal transportation would only intensify. As Duryea foresaw, consumer demand—and passion—would be the primary instigating force for the preeminence of the internal combustion engine.

So why did these vehicles not emerge as the primary device for American transportation? The marketplace for personal transportation marked one of the American economy's most dynamic sectors in the first decade of the 20th century. While entrepreneurs of electric and steam transportation struggled to overcome each technology's difficulties in order to seize the historic moment, innovators of the internal combustion engine did the same. As the American desire for personal transportation spread from a few exceptional, upper-class drivers to include mass consumers, the scale of the enterprise made it increasingly obvious which of the methods for powering vehicles made the most sense.

Giving no thought to its long-term implications, developers quickly realized that burning gasoline offered the most rapidly available solution to the desire for personal transportation. In addition, historical events—particularly the discovery of new supplies—contributed additional incentives to drive gasoline ahead of any competitors for personal transportation. Taken together, these events demonstrate the unique historical convergence of the energy transition of the first two decades of the 20th century. During these formative decades, the 20th century became one powered by petroleum—but personal transportation could have been otherwise.

The timing of the strike at Spindletop, Texas, dovetailed with the public's growing interest in the speed and independence of the automobile. The massive quantities of petroleum drove its price downward. In addition, Edison's experiments with electric lighting forced those in the industry, particularly Rockefeller of Standard Oil, to search for new uses for petroleum. When Henry Ford and other entrepreneurs began manufacturing autos in the United States, they followed the urging of Rockefeller and others and opted for a design powered by an internal combustion engine (ICE) that used gasoline derived from petroleum. A steady supply of cheap crude oil became the necessary resource to support everyday American life after 1900, particularly after Americans had begun their love affair with the automobile. However, this affair almost never got started—quite literally.

In the competitive transportation market, the underfunded development of ICE models began in 1893 when J. Frank and Charles E. Duryea produced the first successful gasoline-powered automobile in the United States. They began commercial production of the Duryea car in 1896—the same year in which Henry Ford operated his first successful automobile in Detroit. The first automobile salesroom was opened in New York City in 1899 by Percy Owen. In 1900, the first automobile show was held—also in New York City. Gas-powered models were frowned on by many consumers; however, they also promised a flexibility not seen in the other methods for powering travel.

The use of the internal combustion engine relied on countless minute innovations that, once pieced together, totaled a relatively reliable device for transportation. As electric cars surged in popularity in the first decade of the 1900s, one of the most frequently stated rationales of consumers was that despite all of its other difficulties, the electric vehicles could be relied on to start and run for at least a minimum amount of time. Starting gasoline-powered vehicles, on the other hand, most often required that one be or have access to a knowledgeable mechanic. In addition, it also required a bit of fearlessness on the driver's part. Although today's drivers happily take such innovations entirely for granted, imagine the difficulty and danger of being the first innovator to explore methods for igniting petroleum distillates and other flammable substances in a stationary chamber that could be incorporated into the design of mobile device for transportation!

This engineering difficulty bedeviled the early automobiles until innovations brought under control what George Baldwin Selden called enough explosive power to "blow your damned head off if necessary" and directed it toward igniting and turning a portable engine small enough to power an automobile (Black, 2006, 84). Throughout the late 1800s, Selden had experimented with a variety of substances in his Rochester, New York, laboratory. By the 1870s, he had eliminated kerosene and other petroleum distillates in favor of gasoline. It was his early success, ironically, that paved the way for the success of alternative methods for powering personal transportation.

His own patent for his "road engine" was finally approved in November 1895, and he was granted 17 years' control over the technology at its very emergence. In 1899, a forward-thinking entrepreneur of bicycles and electric vehicles paid Selden $10,000 for his patent. This began decades of legal wrangling that temporarily clogged the development of the ICE and allowed for the further development of electric vehicles.

Most of the other auto manufacturers combined into a loosely formed group referred to as the Hydrocarbon Association and fought the Selden patent. The legal fees combined, with heavy investment in the infrastructure of electric vehicles, caused the holder of the Selden patent, known as EVC, to consider its options. In a strange twist of irony, the depleted economic condition of EVC forced it, by 1902, to allow the construction of ICE autos so that it could then collect the patent royalties and finance the limited EVC projects still underway, namely in New York. Joining forces in 1903, the manufacturers formed a transportation combine referred to as the Association of Licensed Automobile Manufacturers (ALAM). Operating as a controlled trust, ALAM made certain that most cars cost \$1,000–\$2,000, which was unaffordable to most Americans. Challenges to the trust's control soon emerged, particularly from the workshop of one Detroit businessman.

The Selden patent had been scheduled to expire in 1912 regardless of the court's finding. During the life of the patent, ALAM (which dissolved in 1912) had collected approximately \$5.8 million in fees and artificially forced the personal transportation market first toward electric and then, after the late 1900s, toward the ICE. Throughout, its primary reason for existence was to generate profits from patent fees. Unintentionally, they had also contributed to Henry Ford's legend and the success of his innovations. The 1911 decision led to a cross-licensing agreement among most of the American manufacturers, which would be administered by the Automobile Manufacturers Association (Kay, 1997, 154–45). Even in the 1910s, though, America's vehicular future was not yet determined. In fact, events of 1914 make it clear that the technical issues behind the automobile were not yet clear even to Ford himself.

In the last gasp of alternatively powered transportation in this era, Henry Ford joined forces with electricity pioneer Thomas Edison. Edison's efforts to devise a useable battery for electric vehicles went on throughout the early 1900s. In 1910, Edison established a 200,000-square-foot, four-story factory in West Orange specifically intended to perfect a battery that could last more than 40,000 miles in cars, and for various other duties, as well (Black, 2006, 130). The existing manufacturers of batteries, though, did not wish to see Edison's Type A battery succeed. In addition, although it had been successful in trucks and for other uses, Edison did not wish to commit to becoming a manufacturer of vehicles. Simultaneously, writes Black, Ford came to a quiet realization about his own innovation: his vehicles possessed "a faulty electrical ignition system to drive the pistons" (134). With the settlement of the Selden patent suit, Ford no longer needed to steer entirely clear of the concept of electrically powered transportation. Edison and Ford seemed to be a perfect match for this historical moment. They joined forces in the fall of 1912.

In September 1912, the *New York Times* announced that Edison had perfected "a combination of gasoline engine, generator, and storage batteries by which, for a modest expense, every man can make his own electricity in his own cellar" (Black, 2006, 136). The first such fully operational home was Edison's mansion in Llewellyn Park, New Jersey. Among the many items that could be charged from the central generator was the Type A-powered electric vehicle that Ford planned to mass produce—in fact, he had committed to build 12,500 per month in just the first year of production. Black writes:

> Finally. It was happening. The automobile revolution which began as an electrical phenomenon, would return to the concept advanced nearly a generation earlier. The world could become a cleaner, quieter, more efficient place, drawing its strength from nature, from electricity. The American spirit of independence would be achieved not only by permitting mobility but by enabling stunning individual self-sufficiency. (2006, 140)

Ford announced his plan on January 9, 1914 with the promise that each vehicle would cost between $500 and $700. He also directed that his son Edsel would head up the new electric-vehicle company.

In the midst of such positive spin for the new vehicles, internal experiments with the batteries began to show problems. Keeping up a strong public face, however, Edison said in an interview with the *Wall Street Journal,* "I believe that ultimately the electric motor will be used for trucking in all large cities, and that the electric automobile will be the family carriage of the future. . . . All trucking must come to electricity" (Black, 2006, 156). In the fall, however, while Edison's batteries, which had worked successfully at the lab, continued to fail in Detroit, word arrived that Dodge was also going to release an inexpensive electric car. Finally, October 1914 brought ominous news of potential war on a massive scale in Europe. This was the context for the events of December 9, 1914, when the transportation future of each human changed.

Late in the afternoon on that day, Edison was at work in his laboratory when an explosion ripped through the complex, starting in a film repository. Fires escalated quickly, and Edison immediately ordered his fire brigades to give first priority to protecting the storage battery building. Although the complex was outfitted with supposedly fireproof buildings, the fires burned until the following day. Ultimately, only his private laboratory and the storage battery factory were saved. Edison would never fully reestablish his career, and he ultimately suffered a nervous breakdown. With his personal tragedy and difficulty, the future of electric vehicles was easily extinguished by the panic of war.

Who killed the electric car in the 1910s? No doubt the primary impediment to the use of electric vehicles was the preponderance of those using internal combustion. World War I relied on the use of new vehicles and electrics simply did not offer a secure option. During World War I, the manufacture of automobiles for civilian uses was virtually halted as the industry was mobilized to produce vehicles, motors, and other war matériel for the armed forces. The possibility of alternatively powered transportation was largely shelved for another day.

THE ICE POWERS AMERICA'S TRANSPORTATION FUTURE

Ford's innovations in production and distribution could have been applied to vehicles powered by alternative means. As discussed above, a confluence of factors dictated the American commitment to the internal combustion engine by the end of World War I. The 1920s began a period of cultural, social, and economic growth that drew directly from the preponderance of cheap sources of energy and, in particular, the movement and lifestyle that it made possible. This era saw a cultural gravity slowly creep into the lives of hard-working Americans that changed their vision of progress to include applications of cheap energy without ever establishing how long the finite supplies of this power would last. Similar to the roots of a young tree, the system began simply enough but soon reached so deeply and strongly into reliance on energy that it seemed it could never be changed.

In this landscape, the high-energy paradigm was immediately obvious when planners began perfecting ways of further integrating the gas-powered car into American domestic life. Initially, these tactics were quite literal. In the early 20th century, many homes of wealthy Americans soon required the ability to store vehicles. Most often these homes had carriage houses or stables that could be converted. Soon, of course, architects devised an appendage to the home and gave it the French name, garage. From this early point, housing in the United States closely followed the integration of the auto and roads into American life.

Upper- and middle-class Americans had begun moving to suburban areas in the late 1800s. The first suburban developments, such as Llewellyn Park, New Jersey (estab. 1856), followed train lines or the corridors of other early mass transit. The automobile allowed access to vast areas between and beyond these corridors. Suddenly, the suburban hinterland around every city expanded. As early as 1940, about 13 million people lived in communities beyond the reach of public transportation. As new construction subsequently began, more recent ideas and designs (such as the ranch-style house) remade the American suburb (Jackson, 1985, 102).

Planners used home styles such as these to develop one site after another, with the automobile linking each one to the outside world. The ticky-tacky world of Levittown (the first of four planned communities called "Levittown" was constructed in New York in 1947) involved a complete dependence on automobile travel. This shift to suburban living became the hallmark of the late 20th century, with over half of the nation residing in suburbs by the 1990s. The planning system that supported this residential world, however, involved much more than roads. The services necessary to support outlying, suburban communities also needed to be integrated by planners.

Instead of the Main Street prototype for obtaining consumer goods, the auto suburbs demanded a new form. Initially, planners such as Jesse Clyde Nichols devised shopping areas such as Kansas City's Country Club Plaza, which was a hybrid of previous forms. Soon, however, the commercial strips had evolved into being the social and cultural corridors of the future. These sites quickly became part of suburban development, in order to provide basic services close to home. A shopper rarely arrived without an automobile; therefore, the car needed to be part of the design program. The most obvious architectural development for drivers was signage: integrated into the overall site plan would be towering neon signs that identified the services offered by the adjacent business. Also, parking lots and drive-through windows suggested the integral role of transportation in this new style of commerce (Jackson, 1985, 159).

In the United States, roads initiated related social trends that added to Americans' dependence on petroleum. Most important, between 1945 and 1954, nine million people moved to suburbs. The majority of the suburbs were connected to urban access by only the automobile. Between 1950 and 1976, central city populations grew by 10 million while suburban growth was 85 million. Housing developments and the shopping/strip-mall culture that accompanied decentralization of the population made the automobile a virtual necessity. Shopping malls, suburbs, and fast-food restaurants became the American norm through the end of the 20th century, making American reliance on petroleum for transportation complete (Kay, 1997, 220–25).

The momentum for energy use, particularly in transportation, had clearly swung toward fossil fuels. Each suburb, gas station, and its related accoutrements became part of a fortress around the high-energy existence, leaving other methods of creating power to be relegated under the classificatory label "alternatives" for the rest of the 20th century.

CONCLUSION: KEEPING ALTERNATIVES ALIVE

The high-energy life based on cheap fossil fuels created in the United States a standard of living that proved to be the envy of the world. It brought a greater freedom from disease, want, and discomfort than most nations would ever achieve. And, in fact, the reality of middle-class American life in the second half of the 20th century did come to resemble the utopian visions depicted in the Futurama exhibit at the 1939 World's Fair. Cheap energy made it possible; however, when this lifestyle began to falter, we learned that alternative methods for creating power had never entirely disappeared. Alternative power simply awaited a more cost-effective day.

A critical component of the re-emergence of alternatives at the end of the century was the persistence of the American idea of conservation, which morphed into the modern environmental movement in the 1970s. As this chapter has demonstrated, during the 20th century, the conservation ethic evolved in a parallel universe to that of Americans' high-energy lifestyle. While more and more Americans considered conserving forests, preserving National Parks, and even utilizing renewable energy resources such as river power, the nation's overwhelming rhetoric blazed a path to making the vision of Futurama a reality.

Ultimately, it was this middle-class lifestyle, though made possible by cheap energy, that helped the conservation ethic emerge in full flower in the 1970s, and to become attached to tangible policies. Historians refer to this period as "modern environmentalism," which will be discussed in chapter 4. Clearly, though, alternatively fueled energy never stopped making sense; it was this attribute that kept alternatives alive in the background of American life throughout the mid-1900s and even during the Cold War era when fossil fuels were available at remarkably cheap prices.

In the process of the stunning growth of American economic capabilities, power sources such as wind, solar, and electricity-charged batteries were relegated to fringe status, ultimately to be defined as alternatives, while cheap fossil fuels powered a New America. The finite supply of such fuels, however, promised a new day for such alternative sources of power on down the road of human energy use.

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The 1970s Initiate an Energy Transition

The item was a minor story in the newspaper—practically a footnote—unless you were looking for it. The Associated Press headline from 2007 read: "Maine college to auction off former White House solar panels." By bringing in the 32 panels during the 1980s, Unity College had inadvertently preserved one of the leading symbols of the American struggle over the reality of alternative energy (Friedman, 2008, 14–15).

Faced with such a headline, though, most readers would follow with a basic question. "When was the White House solar powered?" is what most would ask. If anything would close the gap between American reliance on fossil fuels and defining renewable sources as alternative, powering the White House with green methods would function as a most revealing symbol. That is just what the leader who retrofitted the great building hoped. After calling for a nationwide campaign to conserve energy, President Jimmy Carter ordered the panels erected on the roof of the West Wing in 1979. His intention, according to the White House Historical Association, was to set an example for the country. Although the panels created power, they were intended more as a symbol.

The panels served their symbolic function beautifully; in fact, they did so too well. Although the perspective had been unthinkable to Carter and others, other Americans saw the solar panels as a symbol not of American progress but of regress. The panels were removed at the direction of President Ronald Reagan's White House in 1986, after the energy crisis and worries about dependence on foreign oil had subsided. Reportedly, some officials in his administration believed that the panels sent the wrong message—belying national strength and power. Symbolically, they sent a message of weakness.

Most of the former White House solar panels were installed at Unity in 1992. Used to reheat the water used in the 495-student school's dining hall, they became a curiosity for visitors at the college. Although this entire story is fraught with surprise and intrigue, clearly the most significant thing is that the nation depicted thus far as growing from its roots in cheap energy would, in the 1970s, be compelled to so drastically reconsider alternatives. Obviously, serious—even fundamental—changes occurred in much of American thought during the 1970s. Historians mark the 1970s as a period of malaise, which is loosely defined as a period of dissatisfaction with leadership, general apathy, and even some pessimism about the future of the nation. Of course, such culture-wide anxiety grew from many factors—particularly from division and confusion over the war in Vietnam and the presidency of Richard Nixon. A variety of historical approaches, however, have now begun to unpack the complications beneath this monolithic term.

Environmental historians may have cut closest to the crux of the national sentiment by noting the demand for an ethical shift in American consumption in general and in American energy consumption in particular. Seen through the conspicuous consumption that it generated, even accepted terms such as Henry Luce's description of the post-World War II era as the "American century" might remain true; however, the ascendance of the United States was powered by cheap energy, particularly petroleum. If the rise of American power can be tied to access to and use of cheap energy, then 21st-century Americans must consider the obvious implication: that the decline of cheap energy may signal or fuel the decline of the United States' international standing. With such reconsideration, the 1970s emerges as critically important.

As a nation whose activity and power grew from the use, management, and application of inexpensive energy, the United States faced a critical moment in its history when it was first forced to face the finite supply of these energy resources—particularly of petroleum—on which we had become entirely dependent for our everyday standard of living. With his knowledge as a nuclear engineer, President Jimmy Carter infamously attempted to steer the United States from the tailwind of cheap energy that had allowed it to cut a course to world leadership by the end of the 20th century. In 1977, Carter asked Americans to look into the face of our high-energy existence and to consider its long-term sustainability.

In short, Carter proposed a dramatic shift in the dominant human energy paradigm of the last century, no longer to view other sources of energy as alternatives. It was not what Americans wished to hear. In addition, a generation or two of high-energy living had formed an infrastructure that could not change with ease; such infrastructure took the physical form of power plants, superhighways, and sprawl; however, it also took cultural form in

American ideas of living—our very expectations and values about what it meant to have a good life. Indeed, many Americans claimed to have only limited power to change their way of life. This claim seemed to carry some veracity as the shifts in politics and corporate philosophy through the end of the 20th century often functioned to perpetuate the high-energy life of the mid-1900s.

Therefore, the landscape of energy that emerged from the 1970s has proven to be as historic for its missed opportunities as it has been for its successful ones. These missed chances, though, form an important part of the larger energy transition at hand—the one that began in the 1970s and that has continued into the 21st century. This chapter will specifically analyze these shifts in the 1970s, with particular emphasis on the modes of powering personal transportation. The decade proved a crucial juncture for the perpetuation of alternative energy technologies that have now fully emerged in the 21st century. The 1970s, in short, seems to have functioned much like the shock that aroused these technologies from the dormant state in which they had rested for more than a century of energy gluttony supported by the use of fossil fuels.

AN EMBARGO CREATES FALSE SCARCITY

The doldrums of the 1970s were rooted in soil composted from many different political and economic factors, ranging from Watergate to Vietnam, and from the fallout from 60s radicalism to growing complexity in world affairs; however, none of these factors shared the ubiquity of a basic human lesson that emerged in the 1970s: that of scarcity—when the supply is no longer seen as infinite.

Termed "Learning to Live With Limits," a socioeconomic trend emerged that forced hard realities onto the American consumer at every turn. For a generation that knew the expansive culture of energy decadence from previous decades, envisioning scarcity felt like a national failure. Conservation of energy became part of the national discourse, and this discussion awakened new urgency for the development of alternative fuels.

The reality of petroleum dependence had begun to emerge in many ways by the late 1960s. Some of these grew from the forward fringes of new scientific understanding. Others grew from the fringes of a complex social movement to re-conceive of American patterns of consumption. Together, these fringe influences helped to create the critical, shifting terrain of energy consumption in the 1970s: difficult, jarring, and disturbing, these 1970s shifts proved to be the crucial catalysts for the energy transition from petroleum dependence.

Most often, historians boil these socio-economic factors into a single phrase, the "Arab Oil Embargo," to denote the point upon which change in American energy consumption hinged. This proved to be a dangerous over-simplification, as becomes clear when one attempts to trace each strand of these patterns. In fact, the actual event of OPEC's cutting its oil shipments to the West in the 1970s is merely one formative moment—albeit critical—in a decade-long remaking of the way that American consumers viewed their petroleum supply.

For Americans, lines at local gas stations served as one example of massive changes in global affairs after World War II. History teachers usually speak of decolonization to refer to this era during which many additional nations became autonomous, and responsible for their own development and governance. Certainly, the Cold War added a new version of quasi-colonial authority; however, overall, nations in Africa and particularly the Middle East could begin to pursue their own futures. The use and management of every resource took on strategic importance, and, therefore, it follows that the administration of the world's most sought-after commodity reflected these changes most acutely. Simply, when supplies stuttered, there was no net to catch American consumers—no federal method for offsetting the temporary glitches.

Thanks to the stranglehold of Western powers and the large petroleum corporations that dominate supplies, oil morphed into a tradable, ultra-volatile commodity. Historian Daniel Yergin writes that this new era in world oil, demonstrated that "oil was now clearly too important to be left to the oil men" (1993, 612). As political leaders in each oil nation assessed how best to leverage power for their nation from their supply of crude, it took little time for them to also realize the merit of joining forces with similarly endowed nations.

The Organization of the Petroleum Exporting Countries (OPEC) was created at the Baghdad Conference in Iraq in September 1960. Its formation was precipitated by changes in the oil market after World War II. Lacking exploration skills, production technology, refining capacity, and distribution networks, oil-producing countries were unable to challenge the dominance of the oil companies prior to World War II. They formed the first, large-scale, international political group framed around a single resource—a cartel. OPEC's founding members in 1960 were Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. Eight other countries joined later: Qatar (1961), Indonesia (1962), Libya (1962), the United Arab Emirates (1967), Algeria (1969), Nigeria (1971), Ecuador (1973), and Gabon (1975). (Ecuador and Gabon withdrew from the organization in 1992 and 1994, respectively). What these nations had in common was oil. To varying degrees, though, they also shared small size and lack of political influence. Together, though, OPEC's purpose was obvious: to limit supplies in the hope of keeping prices high.

It seems ironic, today, to talk about oil producers needing to manipulate markets in order to keep the price of petroleum profitable, yet major oil companies colluded from the 1920s to the 1960s to prevent prices (and profits) from falling. As their influence waned, other methods were used. One of the most significant difficulties was that, as prices fell, domestic producers simply could no longer compete. Moreover, the Eisenhower Administration concluded (as the Japanese had prior to World War II) that dependence on foreign oil placed the country's national security in jeopardy. The United States responded by implementing import quotas, which were intended to keep domestic prices artificially high and to result in a net transfer of wealth from American oil consumers to American oil producers. By 1970, the world price of oil was $1.30, and the domestic price of oil was $3.18 (Danielsen, 1982, 150).

OPEC's ability to manipulate prices did not fully become a reality until Egyptian leader Anwar Sadat urged his fellow members to "unsheath the oil weapon" in early 1973. The primary rationale for this action was political. Israel's military aggression outraged its Arab neighbors throughout the late 1960s. Israel's attack on Egypt in 1967 had earlier resulted in an embargo, which proved unsuccessful because of the oversupply of crude on the world market. In October 1973, U.S. President Richard Nixon agreed to provide more military jets to Israel after a surprise attack on it by Egypt and Syria. On October 19, the Arab states in OPEC elected to cut off oil exports to the United States and to the Netherlands.

Factoring in production increases elsewhere, the net loss of supplies in December 1973 was 4.4 million barrels per day, which accounted for approximately nine percent of the total oil available previously. Although these numbers told of a genuine shortfall in the overall supply, the fickle petroleum market accentuated the embargo's importance by inserting a good bit of uncertainty and panic. It was the American consumers who felt the impact most.

In order to provide oil to consumers, brokers began bidding for existing stores of petroleum. In November 1973, per barrel prices had risen from around $5 to more than $16. Consuming nations bid against each other in order to ensure sufficient petroleum supplies. For American consumers, retail gasoline prices rose by more than 40 percent. Although high costs were extremely disconcerting, scarcity also took the form of temporary outages of supply. The front on this new resource war could be found on the home front: the American gas station. Many states implemented staggered days for gas purchases based on cars' odd or even license plate numbers.

Intermittently, motorists throughout 1973–1974 needed to wait in line for one to two hours or more—ironically, of course, with their engines running the entire time. In other regions, the worst harbingers were signs that read: "Sorry, No Gas Today." Expressway speeds were cut from 60–70 miles per hour down to 50. Many communities—as well as the White House—forwent lighting public Christmas trees. Some tolls were suspended for drivers who carpooled in urban areas. Rationing plans were leaked to the public, even if they were not implemented. For instance, in the New York City region, the Federal Energy Office estimated that residents 18 years of age and older could expect to receive books of vouchers for 37 gallons per month (Merrill, 2007, 3–6).

By the end of 1973, in fact, lines of vehicles awaiting a gas ration were plentiful throughout the nation. Supplies of petroleum were least disturbed on the West Coast, but by February, even California had adopted odd/even rationing days. Gas station operators were subjected to mistreatment, violence, and even death. Drivers also reacted with venom to other drivers attempting to cut into gas lines. At the root of such anger, of course, was the cruel reality that the events of our everyday lives—kids going to school, adults going to work or shopping, goods moving in every direction, and even cutting our grass—might be constrained, our choices limited. Nothing could seem more un-American.

These petroleum shortages extended into 1974; their implications, though, extended through the rest of the decade. The shock was an abrupt lesson. Although few Americans understood why the price fluctuated so wildly, for the first time, most Americans learned three valuable lessons: petroleum was a finite resource; the United States imported the bulk of its petroleum supply; and the United States was entirely reliant on this commodity. Clearly, our reliance on energy resources acquired from other nations left our nation vulnerable, potentially compromising the economic and military security of our nation.

This dramatic change in the politics of petroleum reconceived the role of alternative modes of energy production. The crisis demanded a response, and by the end of the 1970s, Carter was prepared to introduce a new era in American energy consumption. The difficulty, however, would derive from the ability of American energy producers and consumers to alter their existing energy paradigm. This difficulty was evidenced by political decisions immediately after the first oil shock.

THE CONSERVATION ETHIC FINDS NEW EXPRESSION IN MODERN ENVIRONMENTALISM

Although the embargo had economic implications, it had begun as a political act by OPEC. Therefore, in 1974, the Nixon administration determined that it needed to be dealt with on a variety of fronts, including, of course, political negotiations. These negotiations, which actually had little to do with petroleum trade, needed to occur between Israel and its Arab neighbors, between the United States and its allies, and between the oil-consuming nations and the Arab oil exporters. Convincing the Arab exporters that negotiations would not begin while the embargo was still in effect, the Nixon administration leveraged the restoration of production in March 1974. Although the political contentions grew more complex in ensuing decades, the primary impact of the embargo came from the residual effects it had on American ideas about the petroleum supply.

When energy supplies became a more significant topic after the 1970s Arab oil embargo, a panicked public expected action. Richard M. Nixon, by this point embattled with the growing problem of Watergate but re-elected in 1972, appeared before Americans on November 7, 1973, to declare an energy emergency. He spoke of temporary supply problems:

> We are heading toward the most acute shortages of energy since World War II. . . . In the short run, this course means that we must use less energy—that means less heat, less electricity, less gasoline. In the long run, it means that we must develop new sources of energy which will give us the capacity to meet our needs without relying on any foreign nation.
>
> The immediate shortage will affect the lives of each and every one of us. In our factories, our cars, our homes, our offices, we will have to use less fuel than we are accustomed to using.
>
> This does not mean that we are going to run out of gasoline or that air travel will stop or that we will freeze in our homes or offices any place in America. The fuel crisis need not mean genuine suffering for any Americans. But it will require some sacrifice by all Americans. (Merrill, 2007, 66–67)

In Nixon's speech, he went on to introduce Project Independence, which he said "in the spirit of Apollo, with the determination of the Manhattan Project, [would] by the end of this decade" help the nation develop "the potential to meet our own energy needs without depending on any foreign energy source" (Merrill, 2007, 66–67).

In reality, Nixon's energy czar, William Simon, took only restrained action. Rationing was repeatedly debated, but Nixon resisted taking this drastic step on the federal level. Although he had rationing stamps printed, they were kept in reserve. In one memo, Nixon's aid Roy Ash speculated: "In a few months, I suspect, we will look back on the energy crisis somewhat like we now view beef prices—a continuing and routine governmental problem—but not a Presidential crisis." Nixon's notes on the document read "absolutely right," and, overall, his actions bore out this approach. He refused to be the President who burst the American high of energy decadence.

Of course, any argument for a conservation ethic to govern American consumers' use of energy was a radical departure from the post-war American urge to resist limits and to flaunt the nation's decadent standard of living. Although this ethical shift did not take over the minds of all Americans in the 1970s, a large segment of the population began to consider an alternative paradigm for accounting for our energy use and needs. They became interested in energy-saving technologies such as insulation materials and low-wattage lightbulbs, as well as limits on driving speeds that might increase engine efficiency. As a product of the 1970s crisis, some Americans were even ready and willing to consider less convenient ideas of power generation, such as alternative fuels.

One conduit for such research would be the Department of Energy (DOE) that Carter created at the cabinet level. Similar energy supply crises might be avoided, it was thought, if in the future one agency administered the strategic planning for energy use and development. The DOE's task was to create and administer a comprehensive and balanced national energy plan by coordinating the energy functions of the federal government. The DOE undertook responsibility for long-term, high-risk research and development of energy technology, federal power marketing, energy conservation, the nuclear weapons program, energy regulatory programs, and a central energy data collection and analysis program.

Similar to any government agency, though, the mandate and funding varied with each presidential election. During the next few decades, the DOE moved away from energy development and regulation toward nuclear weapons research, development, and production, which took priority. Following the end of the Cold War, the Department focused on the environmental cleanup of the nuclear weapons industry, nonproliferation, and stewardship of the nuclear stockpile, as well as some initiatives intended to popularize energy efficiency and conservation. As the crisis faded, so too did the political inertia to strategically plan the nation's energy future.

While the DOE did not necessarily present Americans with a rationale for alternative fuels, new ethical perspectives moved through the public after the 1960s, and created a steady appreciation for renewable energy. Interest in these sustainable methods, as well as in conservation, were a part of the public movement in the late 1960s that became known as modern environmentalism.

MANAGING ENERGY WITH AN EYE TOWARD SUSTAINABILITY

Overall, the 1960s counterculture contributed to the development of institutions that would change basic relationships in American life. The American relationship with nature was one of the most prominent shifts. Much of what became known as the modern environmental movement was organized around groups and organizations that prospered under the influence of 1960s radicalism. However, the real impact of these organizations came during the later 1960s and 1970s, when their membership skyrocketed with members of the concerned middle class, and they demanded a political response from lawmakers. There is no doubt that one outlet for this new voice was the fight to develop alternative energy during the 1970s.

Contrasted with the conservation movement of the late 19th century, the social landscape of 20th-century environmentalism had changed a great deal. For instance, many of these environmental special-interest groups would evolve into major political players through lobbying. Nongovernmental organizations (NGOs) broadened the grassroots influence of environmental thought; however, they also created a niche for more radical environmentalists. The broad appeal, as well as the number of special-interest sectors of environmental thought, stood in stark contrast to 19th-century environmentalism. Whereas early conservationists were almost entirely members of the upper economic classes of American society, the new environmentalists came mostly from the middle class that grew rapidly after World War II (Opie, 1997, 418–25).

During the 1970s and 1980s, these NGOs helped to bring environmental concerns into mainstream American culture. Some critics argue that American living patterns changed little; however, the awareness and concern over human society's impact on nature had reached an all-time high in American history. These organizations often initiated the call for specific policies and then lobbied members of congress to create legislation. By the 1980s, NGOs had created a new political battlefield, as each side of the environmental debate lobbied lawmakers.

The American public often financially supported organizations that argued for their various perspectives. Even traditional environmental organizations such as the Sierra Club (estab. 1892), the National Audubon Society (estab. 1905), the National Parks and Conservation Society (estab. 1919), the Wilderness Society (1935), the National Wildlife Federation (estab. 1936), and the Nature Conservancy (estab. 1951) took much more active roles in policymaking. The interest of such organizations in appealing to mainstream, middle-class Americans helped to broaden the base of environmental activists. However, it also contributed to the formation of more radical-thinking environmental NGOs that disliked the mainstream interests of the larger organizations. In fact, many devout environmentalists argued that some of these NGOs were part of the establishment that they wished to fight.

The credit for bringing this new environmental ethic to the attention of the mass public often goes to scientist and nature writer named Rachel

Carson. One of the first writers to take advantage of this increased interest among middle-class Americans, Carson began writing about nature for general readers in the late 1950s. Then, in 1962, Carson's *Silent Spring* erupted onto the public scene to become a bestseller, after first having been serialized in *The New Yorker.* Carson's scientific findings brought into question basic assumptions that Americans had about their own safety and about many of the chemicals that they used to create their comfortable standard of living

Overall, though, the cultural attitude toward the progress predicated on cheap energy and manufactured chemicals was beginning to lose its dominating hold. In the case of Carson's work, her exposé of the health impacts of chemicals helped to disrupt the paradigm that supported Americans' trust, more generally, in technological progress. In a single summer, chemical science and blind confidence in technological progress had fallen from their previously unchallenged pedestals. Here is a portion of what Carson wrote:

> The "control of nature" is a phrase conceived in arrogance, born of the Neanderthal age of biology and philosophy, when it was supposed that nature exists for the convenience of man. The concepts and practices of applied entomology for the most part date from that Stone Age of science. It is our alarming misfortune that so primitive a science has armed itself with the most modern and terrible weapons, and that in turning them against the insects it has also turned them against the earth. (Carson, 2002, 12–14)

Her story and her words would inspire a large portion of the American population to reconsider its society's living patterns.

Following Rachel Carson, in 1968 Garrett Hardin wrote an article that developed the ecological idea of the commons. This concept and his argument of the inevitable depletion of the commons, gave humans a new rationale with which to view common resources such as the air and the ocean. He wrote:

> The tragedy of the commons develops in this way. Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy.
>
> As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" This utility has one negative and one positive component.
>
> Adding together the components . . . the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And

another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all. (Hardin, 1968, 243–48)

This essay marked a crucial moment in Americans' ability to apply the scientific ideas of ecology, conservation, and biology to human life—to assume that we possibly were *not* the exceptional species on Earth. Or, even if we were exceptional, maybe this status came with a responsibility for stewardship and management instead of for expansion.

APPLYING THE ENVIRONMENTAL PARADIGM TO ENERGY

It did not take long for this new way of viewing the human condition to become focused on the ethic behind Americans' high-energy lifestyle. The thinker most often given credit for making this transition in thought is E. F. Schumacher, a British economist who, beginning in 1973, wrote a series of books titled *Small is Beautiful.* One of these books, *Small Is Beautiful: Economics as if People Mattered,* became a bestseller. Like all the books in the series, this one emphasized the need to consider a different view of progress than the expansive, energy-intensive American approach. Building from the idea of limits that the embargo had reinforced, Schumacher emphasized a philosophy he called "enoughness," in which Americans designed their desires around basic human needs and a limited, appropriate use of technology. Later, this approach was termed "Buddhist Economics."

Schumacher particularly faults the conventional economic thinking that failed to consider sustainability and, instead, emphasized growth at all costs and a basic trust in the idea that bigger is better. The key, he argues, was in the conception of new technologies—when inventors and engineers were literally choosing why they pursued an innovation. He writes:

Strange to say, technology, although of course the product of man, tends to develop by its own laws and principles, and these are very different from those of human nature or of living nature in general. Nature always, so to speak, knows where and when to stop. Greater even than the mystery of natural growth is the mystery of the natural cessation of growth. There is measure in all natural things—in their size, speed, or violence. As a result, the system of nature, of which man is a part, tends to be self-balancing, self-adjusting, self-cleansing. Not so with technology, or perhaps I should say: not so with man dominated by technology and specialization. Technology recognizes no self-limiting principle—in terms, for instance, of size, speed, or violence. It therefore does not possess the virtues of being self-balancing, self-adjusting, and self-cleans-mg. In the subtle system of nature, technology, and in particular the super-technology of the modern world, acts like a foreign body, and there are now numerous signs of rejection.

Suddenly, if not altogether surprisingly, the modern world, shaped by modern technology, finds itself involved in three crises simultaneously. First, human nature revolts against inhuman technological, organizational, and political patterns, which it experiences as suffocating and debilitating; second, the living environment which supports human life aches and groans and gives signs of partial breakdown; and, third, it is clear to anyone fully knowledgeable in the subject matter that the inroads being made into the world's non-renewable resources, particularly those of fossil fuels, are such that serious bottlenecks and virtual exhaustion loom ahead in the quite foreseeable future.

Any one of these three crises or illnesses can turn out to be deadly. I do not know which of the three is the most likely to be the direct cause of collapse. What is quite clear is that a way of life that bases itself on materialism, i.e. on permanent, limitless expansionism in a finite environment, cannot last long, and that its life expectation is the shorter the more successfully it pursues its expansionist objectives. (Schumacher, Technology with a Human Face, n.d.)

Although Schumacher's points may have been extreme, they presented a new paradigm in energy management that appealed to some intellectuals.

One of the most noticeable spokespeople of this alternative energy paradigm was economist Amory Lovins. In a 1976 *Foreign Affairs* article titled "Soft Energy Paths" and in his subsequent book, Lovins contrasted the "hard energy path," as forecast at that time by most electrical utilities, with the "soft energy path," as advocated by Lovins and other utility critics. He writes:

The energy problem, according to conventional wisdom, is how to increase energy supplies . . . to meet projected demands. . . . But how much energy we use to accomplish our social goals could instead be considered a measure less of our success than of our failure. . . . [A] soft [energy] path simultaneously offers jobs for the unemployed, capital for businesspeople, environmental protection for conservationists, enhanced national security for the military, opportunities for small business to innovate and for big business to recycle itself, exciting technologies for the secular, a rebirth of spiritual values for the religious, traditional virtues for the old, radical reforms for the young, world order and equity for globalists, energy independence for isolationists. . . . Thus, though present policy is consistent with the perceived short-term interests of a few powerful institutions, a soft path is consistent with far more strands of convergent social change at the grass roots. (102)

Lovins' ideas moved among intellectuals, but found immediate acceptance with neither political leaders nor the general public. The shift, though, seemed to arrive in the form of President Jimmy Carter.

With additional instability in the Middle East by the later 1970s, Carter elected to take the ethic of energy conservation directly to the American people (Horowitz, 2005, 20–25). Carter attempted to steer the nation toward a future of energy conservation and independence. In a 1977 speech, Carter urged the nation:

> Tonight I want to have an unpleasant talk with you about a problem unprecedented in our history. With the exception of preventing war, this is the greatest challenge our country will face during our lifetimes. The energy crisis has not yet overwhelmed us, but it will if we do not act quickly.
>
> It is a problem we will not solve in the next few years, and it is likely to get progressively worse through the rest of this century.
>
> We must not be selfish or timid if we hope to have a decent world for our children and grandchildren.
>
> We simply must balance our demand for energy with our rapidly shrinking resources. By acting now, we can control our future instead of letting the future control us. . . .
>
> Our decision about energy will test the character of the American people and the ability of the President and the Congress to govern. This difficult effort will be the "moral equivalent of war"—except that we will be uniting our efforts to build and not destroy. (2005, 42–46)

In a risky political move, Carter attempted to steer Americans down a path less trodden—in fact, a path of severe difficulty and radical social and cultural transition. It was a path of resource management inspired by the concept of restraint and conservation. It was a lonely argument, when Carter first presented it. However, Americans did respond with some new awareness of conservation and new attention for alternative modes of generating power.

Of energy production in the late 1970s, policy historian Richard N. L. Andrews writes that all previous policies were based on two underlying assumptions:

> One was that cheap energy was essential to economic progress, and the other was that government policies should therefore be used to assure abundant supplies at low prices. Implicit in these principles was the assumption that energy resources would themselves continue to be abundant. . . . That is, these principles were designed to assure and manage energy *surplus* rather than scarcity. (1999, 295)

Although by the 1970s some policies had begun to address pollution and other implications of the use of fossil fuels, regulations forced energy markets to reflect neither the full environmental nor the full economic costs of energy production. Andrews writes that the 1973 embargo initiated three types of policy change related to energy: first, an emphasis on tapping domestic supplies for energy; second, a new recognition that energy conservation was an essential element of any solution; and third, electric utility companies were forced to accept and pay fair wholesale rates for electricity created by any producer.

The Public Utilities Regulatory Policy Act of 1978 opened the electric grid to independent producers, including that generated from renewable sources. Eventually, the Energy Policy Act of 1992 expanded these possibilities nationally by allowing both the utilities and other producers to operate wholesale generating plants outside each utility's distribution region. Andrews writes that "in effect, it thus severed power generation from the 'natural monopoly' of electric transmission and distribution." Although this offered great promise for the development of electricity generation from renewable sources, "by restructuring the utilities to make power production independent of distribution," continues Andrews, "the policy change also removed incentives that had led the utilities to promote demand-side energy conservation" (1999, 301–2).

Therefore, although Carter and others offered a clear vision of our limited future based on increasingly scarce extracted energy resources during the 1970s, by the 1980s, many Americans were returning to business as usual—or worse. However, during the 1970s there were strong initiatives toward alternative energy. Although they did not immediately succeed, it is likely an oversimplification to refer to them as failures.

CONSIDERING OPTIONS ON SIZE AND POWER IN TRANSPORTATION

Many of the conservation measures focused on personal transportation, particularly on fueling automobiles. In order to manage petroleum scarcity, President Jimmy Carter initiated scientific experiments in biotechnology to create a supplemental fuel, which was known as gasohol—gasoline with a 10 percent alcohol content. This product was basically identical to the alcohol used in Ford's 1908 Model T, which could be modified to run on either gasoline or pure alcohol. Henry Ford designed the vehicle with alcohol in mind, which he believed would be "the fuel of the future." Ethanol was used in vehicles through the 1930s, until the large manufacturers focused on petroleum as their exclusive transportation fuel. Ethanol, also called gasohol, became viable and popular again with the disruption of petroleum supplies in the 1970s. In an effort to stimulate the use of this alternative fuel, Congress passed the Energy Tax Act of 1978, which provided an exemption to the four cents per gallon federal fuel excise tax on gasoline for fuel blended with at least

10 percent ethanol. Two additional bills followed by 1980, which promoted the development and use of alternative fuels.

With renewed attention focused on alternative methods for powering transportation, a primary emphasis of legislation has been on promoting alternative fuels that could be run in most gasoline engines. Using laws such as the Alternative Motor Fuel Act (AMFA) and Energy Policy Act (EPACT), legislators elected to attempt to use federal requirements to force automakers to diversify the power sources used by their fleet. First passed in the mid-1990s, these policies have each been updated.

AMFA was designed specifically to encourage the widespread use of methanol, ethanol, and natural gas as replacements for light vehicle transportation fuels. In addition, Congress sought to provide incentives directly to the automakers that would offset the cause and effect paradigm that they bemoaned. During the era of postwar expansion, automakers had consistently argued that they would manufacture and market alternative-fuel vehicles when a supply and distribution infrastructure was available to make their use practical for consumers.

In particular, AMFA emphasized dual-fuel vehicles, which have now become known as flex-fuel vehicles. To provide incentives for such vehicles, AMFA amended the automotive fuel efficiency provisions of Title V of the Motor Vehicle Information and Cost Savings Act by adding incentives for the manufacture of vehicles designed to operate either exclusively or flexibly on methanol, ethanol, or natural gas. Vehicles that operated exclusively on a 70 percent or greater methanol or ethanol concentration, or only on compressed or liquefied natural gas, were recognized by AMFA to be dedicated alternative fuel vehicles. Those that had the capability to operate on either conventional gasoline or diesel fuel, or on a mixture of the fuel and gasoline or diesel fuel, or only on the alternative fuel, without modification to the vehicle, were considered dual-fuel or flexible-fuel vehicles. The incentive for producing such vehicles, of course, was that manufacturers producing alternative-fuel vehicles could raise their fleets' overall average fuel economy, enabling them to create additional low-mileage options.

In a similar fashion, EPACT expanded the definition of alternative fuel to include liquefied petroleum gas, hydrogen, liquid fuels derived from coal and biological materials, electricity, and any other fuel that the Secretary of Transportation determined to be substantially non-petroleum based, and which had environmental and energy security benefits. Beginning in 1993, manufacturers of these alternative fuel automobiles that met the minimum driving range and energy efficiency criteria could qualify for special treatment in the calculation of their CAFE.

These well-intended laws provided a clear possibility for alternatively powered personal transportation after decades of lying dormant. However, for the most part, these flex-fuel vehicles remained in the prototype stage until early in the 21st century, when gasoline prices brought renewed attention to alternatives. During the late 20th century, though, change would come very slowly. Most often, these prototypes were only developed to enable manufacturers to exploit the mileage loopholes for the rest of their fleets. There was no credible effort by a major manufacture to actually create an alternatively fueled vehicle.

In addition to these federal policies intended to force automakers to develop alternatively fueled vehicles, other policy measures were put in place to force them to make ICE-powered vehicles more efficient. The issue came to a political head after the elections of 1977 had brought new Democrats in to shake up Congress. Many of these politicians were not willing to allow the manufacturers to further forestall meeting the requirements established earlier in the decade. Congress stood up to Detroit's threat that implementing these regulations would shut down American plants, and passed a bill requiring them to meet mandates on CAFE standards and emissions. On August 7, 1977, when he signed the bill, Carter announced that the bill provided automakers with a "firm timetable for meeting strict, but achievable emissions standards" (Doyle, 2000, 200).

The new emissions standards also meant the design of cars had to change. In moments of anxiety over fuel supplies, such as the 1970s, American attitudes toward vehicles altered significantly. With a reconsideration of the basic need for vehicles to perform transportation more efficiently—to use less petroleum for their task—Americans immediately altered their view of the few small vehicles already being sold in the American market, such as the Volkswagen Beetle. Thanks to the desire for Beetles, used models from the late 1960s sold for more than new models had just prior to November 1973. The industry reported that standard-size cars outsold subcompacts by two to one just prior to the autumn of 1973. By December, smaller cars were being sold at the same rate as larger ones, and throughout 1974, their sales jumped while the guzzlers remained in the showrooms. American manufacturers simply could not immediately step in and fill this new demand (Volti, 2004, 125).

Stepping into this breach in the market, Japanese manufacturers made a niche for themselves with inexpensive, small vehicles. Although small quickly became much more acceptable to American consumers, the greatest impact on the overall fleet was the growing status of small sedans that resembled Honda's Accord. Previously, writes journalist Christopher Finch, the U.S. manufacturers had resisted homogeneity and ideas such as efficiency and safety. The American car was, despite the pleading of activist Ralph Nader and others, about style. Finch writes:

> Until 1973, the one thing that insulated the American car industry from this tendency was cheap gasoline, which permitted every man a grandiosity of expression that was forbidden to all but the rich elsewhere in the world. After 1973, many Americans began to play by the same rules as Asians and Europeans, and with this came the sameness of product that afflicts the automobile marketplace today. As fins and grinning chrome radiator grilles slipped into the past, they quickly became objects of nostalgia and veneration. (1992, 318–19)

THE ENVIRONMENTAL MOVEMENT ZEROES IN ON ICE

By the second half of the 1900s, many activists had become very outspoken about Americans' having a villain living in their everyday lives: the internal combustion engine (ICE). In its earliest version, this re-imaging of the ICE had little to do with the growing scarcity of petroleum supplies; instead, critics emphasized the inevitable outcome of burning petroleum in car engines: emissions and air pollution.

Air pollution had been documented to possess health impacts for humans since the early 1900s. In the 1940s, air pollution was more broadly construed to be a product of many facets of urban life, not just factories. In cities such as Los Angeles, the phenomenon became known as smog, and was directly connected to exhaust from the automobile's internal-combustion engine. (Typically, smog is not merely used to blend the words smoke and fog, but also to include chemical compounds that linger in the air when sunlight interacts with smoke produced by burning hydrocarbons). The existence of carbon monoxide, carbon dioxide, and sulfur dioxide in such air pollution was not recognized for a few more decades. The connection between smog and auto exhaust is credited to Arie Haagen-Smit, a researcher at the California Institute of Technology. During the 1950s, Haagen-Smit fought off the savage criticism of the auto manufacturers, who claimed that a well-tuned vehicle had no such adverse effects on the air. Severe smog episodes in California kept the issue in the public arena and helped to make the issue one of the primary ones for the nascent environmental movement.

The seminal event in the emergence of modern environmentalism, Earth Day 1970, contained many activities that related to air pollution. In one of the day's most dramatic and public displays, though, New York City's Fifth Avenue was transformed into an auto-free zone. Only pedestrian traffic was allowed to traverse the city's symbolic primary artery. Accomplishing its intention, this public display was meant to strip away the noise, congestion, and exhaust that the vehicles brought to the space.

As scientists began to understand the complexities of air pollution in the late 1960s, it became increasingly apparent that in addition to specific toxic emissions such as lead, the internal combustion engine was a primary contributor to air pollution, which in cities is usually referred to as smog. Emissions from the nation's nearly 200 million cars and trucks account for about half of all air pollution in the United States and more than 80 percent of air pollution in cities (Doyle, 2000, 134).

When the engines of automobiles and other vehicles burn gasoline, they create pollution. These emissions have a significant impact on the air, particularly in congested urban areas. This is hard to track or trace, though, because the sources are moving. The pollutants included in these emissions are carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter. Nationwide, mobile sources represent the largest contributor to air toxins, which are pollutants known or suspected to cause cancer or other serious health effects. Greenhouse gases are pollutants known or suspected to cause cancer or other serious health effects. These are not the only problems, though. Scientists believe greenhouse gases are responsible for trapping heat in the Earth's atmosphere.

Initial efforts at controlling auto emissions date back to 1961, when a single state, California, exceeded anything being considered on the national level and required all cars to be fitted with PCV valves that helped contain some of the emissions within the vehicle's crankcase. Federal legislation began in 1965 with the Motor Vehicle and Air Pollution Act, which was followed in 1970 by the first Clean Air Act. As the new social movement of modern environmentalism took shape after Earth Day 1970, though, constituents forced many lawmakers to consider drastic changes to our vehicles.

The organizer of Earth Day, Gaylord Nelson, in fact, went on record in 1970 saying, "The automobile pollution problem must be met head on with the requirement that the internal combustion engine be replaced by January, 1, 1975" (Doyle, 2000, 64). As discussed above, the 1973 Oil Embargo added supply concerns to the calls for the construction of more efficient engines. One of the major proponents of clean air legislation was Senator Edwin Muskie, a Democrat from Maine. He acted as a bridge between the new environmental NGOs springing from middle-class America's Earth Day exuberance and the 1960s conception of using the federal government to regulate and ultimately solve the nation's various ills. Together, a conglomeration of concerns focused public opinion against the internal combustion engine for its being an inefficient, polluting threat to U.S. health and security. Although Nelson and others argued for banning the engine altogether, the most likely outcome appeared to be placing federal regulations (similar to those used in California) on American cars.

The battle over how far CAFE standards and emissions controls would extend required the auto industry to flex its political muscle like never before. Very quickly, the health and safety concerns morphed into threats of inflated prices on American cars and the economic threat of foreign autos encroaching on the American market. After meeting with Nixon during 1972–73, industry leaders altered their approach. When they met with President Gerald Ford in 1975, the auto industries offered to accept a 40 percent improvement in mileage standards if Congress would ease standards on emissions. Ford agreed and presented this policy to American consumers in his State of the Union address. Although Congress protested, this division (accepting CAFE while relaxing emissions) became the rallying point for the auto industry during the 1970s.

The complex terrain of the policies relating to automobiles demonstrated the technology's primacy in America's social and economic life. Auto emissions were one of the first emphases of environmental policy, with initial legislation passed in 1970 (the National Emission standards were contained in the Clean Air Act). As the details were worked out in Congress, Muskie won a major victory when specific pollutants contained in vehicle exhaust, such as CO and HCl, were required to drop 90 percent from 1970 levels by 1975. The intention, of course, was to force manufacturers to create the technologies that could meet the new standards. Individual states led the way. In 1975, a California act required that vehicle exhaust systems be modified prior to the muffler to include a catalytic converter. Costing approximately $300, early converters ran the exhaust through a canister of pellets or a honeycomb made of either stainless steel or ceramic. The converters offered a profound, cost-effective way of refashioning the existing fleet of vehicles to accommodate new expectations on auto emissions.

In addition, the scientific scrutiny of auto emissions proceeded on one additional, much more specific front. Air testing for emissions and the smog that they created also revealed a now undeniable reality of auto use: lead poisoning. The willingness to tolerate lead additives in gasoline had persisted from the 1920s. Under the new expectations of the 1970s, though, lead emissions presented auto manufacturers with a dramatic change in the public's expectations. By this point, the amount of lead added to a gallon of gasoline hovered in the vicinity of 2.4 grams. The Department of Health, Education, and Welfare, which was home to the Surgeon General starting with the Kennedy Administration, had authority over lead emissions under the Clean Air Act of 1963. The criteria mandated by this statute were still in the draft stage when the Act was reauthorized in 1970 and a new agency called the Environmental Protection Agency (EPA) came into existence. The days of lead's use in American gas tanks was clearly on the wane.

In January 1971, EPA's first Administrator, William D. Ruckelshaus, declared that "an extensive body of information exists which indicates that the addition of alkyl lead to gasoline . . . results in lead particles that pose a threat to public health" (EPA). The resulting EPA study released on November 28, 1973, confirmed that lead from automobile exhaust posed a direct threat to public health. As a result, the EPA issued regulations calling for a gradual reduction in the lead content of the nation's total gasoline supply, which included all grades of gasoline. Following California's lead on catalytic converters, U.S. automakers responded to the EPA's lead phasedown timetable by equipping new cars (starting in 1975) with pollution-reducing catalytic converters designed to run only on unleaded fuel. With the fleet largely converted, 1989 brought Congress to finally ban the use of leaded gasoline (Gorman, 2000). It is estimated that from the 1920s, when manufacturers had convinced Americans that lead (called ethyl) was a safe additive to gasoline, until 1989, 15.4 billion pounds of lead dust were spewed into the air by automobiles (Motavalli, 2001, 40).

Given the degree of regulation and the immense, new expectations placed on vehicles, American auto manufacturers came out of the 1970s feeling under siege. Each leader in the industry forecast expensive shifts that would raise vehicle prices and put American laborers out of work. In fact, some openly speculated about whether or not automobiles could still be manufactured in the United States in the 21st century. They would apply their considerable creativity to extending the American tradition of car making into the next century. However, American manufacturers obviously directed their designs toward circumventing new regulations. In truth, though, air pollution was simply an immediate outcome of burning fossil fuels. The implications and impacts of these emissions would prove even more troublesome to the future of the ICE.

EMERGING SCIENCE CONNECTS EMISSIONS TO LARGER PROBLEMS

The new appreciation of the environmental impact of the ICE was just the beginning of the problems that would face the brokers of America's high-energy existence. During the 1980s, scientists achieved even more detail regarding the environmental impact of auto emissions. Most important, the impact was not limited to local areas, such as the city of Los Angeles. New computer modeling combined with better understanding of the functioning of various layers of the Earth's atmosphere to make clear that something was rapidly depleting the planet's protective ozone layers. In addition, heat was becoming trapped in the Earth's atmosphere at an alarming rate, creating what came to be known as the greenhouse effect. Finally, by the 1990s, scientists concluded that the Earth was warming at a pace without historic precedent.

For most scientific observers, the root of each of these environmental problems—as well as others, such as acid rain—was the burning of fossil fuels, which released massive amounts of carbon (in the form of carbon monoxide and dioxide) into the Earth's atmosphere. Today, the transportation sector alone is responsible for about one-third of our nation's total production of carbon dioxide. And, of course, the internal combustion engine is a primary contributor. Not only is smog unpleasant and unhealthy, it may actually be contributing to the ruination of the entire Earth (Gelbspan, 1995, 9–13).

Some scientists went even further. They argued that the burning of fossil fuels had broadened humans' environmental impact so severely that a new geological epoch should be named: the anthropocene. Chemist Paul Crutzen argued in a 2000 article in *Science* that humans have become a geologic agent comparable to erosion and eruptions, and accordingly "it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geological epoch."

LOOKING FOR TRANSPORTATION ALTERNATIVES

Americans' reliance on mined energy resources created a century of inexpensive energy that has largely molded the society in which we now live. Most experts agree, though, that the next century demands a different model for its prime mover. Alternate sources of energy offer the possibility of reducing dependence on fossil fuels, which would also reduce American dependence on petroleum imports and reduce pollution. Simultaneously, though, significant improvements to energy efficiency and conservation measures arrived, and, in the short term, these adaptations might be the most easily implemented. For instance, a few simple ways to reduce energy consumption might include the use of lighter-weight automobiles and more-efficient engines, improved house insulation, waste recycling, and improved public transport.

In terms of personal transportation, electricity emerged as the most likely replacement for ICE. The rising environmental concerns became focused in California in the late 20th century and, therefore, it is not surprising that so did the development of electric vehicles. CARB helped to stimulate CALSTART, a state-funded nonprofit consortium that functioned as the technical incubator for America's efforts to develop alternative-fuel automobiles during the 1990s. Focusing its efforts on the project that became known as the EV, this consortium faced auto manufacturers' onslaught almost single-handedly.

Maintaining the technology during the mid-1900s, however, had been carried out by a variety of independent developers.

Absent governmental support, and despite the efforts of larger manufacturers after World War II to resist efficiency, independent manufacturers continued to experiment with creating an electric vehicle that could operate cheaply and travel farther on a charge. The problems were similar to those faced by Edison and earlier tinkerers: reducing battery weight and increasing the range of travel. Some of these companies were already in the auto business, including Kish Industries of Lansing, Michigan, a tooling supplier. In 1961, it advertised an electric vehicle with a clear, bubble roof known as the Nu-Klea Starlite. Priced at $3,950, without a radio or a heater, the car's mailing advertisements promised "a well designed body and chassis using lead acid batteries to supply the motive energy, a serviceable range of 40 miles with speeds on the order of 40 miles an hour." By 1965, another letter from Nu-Klea told a different story: "We did a great deal of work on the electric car and spent a large amount of money to complete it, then ran out of funds, so it has been temporarily shelved" (Motavalli, 2001, 40). The Nu-Klea was not heard from again.

As mentioned above, in 1976, the U.S. Congress passed legislation supporting the research into electric and hybrid vehicles. Focused around a demonstration program of 7,500 vehicles, the legislation was resisted by government and industry from the start. Battery technology was considered to be so lacking that even the demonstration fleet was unlikely. Developing this specific technology was the emphasis of the legislation in its final rendition. Historian David Kirsch writes that this contributed significantly to the initiative's failure. "Rather than considering the electric vehicle as part of the automotive transportation system and not necessarily a direct competitor of the gasoline car, the 1976 act sponsored a series of potentially valuable drop-in innovations." Such innovations would allow electric technology to catch up to gasoline, writes Kirsch. However, "given that the internal combustion engine had a sixty-year head start, the federal program was doomed to fail" (2000, 205).

The developments in electric vehicles that followed were mostly of the small-scale variety. The 1979–80 Lectric Leopard from the U.S. Electricar Corporation of Athol, Massachusetts, was based on a Renault R-5, or Le Car, as it was known in the American market. One of the best-selling electrics was the CitiCar, built from 1974 to 1976 by the Sebring-Vanguard Company in Sebring, Florida. The CitiCar was essentially a golf cart equipped with horn, lights, turn signals, wipers, and an enclosed cabin with optional heater and radio. The CitiCar was succeeded by the Comuta-car, an identical twoseater. During the 1990s, a company known as Solectria built electric vehicles based on GM's Geo in Woburn, Massachusetts. Such efforts were celebrated by sustainable-energy groups, but remained well outside the mainstream of consumer vehicles.

When it was developed in the early 1990s, the EV1 appeared to be an exception. Developed with the support of the state agencies, the EV was then leased to consumers by GM in California and Arizona in the late 1990s. There were significant costs involved, because customers were required to have home-charging stations to keep their EV1s fueled. GM worked with the state to establish a few charging stations in shopping centers and office buildings. Despite what seemed like a significant example of industrial and governmental cooperation, the EV did not turn out well. So revealing as an episode of a missed technological transition, the EV1 became the subject of the well-known documentary film *Who Killed the Electric Car?* As the title suggests, although the car gained a passionate following among some users, the project died when California backed down on its mandate for zero-emission vehicles. The primary reason given for the EV's demise was the difficulty developing battery technology. There appears to be more to the story, though.

Journalist Jim Motavalli describes the fight over the EV1 as a California battlefield in the mid-1990s. From billboards to radio talk shows, auto companies spent approximately $34 million to depict CARB as an extremist political group that wished to take away Americans' right to choose their automobiles. Thus, just as some of the auto companies were developing electric vehicles that would satisfy California's guidelines, they were also orchestrating a publicity campaign to do away with the agency overseeing the guidelines. *Car and Driver* magazine called CARB "the most environmentally draconian government agency in the nation" (Kirsch, 2000, 37). GM withdrew its support for the two-seat coupes. The cars were ordered back to the manufacturer for crushing, much to the dismay of a vocal group that fought to keep them on the road. GM was not the only automaker to cancel production of electric-battery vehicles so it could focus on hybrids and hydrogen fuel cells; with each cancellation, the chances of success for a mass-production electric-battery car seemed less likely.

GIVING DIESEL AND BIOFUELS ANOTHER LOOK

Although they were resisted by large carmakers, after the 1970s, many of the initiatives for alternative fuels took shape in laboratories, ranging from massive agricultural and petrochemical corporations to institutes of higher education to, of course, the garages of private citizens. In fact, experiments with what have become known as "biofuels" have never really stopped. After an early history of success, biofuels largely lost out to the use of inexpensive fossil fuels in the United States' expanding economy. In many European nations, national governments sponsored experiments with various forms of biofuel development. In the United States, the federal government had less involvement. American experiments were primarily carried out by agricultural experiments and particularly emphasized the use of soybeans. By the end of the 20th century, though, a variety of other experiments had progressed.

Most large-scale experiments with biofuels focused on ethanol, as discussed above. One of the most significant undertakings grew from the efforts of Ag Processing Inc. (AGP). In 1994, AGP, the country's largest soybean-processing cooperative, formed a new joint venture called Ag Environmental Products (AEP). In 1996, AGP opened a new batch-process biodiesel plant with a capacity of five million gallons (17,500 tons) in Sergeant's Bluff, Iowa, adjacent to an existing seed-crushing facility. The operation represented an exciting new frontier for biofuels.

In the spring of the following year, AEP provided biodiesel fueling stations at 10 farm co-op locations in 6 Midwestern states. Other stations were subsequently added. Over the years, the $6 million soy methyl ester facility at Sergeant's Bluff has produced a wide range of products, including biodiesel, solvents, and agricultural chemical enhancers under the SoyGold brand name, which were promoted and marketed for AEP. Over the last few decades, biodiesel produced by AGP has been used in a wide range of vehicles by customers across the country.

Other, similar operations were established throughout the United States during the 1990s. These experiments set the stage for an exciting new era in energy when the high price of petroleum again made it feasible.

SYNTHETIC FUELS

The frontier of an energy transition can be uncomfortable. All across the United States, a variety of ingenious power producers learned the hard way that Americans were hooked on fossil fuels. One of the most intriguing and revealing examples lay in a lonely section of Colorado.

When Exxon released its white paper "The Role of Synthetic Fuels in the United States Energy Future" in 1980, a new era seemed poised to unfold on the American West. Declaring an energy emergency, Exxon suggested rearranging the drainage system of North America to pave the way for massive development of oil made from shale rock. The largest known supplies of oil shale lay in western Colorado, where towns such as Rifle, Parachute, and

Craig stood to become the centers of one of the largest energy shifts in American history.

One resident of Rifle spoke for many regional residents when he said, "Oil shale is here to stay. When you have companies that have committed a good many millions to development programs, they're not in here for fun. They're here for real." Historian Andrew Gulliford writes: "With the energy boom of the 1970s, small towns were changed overnight by rapid growth" (Gulliford, 1989, 23). Oil shale was a processing-intensive industry that derived oil from shale rock. The Colony Oil Shale Project would cost Exxon $5 billion and involve the construction of entirely new communities, including Battlement Mesa, which was expected to exceed 25,000 residents.

This region had boomed previously. Between 1915 and 1925, oil shale seemed to be a viable prospect for future energy development. A significant limiting factor, however, was technology. This first boom was largely spent determining how to mine and process oil shale. As the processes became known, oil shale lost its economic viability. Massive amounts of petroleum had been found in Texas and Oklahoma. The oil shale boomers were left with few options: oil shale would have to wait for another day.

That other day seemed to arrive in 1977 when President Jimmy Carter called for a comprehensive national energy policy. The earlier boom had lacked investment capital and technology. During the late 1970s, writes historian Andrew Gulliford, "capital was plentiful, but there was still no technological breakthrough" (Gulliford, 1989, 145). By spring 1980, a dozen companies planned oil shale plants capable of producing thousands of barrels of oil per day. Most major U.S. petroleum companies were involved, with one conspicuous absence: Exxon U.S.A.

In August 1980, Exxon stunned the rest of the industry with its white paper. Exxon proposed to have a 50,000-barrel-per-day oil shale plan operating by 1985 that would produce eight million barrels per day by 2000. Before long, unemployed Americans arrived from throughout the United States to find their future in southern Colorado.

While this future promised employment and additional energy resources, the consequences were also evident to everyone involved. Shale would be mined and processed, spewing tons of sulfur dioxide into the pristine air. Coal would be strip-mined and burned in nearby, coal-fired power plants. Additionally, each barrel of oil required three to four barrels of water during processing. This was a steep requirement in a semi-arid region.

Regardless, towns such as Silt, Colorado, worked around the clock to make themselves as attractive as possible for the approaching corporate boom. Silt spent $3 million on infrastructure, including sewer lines, street improvements, and the construction of a new city hall. By the end of the 1970s, Silt's population had tripled. Rifle was one of the towns nearest the Colony Project's main processing plant. Following Carter's call for accelerated development, housing and motel starts were put into place. One resident of Rifle said, "This town's gone plumb crazy. There's a lot of people worried about conditions, but there's few people willing to put their backs against the wall and start pushing to save what we have—our way of life" (Gulliford, 1989, 243).

In June 1980, Carter signed a bill providing $20 billion to establish the Synthetic Fuels Corporation and another $88 billion to fund it. These were the carrots dangled in front of petroleum companies to spur oil shale development. "This is a proud day for America," exclaimed Carter. "The keystone of our national energy policy is at last being put into place." Synfuels, he went on, "will dwarf the combined programs that led us to the moon and built our interstate highway system."

That same month, Exxon negotiated with ARCO to purchase their interest in the Colony Oil Shale Project for $400 million. A journalist for the Rifle newspaper described the impact of this purchase: "That's when all the lights on the pinball machine lit up." In general, Gulliford writes, "The personal, face-to-face relationships that had characterized the small rural communities gave way to the impersonality of big business." Nearly every aspect of life in Rifle changed. "It affected the types of social clubs in the community. It affected the school population. It affected how city hall conducted its business. It affected what types of tools the hardware store inventoried. It affected the menu in local restaurants" (Gulliford, 1989, 234–36).

The oil shale communities demonstrated how rapidly energy development dollars could alter local economies and communities. However, Rifle and its neighbors were destined to create an entirely new formula for bust from the mirage of alternative energy: these boomtowns busted without ever really having their actual economic growth. America's uncertainty about alternative fuels materialized before these industries could develop.

Construction continued during the winter of 1982, involving many companies, including Union, Exxon U.S.A., Chevron, Superior, Phillips, and Mobil. Estimates had begun to circulate that the industry would employ as many as 870,000 personnel. On May 2, in boardrooms in Houston and New York City, company officials decided that their vision of the future had been incorrect. Exxon suddenly and publicly announced that the Colony project would not be cost effective, and therefore it was pulling out of it entirely.

The news swept the region and then the nation. No one could conceive that any company, even the largest corporation in the world, could simply turn its back on a $920 million investment. "And overnight," writes Gulliford, "panning for growth stopped. There had been countless plans for a boom, but not a single plan existed for a bust of such epic proportions" (Gulliford, 1989, 284–86). Twenty-one thousand workers were immediately out of work, thousands others lost the promise of jobs, and thousands of dollars had been wasted on building and planning.

Experiments with alternative fuels of all types were forced to ride the cycles of price for fossil fuels. When the price rose and supplies seemed certain to diminish or dwindle, the additional costs of alternative fuels such as synfuels became easier to absorb, arousing investor interest. In each cycle, though, the fossil fuel prices did not remain high, and alternative fuels remained uncompetitive. If Americans could continue to squeeze more years out of cheap fossil fuels, that appeared to be their preference. In fact, their vehicular choices during the last two decades of the 20th century left no doubt about this fact.

CONCLUSION: THE ANTI-CONSERVATION VEHICLE—AMERICA'S SUV FETISH

Energy transitions require difficult social, economic, and cultural changes. As a product of these consumer preferences, new technologies might not evolve as rapidly as we, in hindsight, think that they should have. As we look back on the 1970s from the 21st century, we see many new voices taking on the logic and rationale of Americans' high-energy existence. In hindsight, it seems clear that, for the first time, American consumers knew that their primary energy regime was not sustainable. However, when the price of oil dropped during the 1980s, Americans lost the imperative for change.

Maybe the best example of this collapse of the alternative initiative is in the transportation sector: the SUV. Which came first, the American consumer's taste for large vehicles or the manufacturers' emphasis on these models? It appears to be a hand-in-glove, synchronistic relationship. The irony, though, is that the policies created to conserve petroleum supplies—particularly the 1978 establishment of CAFE standards—spurred the increase in the size and weight of vehicles traveling American roadways. Auto manufacturers carefully studied the new guidelines of the 1970s and concocted the best hope for their industry's future. Instead of pursuing the efficiency mandated by the new guidelines (a course they would leave up to Japanese manufacturers), American carmakers found a loophole and exploited it. Their savior, of course, was the large SUV sought by many Americans in the 21st century.

What began as gimmicky, small-selling vehicle for a specific purpose, morphed into ubiquity through the odd convergence of consumer taste and auto manufacturers' interest in exploiting a specific niche in new vehicle regulations. As defined by the CAFE standard, a light truck is any four-wheel vehicle weighing less than 8,500 pounds that is not a car. Although arbitrary, this category, therefore, includes vans, minivans, pickup trucks, and sport-utility vehicles. "In the mid- to late 1980s," writes auto design historian, David Gartman, "upscale demands for functionality and distinction" brought small-market, specialized vehicles into the mainstream (1994, 222).

In the creation of the Light Truck category, though, American manufacturers had found their safety valve. Of course, this new category of vehicle included very few models when the standards were set (approximately 10 percent of the entire fleet) (Volti, 2004, 143)). The light-truck share of the passenger vehicle fleet rose to 20.9 percent in 1975 and to 30 percent in 1987. In 1995, this had risen to 41.5 percent. And, remarkably, by the year 2001, there were almost equal numbers of cars and light trucks on the road (approximately 8.5 million of each). In a bitter irony, the CAFE standards and ensuing legislation had created the opportunity to build large, heavy, inefficient vehicles. And, to the shock of owners of AMC and other manufacturers, Americans wanted such vehicles.

Luxury versions of the Suburban, the Chevy Tahoe, and the GMC Yukon each became available in 1994. These were followed before the end of the decade by the Ford Expedition and Lexus LX-450 in 1996, the Lincoln Navigator in 1997, the Cadillac Escalade in 1998, the Ford Excursion in 1999, and the Toyota Sequoia in 2000. Unlike the luxury cars that they were replacing, large SUVs brought manufacturers massive profits—normally as much as $15,000 per vehicle. In most cases, these vehicles almost single-handedly saved the Big Three during the 1990s. In the luxury sector of the car market, cars made up 95 percent of all purchases in 1990. By 1996, cars made up only 44 percent of that sector!

SUVs were originally designed for work crews, hunters, residents of snow country, and others needing to travel off-road. By the end of the 20th century, though, they were the car of choice for soccer moms, Secret Service teams, business executives, sports stars, and gangster rappers. Thanks to a convergence of changes in air regulation and tax law, largely orchestrated by auto manufacturers and their hired lobbyists, while environmentalists and others attempted to develop new technologies for transportation, Detroit rejected them. Journalist Paul Roberts writes: "The SUV represent the height of conspicuous energy consumption. The extra size, weight, and power of the vehicles are rarely justified by the way their owners drive them. Even though owners and carmakers counter that the SUV's greater size, weight, and capabilities provide an extra margin of safety, studies indicate that SUVs not only are more likely to kill people in cars they hit but, because they roll over more easily, can actually be more dangerous to their occupants as well" (Roberts, 2004, 154).

Viewed objectively—for instance, as a scientist might—we must reflect on the remarkable data of the late 20th-century use of petroleum:

- From 1960–2005: The amount of miles driven by Americans quadrupled.
- The light truck market share of 10% grew to nearly 50% by 2001.
- The biggest-selling vehicles in the United States by the year 2001 had become two full-size pickups, the Ford F-150 and the Chevrolet Silverado. (Roberts, 2004, 274)

Clearly, the era of alternatively powered transportation had not truly arrived at the end of the 20th century. However, this era of denial remains a portion of our energy transition. We might call it, for instance, the era when we hoped our suspicions were wrong.

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5

Assessing Renewable and Alternative Energy Technologies

By the end of the 1970s and 1980s, Americans were ready to look again at methods of producing energy and possibly to reconsider their use of alternative energy. Although a transition and redefinition began during this era, it did not overtake the culture of Americans' high-energy existence, mostly due to the cheap energy prices of the 1990s and early 2000s. In this chapter, we survey various methods for creating alternative energy, and bring its development up to the present.

To properly define our terms, let's begin with the fact that all forms of renewable energy, except geothermal and tidal, are variations of solar energy. Their existence requires energy from the sun. Classic solar energy can be used to generate electricity or to provide heat and warmth. But solar energy can also be absorbed by the Earth's atmosphere to produce wind. Wind energy results from the movement of air masses, due to the air being heated and expanded by sunlight. The various forms of Biomass energy result from the growth of plants that require sunlight for the plants to grow in the first place. Hydro-energy is a result of rainfall, which is caused by the natural evaporation of water from the heat of the sun. Ocean Thermal Energy Conversion (OTEC) is the extraction of heat energy from the warm surface waters of the ocean that are warmed by sunlight. In addition, energy conservation should also be considered a source of renewable energy.

In addition to renewable energy sources, there are a few alternative non-renewable energy sources that are not currently utilized fully in the United States. Among these are oil sands, oil shale, and nuclear fission. Although each of these has vast resources in North America, they are not renewable and will eventually be depleted. All three produce substantial amounts of pollution that must be captured and remediated in order to protect the environment. Nuclear fission is unique in that it does not produce any CO_2 or other atmospheric pollutants. In addition, it has been well demonstrated for over 50 years that the high-level radioactive waste from nuclear fission can be captured and stored with no damage to the environment (Deutch, 2009). On the other hand, oil sands and oil shale are alternative energy sources in name only. When compared to traditional fossil fuels, both oil sands and oil shale produce more CO_2, more other types of atmospheric pollutants, and a higher use of fresh water. And unlike nuclear fission, the ability to capture, store, or otherwise remediate the pollution generated from oil sands and oil shale energy sources has yet to be demonstrated.

Renewable energy is, by definition, replenished on a regular basis. In addition, renewable energies (including nonrenewable nuclear fission) do not contribute to global climate change because they don't increase the amount of carbon dioxide in the atmosphere. Most renewable energy is generated without emitting any water or air pollutants. Biomass is an exception to this rule, because it emits a similar amount of pollution as some fossil fuels, but still no direct emission of CO_2. However, biomass may result in massive emissions of CO_2 if displaced food crops are grown in deforested regions.

The two renewable exceptions of geothermal energy and tidal energy owe their existence to the origins of the universe. Tidal energy comes from the motion of the Moon around the Earth. Geothermal Energy comes from the heat generated deep within the Earth from the decay of naturally radioactive ore, which exists in small concentrations within the Earth. Although these energy resources are not being replenished, they will still last a billion years, and are therefore usually put into the renewable energy category.

Every form of renewable energy comes with its own advantages and disadvantages. More importantly, each form of renewable energy entails some type of negative environmental impact, which will be discussed below. In most cases, the environmental impact from a renewable energy source is less damaging than that from a fossil fuel source. Thus, a renewable source would be more desirable. Unfortunately, until recently, most renewable energy sources were considerably more expensive to utilize than traditional fossil fuels. Thus, more expensive renewable energy sources could only be justified using the reduced environmental impact or by considering the indirect financial cost of the environmental impact from a fossil fuel. However, in some cases today, a renewable energy source is less expensive than a traditional fossil fuel. When the indirect costs of fossil fuels are added to today's energy prices, most renewable energy sources are much cheaper.

BIOMASS ENERGY

Biomass energy is the result of the conversion of sunlight into usable energy. Plants absorb energy from the sun as they grow. That energy can then be extracted as the plant mass is either burned or converted into a more convenient liquid (ethanol) or gaseous (methane) fuel similar to gasoline or natural gas. Thus, biomass is really just an indirect form of solar energy. The most important advantage of biomass energy is that it is well suited as a direct petroleum substitute that can fuel all forms of transportation without major modifications to existing transportation technologies. Just recently in 2006, the biomass sector surpassed hydropower, making biomass the most utilized renewable energy in the United States.

Biomass is a renewable energy source because each year the plant life which biomass depends upon is renewed in a new growing season. During the growing season, while the plants are absorbing energy from the sun, they are also fixing carbon from the atmosphere into the plant mass. When the plant mass has its energy extracted, this carbon is then released back into the atmosphere. When averaged over one or several years, the amount of carbon emitted is balanced by the amount of carbon that is absorbed. Thus, biomass energy, in theory, does not contribute to global climate change, and it is considered CO_2-neutral.

Unlike other renewable energy sources, biomass is not pollution-free. In fact, the pollution from many biomass sources can be significant. Ethanol and biodiesel both emit the same type of pollutants (except for CO_2) as their fossil-fuel companions. Wood-burning stoves, pellet stoves, and corn stoves release more pollution (other than CO_2) than natural gas furnaces, but less than coal stoves. When biomass involves the growth of crops specifically for the energy market, then the water pollution and soil degradation of the farmland become real issues. Furthermore, a new problem has emerged recently in the world crop market. Since 2006, research now shows that farmers in the United States who switched crops from soybeans to corn for the ethanol market, or grew their soybeans for biodiesel rather than food, created a decrease in the world supply of soybeans (Laurance, 2007). This supply loss was then replaced by new soybean production in countries such as Brazil and Indonesia, where the crops were then grown on land that was stripped of tropical rain forest. The great irony of this is that cutting down an acre of tropical rain forest results in more carbon emissions than are offset by the ethanol production from one acre of corn or any other food crop (soybean, sugarcane, etc.) (Fargione, 2008).

Biomass crops should not be considered renewable, unless they are grown in a sustainable manner and on land already void of productive forests. Even when biomass crops are grown in one region in the most environmental and sustainable manner, this does not preclude the fact that the displaced food crop will be grown elsewhere in the world using the worst non-sustainable methods, or even on cleared tropical rainforest land. When this happens, the carbon footprint of such clean biomass fuels is far greater than the dirty fossil fuels they were meant to replace.

Ethanol and Biodiesel

For much of the previous three decades, since 1974, biofuels were dependent on government incentives to keep production and further research plodding along, since biofuels were not cost-competitive when compared to traditional fossil fuels. Ethanol was seen mainly as an additive to be used in small quantities. It could be used as an octane booster and as a gasoline oxygenator so that the reformulated gasoline would burn more cleanly. However, today ethanol is viewed differently, as a fuel in its own right, which can be used in mass quantities. Ethanol is now often considered a pathway for the United States to become less dependent on foreign oil, as a solution to the diminishing supply of petroleum, and as a renewable fuel that reduces carbon emissions.

Ethanol is an alcohol that is produced by the fermentation of sugar. This sugar can come from a variety of plant feedstocks such as sugarcane and sugar beets, or from starchy foods such as corn. Ethanol production in the United States mostly uses corn feedstock. However, in other nations, much higher energy yields are achieved using other feedstocks such as sugarcane and beets. Some of those feedstocks are not practical for use in the United States, while others are not used for other reasons. Sugar can be fermented directly, whereas starch must first be broken down into sugar, using enzymes. The alcohol is then distilled and dried to increase its purity. Each of these steps, including the planting, tending, and harvesting of the crop itself requires energy input. At the farm, the energy inputs are diesel fuel for tractors and natural gas for manufacturing fertilizer and herbicides. At the ethanol plant, the energy input may be coal, natural gas, or even methane. Methane is used at some plants that have combined ethanol production with animal feedlots, in which the methane is produced from animal waste.

Ethanol production today has a positive energy balance. That is, the process yields about 30–50 percent more energy than it consumes. Interestingly, since petroleum represents only about 17 percent of the energy that goes into ethanol production, most of the energy inputs are domestic energy sources for the United States, like coal and natural gas. Thus ethanol is effectively a way to convert smaller amounts of coal and natural gas into larger amounts of liquid ethanol for transportation use (Shapouri, 2004). However, there are still issues about where and how displaced food crops are to be grown either in the United States or elsewhere in the world.

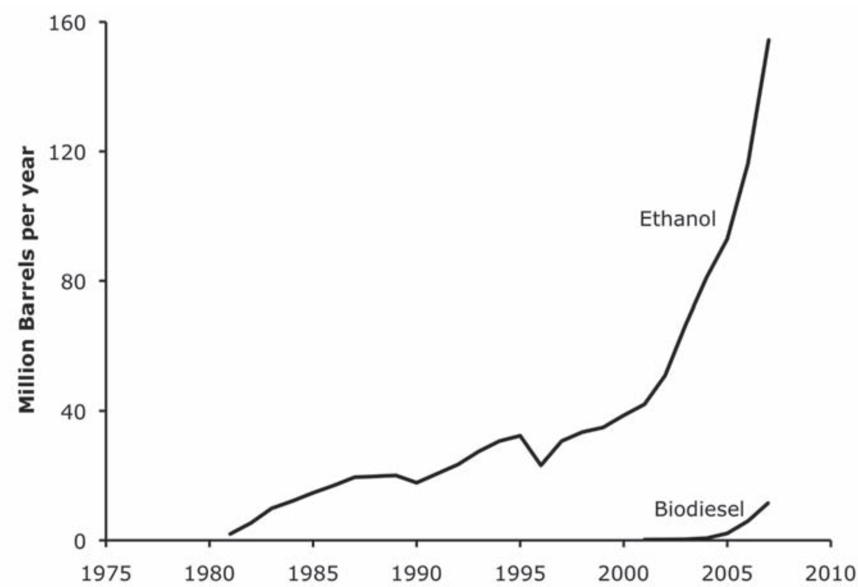
For most of the past three decades, ethanol was dependent on government incentives to keep its production profitable. However, when the price of gasoline rose above $2.25 in 2005, ethanol suddenly became cost-competitive with gasoline. Another significant boost from the petroleum industry started in 2000, when one of its preferred additives (methyl tertiary-butyl ether (MTBE)), a suspected cancer agent, began turning up in aquifers. As states moved to ban MTBE, ethanol was found to be an adequate replacement, which suddenly created a two-billion-gallon per year market for it by 2007. In addition, the first decade of the 21st century saw Congress extend tax credits and tariffs for ethanol while requiring that 7.5 billion gallons of the nation's fuel come from biofuels by 2012. Many politicians are trying to push that figure even higher, to 35 billion gallons by 2017 (Bush, 2007) or to 60 billion gallons by 2030 (Obama, 2008).

The growth in the American ethanol market has been profound. For instance, by the end of 2008, Nebraska's 16 ethanol plants consumed approximately one-third of the state's crop. As an energy resource and not just a feed crop, though, corn prices doubled. In addition to its use across the United States as an additive, approximately 1,200 stations, scattered mostly across the Corn Belt, sell ethanol in the form of E85 (85 percent ethanol, 15 percent gas), which can be burned in specially designed engines (these engines are commercially sold as Flex-Fuel models). Ethanol delivers 30 percent fewer miles per gallon than gasoline; however, even with a lower energy content, it has remained competitive with gasoline in recent years. Obviously, more and more ethanol plants will be appearing throughout the American corn belt.

In 2006, when it appeared that gasoline prices would stay above two dollars per gallon and would likely be even much higher, ethanol became a bargain. Since much of the technology had already been thoroughly developed during the preceding two decades, all that the biofuels market needed to blossom was an influx of investment. This investment came, and the industry boomed around 2006 (see Figure 5.1). Farmers realized that they could make much more profit growing grain for the biofuel feedstock market than for the traditional grain markets (food, feed, and sweeteners). This then led to the unintended consequence of increasing the price of all grains, which has now led to an inflationary impact on food prices. This was true not only for grain-based foods such as bread and cereal, but also for dairy and meat products produced from grain-fed animals.

Surprisingly, the success of the biofuel industry has had an adverse effect on itself. Many small ethanol plants that sprang up all over the corn-belt were

Figure 5.1
Growth in Ethanol and Biodiesel Production in Recent Years



Source: U.S. Energy Information Administration.

profitable in 2006 and 2007. These small plants, which were quick to build and begin operations, used natural gas as a source of heat to process the bio-feedstock. Much larger plants, which were slower to finance and construct, used coal to process the bio-feedstock. Now that the demand for corn has increased, the price for the corn-based feedstock has subsequently increased so much that these natural gas plants are no longer competitive with the large coal plants. As a result, many of these smaller ethanol plants are now closing.

Ultimately, for the United States to obtain a large fraction of its energy from biofuels, the growing of bio-feedstock must be increased dramatically. Very large-scale production of biofuels is hampered by the availability of land that can be farmed sustainably. For example, the United States currently has 442 million acres of farmland (see Table 5.1). Assuming a yield of 500 gallons of biofuel per acre, which is the highest yield using current technology, the United States would need 460 million acres of farmland just to replace the 230 billion gallons of transportation fuel (gasoline, diesel, jet fuel, etc.) that is used today. Sure, this can be done, but it will require an increase in farmland and the elimination of all food production. We would all starve.

Creating massive amounts of additional farmland is not necessarily a good option either. Mountainous forests are physically unsuitable for farming, and

Table 5.1
Land Use in the United States

Land Use Category		*Millions of Acres*
Crop		442
Forest		651
Grassland pasture and range		587
Special use (mostly parks and wildlife)		297
Urban and residential		60
Miscellaneous others		228
	Total U.S. land	2,300

Source: U.S. Economic Research Service

in terms of CO_2, it is more harmful to cut down a forest to plant a biofuel crop. An acre of land may be used to yield 500 gallons annually of carbon-neutral biofuel, but an acre of healthy forest can absorb and sequester the carbon equivalent of 1,000 gallons of gasoline. Thus, it would be better to use fossil fuels and to sequester that carbon by planting new forests than to cut existing forests to grow biofuel crops. Even if forests are not cut down for additional cropland here in the United States, forest may be cut down elsewhere in the world, since food is very much a commodity traded on in the world market. Indeed, this is precisely what has happened in recent years!

Of course, the forest is also very important ecologically, and there are other land-use issues at stake. Grasslands and pastures are not used for farming, because their soil and annual rainfall will not sustain crop production. In addition, it is believed that a large amount of current U.S. farmland is already being farmed in an unsustainable manner, which worsens not only the future of biofuels, but also of food production.

These considerations have led pilot projects in the United States to experiment with making ethanol from cellulose, acquired from non-crop biomass (switchgrass and wood). One ton can be converted into 70 gallons of ethanol in about a week. A primary difficulty in processing these grasses is ridding them of lignin, which binds the cellulose molecules together and gives plants the structural strength to stand up and catch the sun. Lignin also makes plant matter hard to break down in chemical processes; therefore, processors first treat the feedstock with heat and acid. Enzymes then break down the cellulose into sugars. Some companies are using proprietary biotechnology to break down the cellulose without the use of acids, enzymes, or heat; and they report success in the laboratory. Efficiencies in the laboratory are being reported that are much greater than those achieved for making corn-based ethanol, but these methods will need to be evaluated more completely once they are in commercial production.

Nonetheless, if this technology is put into large-scale use, non-crop biomass feedstock can be grown on land without displacing current crops. Furthermore, switchgrass and fast-growing trees can also be grown with a much lower environmental impact when the actual planting, tending, and harvesting procedures are taken into account. But land will still have to be used, and the impact of that use on the ecosystem must be considered.

Perhaps the only way for biofuels to ever be used on a grand scale is to use a different feedstock that can be grown under very different conditions. This feedstock is specially bioengineered algae, which can be grown using wastewater or saltwater, even in desert or ocean locations where land use is not such a problem (Chisit, 2008). This is currently being tested in holding tanks, and there are commercial-scale operations currently under construction. Like cellulosic technologies, algae technologies are also proprietary, and will need to be independently analyzed for their energy balance and environmental impact. But if initial reports are correct, algae-based biofuels grown in an area the size of the Mohave Desert could provide all the motor fuel currently consumed in the United States.

Methane and Other Waste Products

Even if ethanol and biodiesel are not possible on the grand scale, there are other, less-glamorous, biomass applications that will continue to thrive. Methane, which is used as a replacement for natural gas, can be made using anaerobic digestion of animal and human waste (excrement). During this anaerobic digestion, the waste is contained in a large tank and allowed to decompose without oxygen from fresh air. Bacteria work on the waste at a maintained temperature, and methane is collected. This is most commonly done by dairy farms and feedlots using animal waste, but it can also be done by city sewage treatment facilities using human waste. The methane is then used by the farm or city as a source of clean renewable energy, or sometimes added to existing natural gas pipelines and sold to utility customers.

The primary reason for a farm digester is not just to produce methane. A significant problem and expense facing large dairy farms and feedlots is the disposal of animal waste. By collecting and digesting the animal waste, a dairy farm can both cut expenses and make their own energy at the same time. Some cities will also digest the human waste collected from sewer systems to produce methane. The energy produced can then be used to offset the cost of maintaining the city's sewer system.

Other applications of biomass energy serve a similar dual-purpose role. When a paper mill uses wood pulp to make paper, it must also heat a great deal of water. Natural gas used to be the fuel of choice for heating this water, but as natural gas prices have increased, this has become very costly. Paper mills have now discovered that they can just burn the wasted wood, parts of a tree not useful for wood pulp, to heat the water. As an added bonus, the paper mill does not have to pay to haul away and dispose of the wasted wood. Thus, the mill solves three problems simultaneously: it saves money on energy costs, saves money on disposal costs, and helps the environment all at the same time.

SOLAR ENERGY

Solar energy can be harvested in four different ways. First sunlight can be converted directly into electricity using photovoltaic panels. Secondly, sunlight can be collected and used to heat water or air with the use of a solar thermal collector. Solar thermal electricity can be generated by concentrating sunlight to boil water that can then be used to generate electricity with a steam turbine. And lastly, passive solar energy is possibly the most underrated form of energy in use today. Simply by altering the design of buildings, one can maximize the amount of sunlight shining through windows to passively heat the building during winter.

Solar energy is available everywhere on the planet. The only difference between various locations is the amount of solar energy received on an average day. Solar technology costs the same, regardless of how sunny it might be. And since a given solar panel or collector will produce more energy when it is used in a sunnier location, there are some places where solar energy makes more economic sense compared to other locations. Solar energy is abundant enough to easily provide all the energy demands for both the United States and the world in general. All four methods of collecting solar energy are pollution-free, emit no CO_2, and in most cases use no fresh water.

Photovoltaic Solar Energy

Photovoltaic (PV) panels are the most sought-after solar technology. These panels can be installed anywhere that receives sunlight. When installed for electric consumers, PV panels will offset the amount of electricity that must be purchased from the utility, and it is even possible to reduce the annual electric bill to zero, except for a monthly customer charge.

Photovoltaic installations currently run about $8 per watt for an installed system. At this rate, they are not cost effective, except for off-grid applications.

However, in many locations, local, state, and federal incentives are available to reduce the cost of a solar installation. In some locations, these incentives will reduce the cost to as little as $2 per watt. With these large incentives, solar photovoltaic can actually provide electricity at less than 10 cents per kWh, making solar cheaper than paying the utility company. It is a wonder that more people are not switching to solar in these states.

In the very long term, prices for PV panels and equipment should continue to fall, and the price for electricity should continue to rise. Thus, solar PV technology will become cost effective in a greater number of locations. A second reason why solar PV energy will probably ultimately become the energy choice of the future is one of efficiency coupled with diminishing land resources. Photovoltaic panels currently have efficiencies of about 15 percent. This may not seem very high, but it is extraordinarily efficient when compared to other ways of converting solar energy into useful electricity, or fuels such as ethanol. In a good location, using current technology, one acre of solar PV can produce 1.3 million kilowatt-hours of electricity per year. To generate the same amount of energy, a biofuel technology would need to produce around 50,000 gallons of fuel per acre, which is far more than is possible in the foreseeable future. Because of this high efficiency, PV also has the lowest land use requirements of the four primary renewable energies of wind, solar, biomass, and hydroelectric, not to mention a lower land use than even fossil fuels. As spare land for growing much less efficient biomass becomes scarce, the higher price for solar PV technology will seem like a bargain.

Solar Thermal Collectors

Solar thermal collectors are usually used to supply hot water, which makes up 10–15 percent of a home's energy use and can be the primary energy expense of some commercial and industrial users. But thermal collectors can also be used to provide space heating even in very cold climates. Model homes have been built designed to use 100 percent solar heating in places like Vermont, Chicago, and Edmonton (Canada), which are pictured below (see Figure 5.2). Some of these homes can even be built so that they are cost effective without government subsidies; however, subsidies are usually required for such net zero-energy homes. Even if a home cannot be heated year-round, it is possible to substantially offset the amount of other energy required to heat the home.

There are three basic types of solar thermal collectors, depending on the climate and the desired hot water temperature. The cheapest collectors are unglazed collectors, which are mainly used to heat pool water. For domestic hot water, glazed flat-plate collectors and evacuated-tube collectors are used.

Figure 5.2
Model Net-Zero Solar Homes
(a) Riverdale NetZero Project (www.riverdalenetzero.ca); (b) Avalon Discovery 3 Home (http://www.avaloncentralalberta.com/html/build_green/discovery_3_design.php)

Source: Photographs provided by Gordon Howell.

Both of these are capable of heating water to 125°F or even much hotter, and the selection between them usually depends on the climate. Glazed flat-plate collectors do not work as well on cold days as evacuated-tube collectors, which can efficiently heat water to over 125°F even when the outdoor air temperature is well below freezing. However, since evacuated-tube collectors are more expensive, they tend to be used only in climates that are frequently exposed to below-freezing temperatures. Glazed flat-plate collectors are ideal in warmer climates.

In most areas of the country, a solar hot water system can be installed for $4,000–$8,000, excluding state and federal incentives. A federal incentive reduces this by 30 percent, and state incentives can reduce this even more. The average home spends about $300–$400 annually on hot water and about 75 percent of that can be provided with a solar system. Thus, when incentives are included, a solar hot-water system can usually pay for itself in less than 10 years. In the worst of locations (from New Hampshire to Michigan) and with no state or local incentives, it will take 15 or 20 years to pay for itself.

Passive Solar Energy

Passive solar energy is mainly used to contribute to the heating of a home. Any home with a south-facing window that receives sunlight uses passive solar. A properly designed modern window will allow more heat to pass into the home on sunny days than it allows to escape at night and on cloudy days. By doing this, the heating requirements of a passive solar home can be substantially reduced. Designing such a home does not need to cost more either. Passive solar homes are usually oriented with a main wall facing southward, have more windows on the south side, and fewer windows on the north side. Passive solar does not require the use of any pumps, fans, or other mechanical or electronic equipment, and thus there is nothing to maintain or to be repaired.

A very successful passive solar home will have large windows facing south or nearly south that are not shaded, except possibly for the first and last hours of a day. It is helpful for the home to have dark walls or floors that will absorb the sunlight that passes through the windows. In order to store this heat after the sunlight is gone and to moderate the amount of temperature rise during sunny hours, thermal storage is needed. The easiest way to build thermal storage into a home is to use thick masonry floors, walls, or room partitions. If the sun can shine directly on this masonry during the day, it will warm up during the day, absorb excess heat, and then give off this heat at night. Since some rooms will not be able to have a southerly exposure, there also needs to be some distribution of heat throughout the home to prevent one side from being much warmer than the other. This can usually be accomplished with natural airflow in a well designed home. In order to prevent a passive solar home from overheating during the summer, it is necessary to shade the windows. This can be accomplished with properly designed roof overhangs, awnings, or properly sized and located deciduous trees.

Solar Thermal Electricity

The most economical industrial application for solar energy is the thermal production of electricity. For this, an array of mirrors is usually used to concentrate sunlight on either a pipe of water or a tank of water to heat it and produce high-temperature steam. This steam is then used to produce electricity, just like the steam from a coal or nuclear power plant. Solar thermal electricity has evolved such that it is now about 10 cents per kilowatt-hour, compared to an average wholesale price from other sources of about 5 cents per kilowatt-hour. The price of solar thermal electricity continues to fall as technology improves, and will be competitive with traditional fossil fuels within the next decade. If any type of carbon tax is imposed on fossil fuels, solar thermal may immediately become competitive.

Solar energy can only be collected during daylight hours. However, the scale of solar thermal electricity lends itself to the short-term storage of solar energy. This works by collecting excess solar energy during the daytime and storing this energy by heating up a very large tank of special salt or oil. This tank becomes very hot, and the heat can then be extracted during evening hours when there is still a demand for electricity. This storage method is only practical for a few hours' worth of electricity. Electricity is in highest demand from about 8 A.M. to 10 P.M. Since the sun does not shine this late in the day, being able to store a few hours' worth of electricity means that solar energy can be used to meet peak power demands after sunset. Solar energy may still not be available on cloudy or rainy days. But in air-conditioning-dominated climates, electricity requirements are not as great on cloudy or rainy days either.

WIND ENERGY

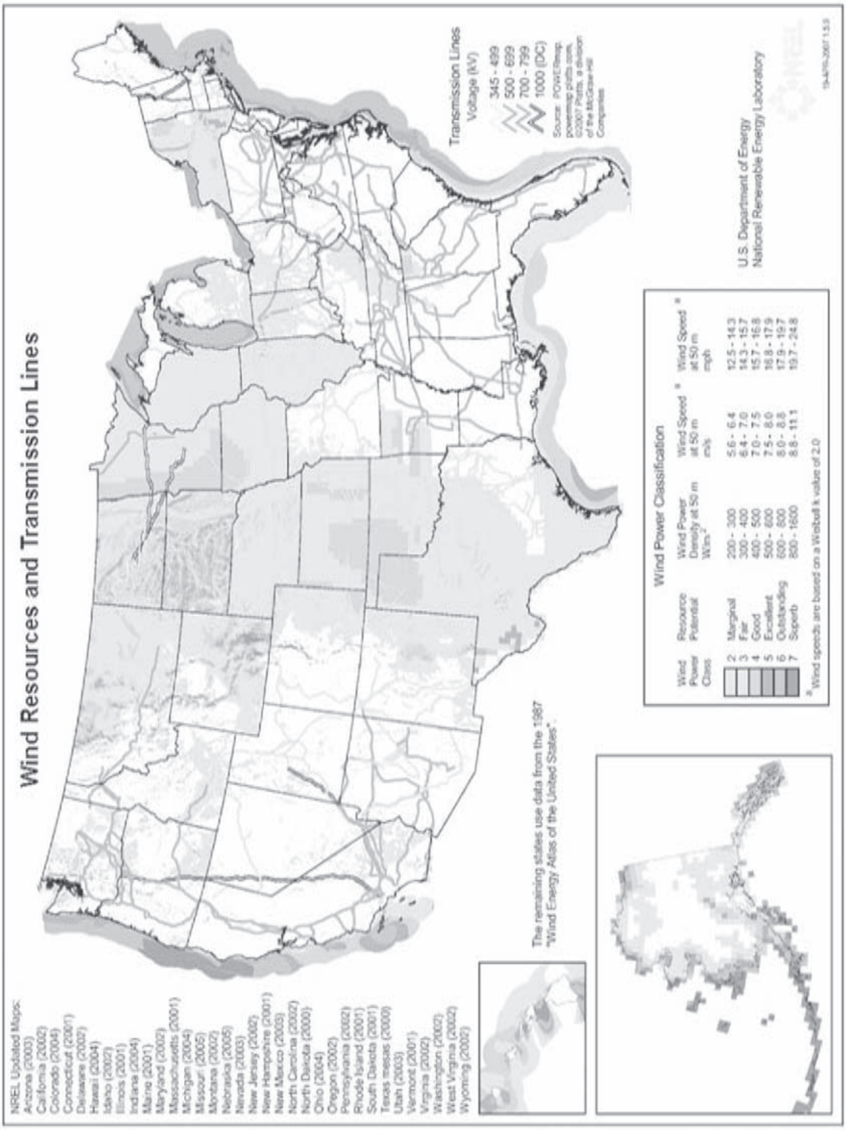
When the sun shines on various parts of the earth, the air in those areas is warmed and expanded. This expanding air is what we call wind. A wind turbine is a device that transforms the kinetic energy of this moving air into electrical energy. Modern wind energy is used only to generate electricity, and is limited to only the times when the wind blows. There are methods to store energy from windy times so that the energy can be used when the wind is not blowing, but this is rarely done due to the added cost. Currently, wind energy can be produced for less than five cents per kilowatt-hour (kWh), compared to the average electricity cost of five to six cents per kilowatt-hour for fossil fuels. This makes wind very competitive in locations with good wind resources, which is why there has been a marked increase in the use of wind energy in recent years (see Figure 5.3). In less windy locations, it is not as competitive with traditional fuels.

Not every part of the United States has the same potential for developing wind energy, as shown in Figure 5.4. Furthermore, in some mountainous locations, the suitable areas are limited to ridge tops and nearby sites. Wind turbines can be installed at less suitable locations, but will yield less, and the electricity that is produced will cost more. The efficiency of wind turbines has been shown to increase as the size of the wind turbine becomes larger. Current utility-scale wind turbines sit atop towers 100 meters tall or more, and have blades that are 100 meters in diameter. Such turbines generate about 2 megawatts (MW) of electricity with a duty factor of about 25 percent. A duty factor is a measure of what percentage of time the generator is running at full capacity. This 25 percent duty factor is like running at full capacity one-fourth of the time, and being stationary three-fourths of the time, but in reality, the wind turbine will turn at less than full capacity most of the time and will rarely be stationary in a good location.

At this rate, about 1,500 wind turbines are needed to replace a typical, large coal-power plant (1,000 MW). Some argue that due to the land requirements of 1,500 wind turbines compared to that of a single coal plant, wind farms are a poor use of land. However, such a comparison ignores the vast amount of land required by the coalmines and transportation infrastructure necessary to fuel just a single coal power plant. In addition, wind turbines can also be erected in locations where the land use is shared with farming, grazing, or even commercial and industrial uses

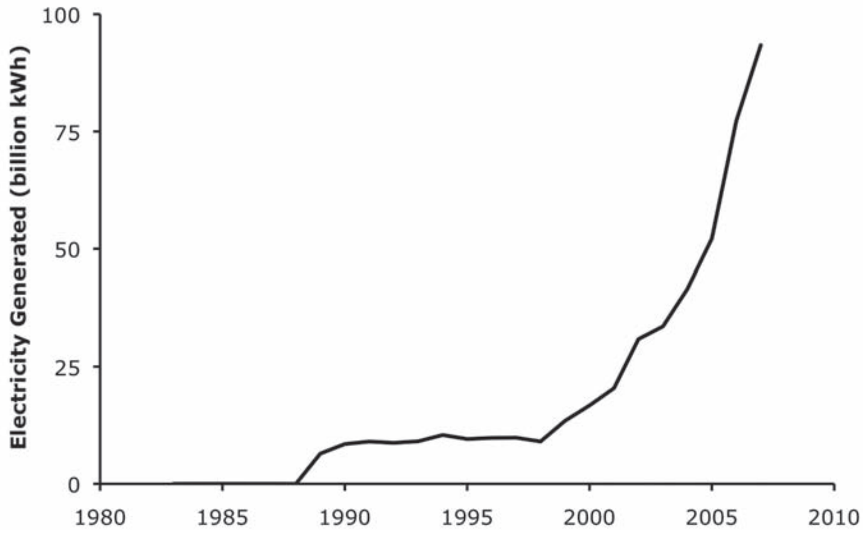
For the individual, a small-scale wind turbine (under 20 kW) may also be cost effective. The unit cost of small wind turbines, at about \$4–\$6 per watt, is much more than utility-sized wind turbines, which cost about \$1–\$1.5 per watt to install. However, since a small-scale wind turbine generates electricity for the consumer, which is valued at the retail price instead of at the wholesale price, this higher installation cost can still pay for itself under certain circumstances. When financed over 20 years and installed in a very good location, small-scale wind turbines can generate electricity at about 25 cents per kilowatt-hour. This is not cost effective, but when combined with federal tax credits, this is reduced to 17 cents per kilowatt-hour, and some state incentives will reduce this by even more. For example, in New York, the post-incentive cost to the homeowner can be under 10 cents per kilowatt-hour, which is

Figure 5.3
Wind Resource Map for the United States



Source: U.S. Energy Information Administration.

Figure 5.4
Wind-Generated Electricity in the United States



Source: U.S. Department of Energy, National Renewable Energy Laboratory.

cheaper than retail electricity. In any situation, producing ones own electricity is a great way to be protected from rising energy costs in the future.

Since wind energy has become cost-competitive with current fossil-fuel technology (coal and natural gas), there has been a surge in the number of wind farms that have been constructed in the United States. Wind energy produces no CO_2, no air pollution, and no water pollution. Wind turbines do produce some noise pollution, which may be a concern to adjacent homeowners; and they are said to be an eyesore to some, while beautiful to others. But there is much conflicting information about the severity of this noise pollution, the aesthetics of the wind turbine, and the affect on adjacent properties' value. Wind turbines are known to kill bats, although the reason for this has yet to be found. When located in the Allegheny Mountain highlands (Pennsylvania and West Virginia), each turbine kills an average of 50 bats per year, whereas a wind turbine in the plains states kills about 5 bats per year.

Unfortunately, wind turbines are often criticized for several unfounded reasons. It is often said that wind turbines kill substantial numbers of birds by striking them in mid-air, but it is now known that fewer birds are killed by wind turbines than by many other man-made objects, such as cars, houses, and other structures. In fact, less than 0.01 percent of bird deaths related to man-made structures are attributable to wind turbines.

In North America, wind can supply a very large amount of energy. It is estimated that wind turbines located across farm and grazing land in North America could generate all of the annual electricity used in North America. The problem with such a broad estimation is that the generation of this energy is not at the same location as the demand. This electricity can be transmitted to where it is needed, but the current national grid would need to be expanded considerably. In addition, weather does not always coincide with the demand for electricity. Thus, if it is not windy on a hot summer afternoon, those relying solely on wind energy from one particular region will find themselves without air-conditioning. However, this problem could be partially mitigated with an expanded national electric grid, since it is usually windy at least somewhere on the continent.

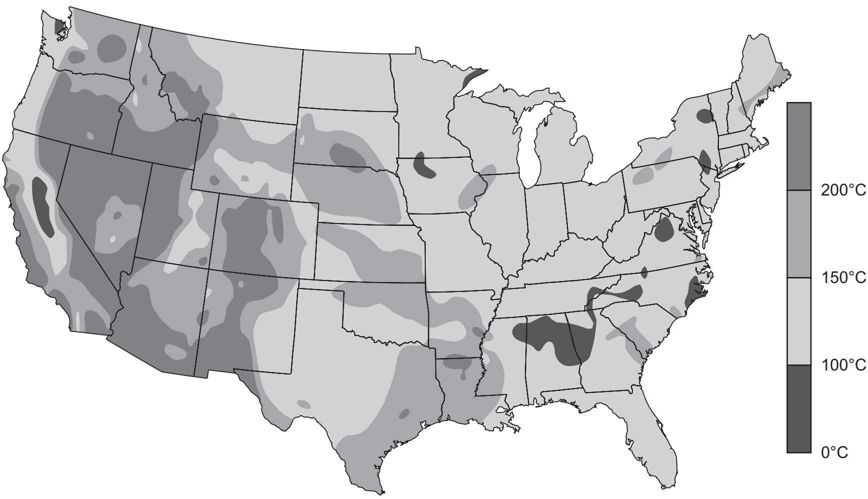
Using the current electrical grid, it is estimated that wind energy can only be used to provide 20 percent of the electricity demands of the nation, or only about 10 percent of the total raw energy consumed in the United States. Wind currently provides only about 1 percent of the nation's electricity, but that number has been increasing at an annual rate of over 25 percent. At this rate, wind energy could reach the 10 percent threshold by 2020. Beyond this threshold, an updated electrical grid would be required.

GEOTHERMAL ENERGY

Geothermal energy is a possible energy source of vast proportions. To extract geothermal energy, holes are drilled into deep rock strata in which the ground temperature is high. At least two holes are needed. Water is pumped down one hole, heated by the rock below into steam, and the hot steam escapes through the second hole. This steam is then captured at the surface and used to power a steam turbine to generate electricity. To produce more electricity, one needs simply to pump more water into the ground. Unfortunately, if too much water is pumped into the ground too quickly, the hot rock strata will be cooled off, and eventually the entire site will have to be abandoned for many years. Also, the underground rock structure must be fractured in some way so that the water can migrate from the injection hole to the steam hole.

Like solar and wind, geothermal energy could easily provide all the energy needed in the United States. Also like wind and solar photovoltaic, geothermal energy would mainly produce electricity. Unlike most renewables, geothermal has the distinct advantage of being able to produce electricity on demand anytime of the day or night. However, geothermal is also more geographically limited than either wind or solar, as seen in Figure 5.5. Thus, for geothermal to be anything more than a West Coast niche power resource, a vastly expanded national grid would be needed.

Figure 5.5
Geothermal Resource Map for the United States



Source: U.S. Department of Energy, National Renewable Energy Laboratory.

Geothermal electricity does not emit any CO_2, and since it is renewable, it will never run out. Some geothermal plants require the use of water, which may soon become a precious commodity. Or in some plants, wastewater is injected into the ground instead of fresh water. In some cases, geothermal releases pollutants such as sulfur oxides, which are the primary cause of the pollutant acid rain. But there are also plant designs that do not result in these emissions.

Currently, less than 0.5 percent of the electrical energy used in the United States comes from geothermal, and the growth of geothermal has stagnated over the past decade. Current installation costs are comparable to wind energy, which should make geothermal cost-competitive with fossil-fuel energy sources; however, geothermal receives less than four percent of the federal incentives that wind receives. Any type of carbon tax or incentive equivalent to that which wind receives will make geothermal even more competitive. Thus, time will tell whether the use of geothermal energy follows the same growth trend that wind currently enjoys.

Geothermal can also be used in a very different way for heating systems. Instead of extracting heat at a very high temperature (>100°C) heat can be extracted at a low temperature (<20°C) to assist an electric-powered heat pump for space and water heating. In many areas, this is the most economical way to heat a home or business. (See the Energy Conservation section below for more discussion).

HYDROPOWER

Hydropower has traditionally been referred to as hydroelectricity. Traditional hydroelectricity results from the construction of a dam that blocks and stores river water for a variety of purposes. More recently, hydropower has been extracted from ocean tides (tidal energy) and from freely flowing rivers and tidal basins (hydrokinetic energy).

Traditional Hydroelectricity

Hydroelectricity has been used successfully for many decades and provides about 2.5 percent of all the energy used in the United States. But with few exceptions, hydroelectricity in the United States and worldwide is a byproduct of projects designed mainly to control floodwaters, provide reliable fresh water, and to provide areas of recreation.

Hydroelectricity works by having a dam that stores water at an elevated position. The water pressure created by the lake then pushes water through a turbine located at the base of the dam to generate electricity. Since the flow of water can be controlled, it is possible to control when the electricity is generated. And since the lake can store a massive amount of water, electricity can also be generated in times of dry weather.

Some dams are large, such as the Grand Coulee Dam, which has as its primary mission the storing of irrigation water for the Pacific Northwest. But most dams in the United States are much smaller, such as the Raystown Lake Dam in Pennsylvania. This dam's primary purpose is to control floodwaters, and thus the generation of electricity is strictly limited to when flood-causing weather conditions dictate that water be released from the lake. Even if there is a shortage of electricity in the region, this dam is forbidden to release extra water unless allowed by weather conditions. Financially, dams are so costly to construct that they are not competitive with other sources of energy. Thus, only by providing other uses to society, such as flood control and fresh water, can the cost of a dam be validated.

Hydroelectricity emits no pollution or CO_2, but they have a very large impact on the local ecosystem. Vast amounts of land must be submerged, and both wildlife and humans will be dislocated. Sediment tends to build up in the lake behind the dam, while erosion becomes a problem downstream. Stream and riverbank ecosystems are replaced by less diverse lake-edge ecosystems. Also, the dam itself fragments a river system's ecosystem into those above and below the dam. This has led to the disappearance of certain aquatic species such as salmon above the dam. Recreational use changes from river- and forest-based uses to lake-based recreational uses.

The United States currently generates 2.5 percent of its total energy from hydroelectricity. This amount could rise in the future, but only up to a maximum of about 5 percent. Most suitable dam sites are already being utilized, and public resistance to building more dams is strong, due to their expense and environmental impact. Thus, one should not consider hydroelectricity a significant solution to our future energy needs.

Tidal Energy

Tidal energy is used only to generate electricity. Water turbines, similar to those used in dams, are turned by the flow of seawater during the incoming and outgoing tides. To make use of this, a barrage (similar to a dam or dike) is usually built across the opening of a bay or estuary. Water then flows through the turbine from one side of the barrage to the other four times a day in an extremely predictable manner. The best locations for tidal energy are where there is a significant difference between low and high tides and where a relatively short-distance barrage can trap a very large amount of water. For example, the difference in elevation between the high tide and low tide along the Gulf of Mexico is only one foot, and along most of the East and West Coasts, it is only several feet. None of these are suitable locations for tidal barrages to be built. But this does not mean that tidal power can't be used. There are isolated locations that receive tides of more than 10 feet that could be tapped for tidal energy projects. The largest site in use today is at the mouth of the Rance River in France, which produces 240 MW (compared to 1,000 MW for a typical large power plant). A proposed site in the Bay of Fundy, Nova Scotia, Canada, could provide half of Canada's entire demand for electricity.

Hydrokinetic Energy

Similar to wind energy and tidal energy is hydrokinetic energy. Water currents are created from the natural flow of a river, by tidal action, or by wind-driven waves. In a simplified view, a wind turbine is built below water to be turned by the moving water. For river application, these turbines are submerged in deep rivers so that they don't interfere with shipping traffic. No large-scale hydrokinetic power stations have been built anywhere in the world, to date, although there are many small-scale pilot projects currently ongoing, including one in the East River of New York City. With further development, this may become a suitable source of renewable energy, and its cost will be better understood.

Tidal and hydrokinetic power are both limited to production along coastal areas, but that electricity can be transmitted long distances inland using an updated national grid. Hydropower from tides is only produced at certain times of the day and doesn't always match the electrical demand of society. In contrast, hydrokinetic power from rivers is produced steadily all day. Both types of hydropower also interfere with free-flowing ship traffic, which must then be routed through locks, or around and over submerged turbines.

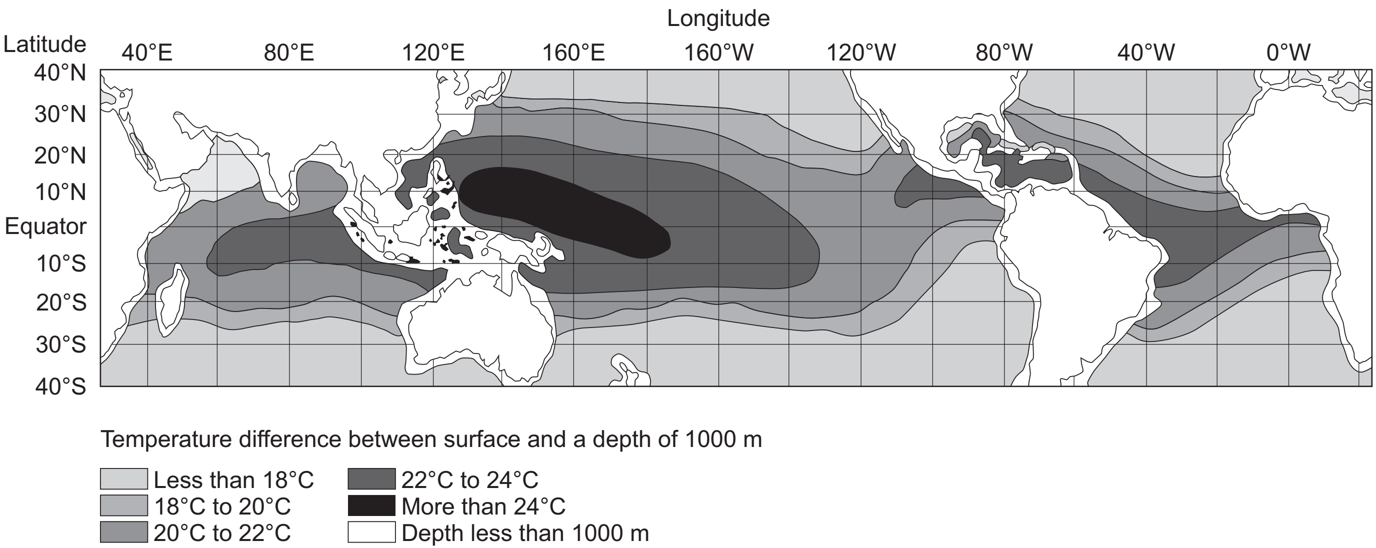
Tidal and hydrokinetic energy are pollution-free and emit no CO_2. However, they do have an impact on the ecosystem similar to that of dams, but not quite as severe. Tidal projects utilizing a barrage will fracture a bay's ecosystem and change the species that tend to thrive. Ocean species will be less prevalent, while river species will thrive. Some fish will be killed by trauma from the water turbines, even when protective technology is utilized. Turbidity will be decreased in the bay, making the water more clear, but will also have both positive and negative effects on the ecosystem. The environmental impact of hydrokinetic energy projects in open water and in rivers is fairly unknown at this time.

OCEAN THERMAL ENERGY CONVERSION (OTEC)

Ocean thermal energy conversion (OTEC) is the concept of using the temperature difference of warm, surface ocean water and cold, deep ocean water. This temperature difference can then be used to power a heat engine similar to the steam turbines found in most large power plants. There are many problems with OTEC, such as suitable locations being far off the coast and not near major energy-consuming countries, as seen in Figure 5.6. The cost of OTEC is also unknown, since no test plants have yet to be built.

OTEC does have the advantage of being able to produce very large amounts of energy and to produce the energy on demand when it is needed. But the most serious problem is one of basic physics. The maximum efficiency of a heat engine generating electricity is dependent on the temperature of the warm or hot fluid being used. A typical steam turbine using steam that is heated to 500°C is theoretically limited to 50 percent efficiency, and in the real world, 40 percent efficiency is the upper limit for this operational temperature. The latest technology for steam turbines is pushing this temperature up to 700°C for a real-world efficiency of 50 percent. OTEC uses water that is only warmed to 25°C, and thus has a theoretical limit of eight percent. Assuming that an efficiency of 5 percent can be achieved, just to provide 10 percent of the world supply of energy would require the pumping

Figure 5.6
World Ocean Map Showing Temperature Gradients Favorable to OTEC Use



Source: U.S. Department of Energy, National Renewable Energy Laboratory.

of more than 60 trillion gallons per day of cold seawater from deep in the ocean up to its surface. This amount of water would fill the Gulf of Mexico every 10 days. The ecological harm of redistributing this much seawater is unknown. It could be either benign or immensely disastrous.

OTEC also would not produce any pollution or CO_2 directly. However, it may be a tremendous indirect source of both pollution and CO_2. A large portion of the CO_2 that is emitted into the atmosphere both naturally and by mankind is absorbed into the ocean. If not for this natural sink of carbon, the concentration of CO_2 in the atmosphere would be much greater, and the Earth would be much warmer than it is today. The amount of CO_2 that dissolves in seawater decreases as the water is warmed up. Thus, if massive amounts of cold seawater were pumped to the surface and then warmed up, the CO_2 that has been trapped in this seawater would be released, having the same effect as burning fossil fuels. Also, deep ocean water is rich in nutrients. When brought to the surface, an algal bloom may be created that will in turn cause dead zones in the ocean.

Energy Conservation

A popular old saying is "a penny saved is a penny earned." This is never truer than with energy. Although with energy, perhaps the saying should be "Energy conserved is renewable energy generated." Although this may not sound as poetic, it is just as true. The difference between energy conserved and renewable energy generated is in the cost required to do each. Even though both options have the same impact on the environment, they have very different costs. By considering a variety of examples, it is clear that in nearly all cases, it is cheaper and easier to conserve energy than to generate renewable energy. Also, a person's lifestyle does not need to suffer in order for conservation to occur. In fact, in many cases, conservation efforts will improve lifestyle.

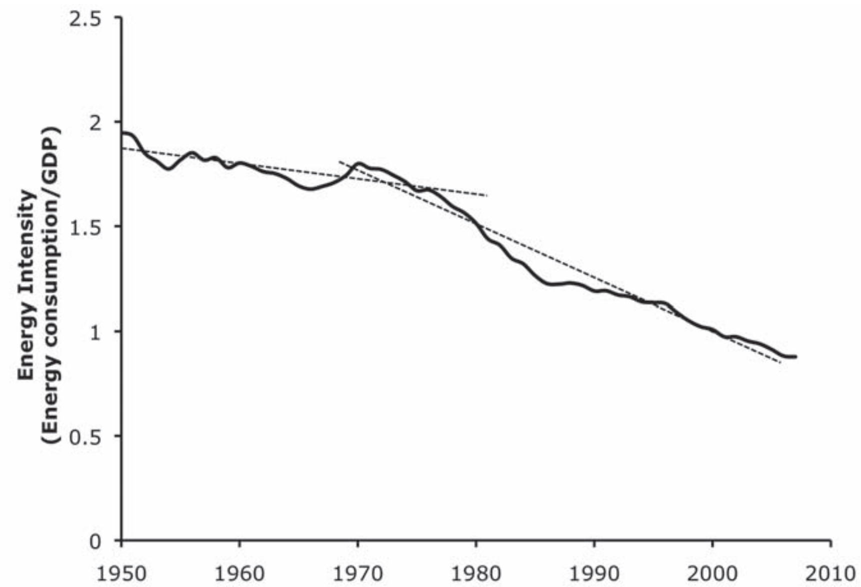
Consider a homeowner who has a home full of incandescent lightbulbs that use an average of 1,310 kWh of electricity per year (30–60 W bulbs used for an average of two hours each per day). These bulbs could be replaced with compact fluorescent bulbs (CFLs) to cut that electrical consumption down to 280 kWh per year, for a savings of 1,030 kWh per year. The conserved electricity would no longer have to be generated using fossil fuels or any other energy source, and would no longer lead to emissions of CO_2 or other pollutants. But if alternative renewable energy were used to generate an annual 1,030 kWh, the same reduction in fossil fuels and pollution would have been achieved. Even though both options have the same impact on the environment and energy independence, the homeowner will spend only \$50 for the purchase of 30 CFLs, compared to about \$4,000 for solar panels to generate a comparable amount of renewable energy. In this case, conserving energy is about 80 times cheaper than generating electricity using renewable solar energy. There are many other ways to conserve energy that are also cheaper than generating renewable energy. Alas, it is far cheaper to conserve energy than to generate renewable energy.

From the beginning of modern history, economic productivity could always be measured simply as a function of how much energy was consumed. A 10 percent increase in GDP required a 10 percent increase in total energy consumed. But in response to the energy crisis of the 1970s, much of the economic growth that has occurred since has been the result of conservation measures. Recent economic growth has occurred more from increased efficiency and conservation measures than from an increased production of raw energy. Buildings today are far more energy efficient than their predecessors 30 or 50 years ago, not just in terms of lighting, but also in terms of heating, air-conditioning, water usage, construction materials, design, and appliances. Many of these improvements have been a result of government mandates on efficiency, such as those for lighting, appliances, and low-flow water fixtures. But other improvements are the result of voluntary advances driven by market forces.

A way to measure the energy efficiency of a society is determined by the ratio between the total energy consumption and the gross domestic product. This ratio is called *energy intensity*, and a smaller energy intensity reflects a more efficient society. Since both energy consumption and GDP depend on the population size, the ratio of these two is independent of population. The energy intensity of the United States has continually decreased. Its energy intensity decreased by eight percent from 1950 to 1970. However, after the energy crisis of the 1970s, its energy intensity decreased by 35 percent, from 1980 to 2000, as shown in Figure 5.7.

As just discussed, the United States has become significantly more efficient, particularly over the past 30 years, and continues to improve each year. However, compared to other nations, the United States is still very inefficient. The United States has an energy intensity 50 percent greater than the rest of the G7 nations (Canada, France, Germany, Italy, Japan, and the United Kingdom). This indicates that there are still many more efficiency improvements and societal adaptations that can be made in the United States that have already been made in other technologically advanced nations. If the energy intensity of the United States were reduced to the average of the other G-7 nations, its energy consumption would be reduced by the equivalent of five billion barrels of oil per year, which is almost as much oil as is consumed by the United States each year. This is certainly more oil than is being imported. Using "a penny saved is a penny earned" logic, this is equivalent to building

Figure 5.7
Graph of Energy Intensity from 1950 to Present
Energy intensity is the ratio of total energy used and the GDP. GDP has been adjusted for inflation to $2,000.



Source: U.S. Energy Information Administration.

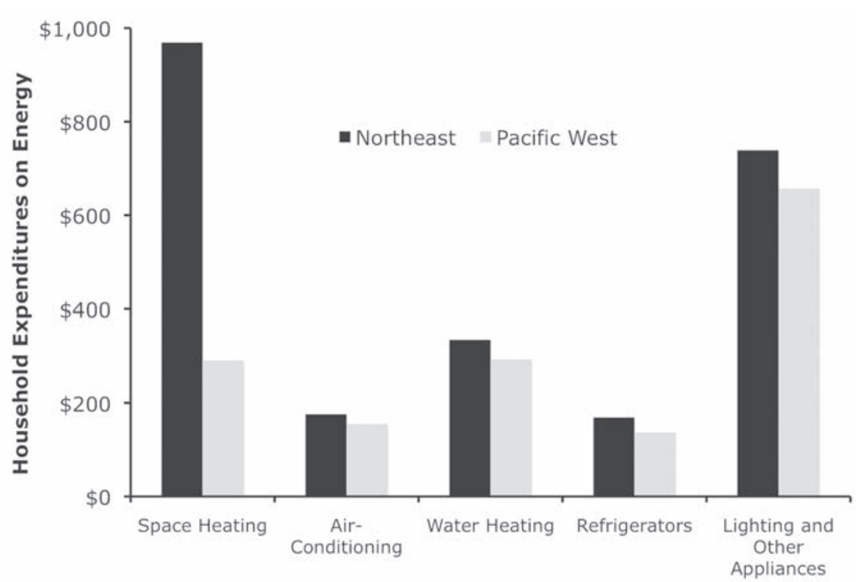
about 3,000,000 MW of alternative energy capacity. This is a very substantial amount, considering that the United States currently only has 100,000 MW of alternative (electric) energy capacity. Reducing the energy intensity of the United States is not even something that harms the economic strength of the nation. Rather, it makes the United States more competitive with other nations that already have similarly low-energy intensities.

Most energy-efficient or conservation measures require an upfront investment, and then pay for themselves over time. For example, for an additional 10–20 percent more in construction costs, a new home or business building can be built to be much more energy efficient with respect to heating and air-conditioning. Methods of doing this involve super-insulating the home, making it nearly airtight with energy-recovery ventilation, using double-, triple-, and even quadruple-pane windows with appropriate low-E or high-gain glass, and finally using an advanced heat source such as a geothermal heat pump, passive solar design, or at the very least an ultra-efficient condensing furnace.

The added costs of building such an ultra-efficient home amount to about $40,000 for a $200,000 home. The energy bills for that ultra-efficient home would then be reduced by about 85 percent, resulting in an annual savings of about $2,000. At this rate, the added expense for the ultra-efficient home pays for itself in just 20 years, or much faster when inflationary increases in energy costs are considered. A secondary financial value is that the financing cost of the added construction cost is usually tax-deductible for the homeowner, whereas the higher utility bills for a traditional home are certainly not. Of course, that home could also have been built in a standard way, but with 85 percent of its energy produced from solar panels. But the cost of a solar installation that generated $2,000 of electricity per year would likely exceed $100,000, meaning that it is indeed better to conserve energy than to generate renewable energy. Or, if someone really wants to go all-out, he or she can build a home doing both of the above and have a net zero energy home.

There is a variety of cost-effective energy savings that can be achieved in virtually every home in the United States. Figure 5.8 shows the typical energy expended on various end uses in the home. The largest single use is home space heating, followed by water heating. Very distant in usage level from these are the various electrical appliances. The greatest of the appliances are

Figure 5.8
Energy Use in the Home



Source: U.S. Energy Information Administration.

the air-conditioner, refrigerator, lighting, and clothes dryer. On average, all other appliances are under two percent. Examples of cost-effective efficiency improvements for heating, air-conditioning, and lighting have already been given, which conserve over half of the energy used, but there are also more efficient ways to accomplish the tasks of water heating and clothes drying, as well as to improve refrigerators and other appliances.

Hot-Water Savings

The best way to conserve energy for water heating is simply to use less hot water. This can be done with low-flow showerheads, using a front-loading clothes washer instead of a top-loading washer, and by using a dishwasher instead of washing dishes by hand. Further reductions can be achieved by insulating hot water pipes, using energy-recovery drains, and switching to more efficient water heaters, such as on-demand heaters that have no standby losses.

Modern showerheads have aerators in them that reduce the rate of water flow to 2.5 gallons per minute (gpm) or less without sacrificing showering comfort. Many showerheads sold before 1992 will consume two to four times as much water as the most recent low-flow designs. Replacing an old showerhead with a flow rate of 5.2 gpm with a 2.5 gpm model will save about $200 per year and pay for itself in just a month or two. Replacing a standard low-flow model (2.5 gpm) with an ultra-low-flow model (1.2 gpm) will save about $100 per year.

Front-loading clothes washers save the typical homeowner about $200 per year in both energy and water expenses. These machines typically cost under $1,000, so they pay for themselves in less than five years. A rather novel device that also saves about $200 per year is the energy recovery drain. This device extracts the energy from the shower drain to preheat the incoming cold water. By doing this, over half the energy used for taking a hot shower can be conserved.

Some think that conserving energy requires a reduction in lifestyle (e.g., living in the dark or a cold home), but this is simply not the case with most conservation technology. Using many of these conservation technologies provides side benefits that increase lifestyle and comfort. Energy saving CFLs last much longer than regular lightbulbs, so they don't need to be changed as frequently. Front-loading washing machines leave less soap residue on clean clothes, resulting in faster drying times, and don't wear out clothes as fast as top-loading machines. An energy-recovery drain extends the length of time one may shower with hot water, so one is unlikely to ever run out of hot water in the shower. An on-demand water heater provides an unlimited amount of hot water. And of course, an automatic dishwasher eliminates the need to wash dishes by hand. Consumers in air-conditioning-dominated climates can

Table 5.2
Hot Water Energy Savings in the Home

	Investment Required	*Annual Savings*	*Payback Period*
Switch from high-flow to low-flow showerhead	$20	$540	2 weeks
Switch from low-flow to ultra low-flow showerhead	$50	$200	3 months
Front loading washing machine	$1,000	$200	5 years
Switch from an electric tank heater to an electric heat-pump heater	$1,500	$300	3 years
Switch from a natural gas tank heater to a natural gas–instananeous heater or an electric heat-pump heater	$1,500	$150	10 years

make use of heat pump water heaters (HPWHs), which cut the amount of energy (and expense) used for hot water by 50–75 percent. HPWHs combine air-conditioning, dehumidification, and water heating all in the same unit. Table 5.2 lists common methods of conserving energy with water heating.

Appliances

Not all appliances use the same amount of energy. Major appliances are required to have an energy efficiency label that gives the average amount of energy consumed each year by the appliance. Thus, when shopping for a new appliance, it is easy to make comparisons and purchase the appliance that consumes the least amount of energy. Appliances that use the least amount of energy are given the government's Energy Star rating. It may be necessary to pay more money for an Energy Star appliance, but the more efficient appliance will usually pay for itself within a few years. It is even possible to replace a perfectly working old appliance with an energy-efficient new appliance and have the new appliance pay for itself with the energy savings achieved.

In today's world, the biggest energy-consuming appliance is the clothes washer, not the refrigerator. Replacing the traditional top-loading washing machine with an Energy Star front-loading washing machine will usually save about $200 per year. The savings come from less water use, less dryer use, and less detergent use. And, of course, less water means less water that needs to be heated for hot and warm cycles.

Refrigerators are next on the list of energy use in most homes. It is often said that replacing a refrigerator that is more than 10 years old with a new Energy

Star refrigerator will pay for itself within 10 years; however, this is no longer the case. That statistic originated in about 1990, and referred to 10-year-old refrigerators as those manufactured in the 1970s. EnergyStar provides a Web site that can be used to determine how much energy an old refrigerator or freezer uses (http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator). This can be compared to the energy ratings of current Energy Star appliances to see what the savings would be and whether it is worthwhile to update your appliances. This of course assumes that your old appliance is working properly and has been well maintained. A poorly maintained appliance is likely to use much more energy than when it was first placed into service. If you're unsure about the amount of energy your appliance actually consumes, it is possible to purchase a wattmeter (pictured in Figure 5.9) that will measure the actual energy consumption of your appliance.

Figure 5.9
A Wattmeter
The wattmeter manufactured by P3 International can be used to monitor the actual electricity used by various appliances to make sure they are functioning as indicated by their original energy ratings. The meter can also be used to measure phantom loads when a device is in stand-by mode.

Source: Courtesy of P3 International.

Paying to Conserve Energy versus Energy Conservation as an Investment?

Consumers usually attempt to spend as little as possible. However, it is often the case that people become too concerned with spending as little as possible in the short term, while ignoring the long-term cost of their expenditures. Homebuilders are keenly aware that most homebuyers are trying to buy a home for the lowest price possible. However, in the case of the new home, this is not the most important issue for a wise consumer. Most homes are purchased using a mortgage, and a wise homebuyer should be interested not just in the price of the mortgage, but also in the total price of owning and maintaining a home. Besides maintenance and insurance costs, this would include the mortgage and utility payments. It is usually the case that a more energy-efficient home costs more to build, and therefore has a higher mortgage payment. However, a more energy-efficient home also will result in smaller utility payments.

Since it is the combination of mortgage and utility payments that is important, a homebuyer should clearly be interested in spending $19 more on the mortgage in order to save $20 on utilities. That homebuyer should be even more interested in spending $5 more on the mortgage bill in order to save $20 on the utility bill. Conversely, it is a very uninformed and unwise homebuyer who willingly saves $15 on the monthly mortgage bill in order to spend $25 more on the monthly utility bills. And yet this last case is exactly what happens whenever a new home is built using the standard 80 percent-efficient natural gas heating system with which many new homes are in fact built.

Two other small examples of new homebuyers missing out on good deals are the front-loading washing machine and the energy-recovery drain. When installed in a new home, each of these would result in an increased mortgage bill of about two or three dollars per month. And yet each of these would result in a utility bill savings of about $20 per month. Over the lifetime of a typical 30-year mortgage, opting out of these two energy-saving devices will cost the homeowner approximately $7,000, or even $20,000 when inflationary increases in energy costs are considered. Sadly, most homebuyers have no idea they've been duped out of $20,000, which would have been equivalent to the production of 200,000 kWh of renewable energy.

Like any investment, the greater the amount of money invested, the greater the potential earnings, or in this case savings. Since most residential energy is used for home heating and air-conditioning, the best way to save is to decrease the amount of heating and air-conditioning required. This means increasing the amount of insulation, building a home which is as airtight as possible with the correct type of energy recovery ventilation, using high-quality windows and doors that far exceed the minimum efficiency requirements, and most importantly, making the most of passive solar heating and passive solar cooling.

As the home is made more and more efficient, the amount of initial investment starts to approach the amount of energy saved in the utility bills, and may even surpass it. Thus, it becomes a real question of economics as to whether it is wise to spend $200 more for a monthly mortgage bill in order to save $160 on the initial monthly utility bills. In a sense, this becomes a question of whether the homeowner thinks that energy bills are going up or whether energy bills will be going down in the future. Since the traditional mortgage is a fixed interest mortgage, the mortgage payments will be fixed. Thus, if the homeowner believes that energy bills will be going up in the future, it is actually wise to be willing to spend more money on the monthly mortgage bill than the savings on the initial monthly utility bills. So, in the long run, as the utility bills go up in price, a savings will be realized. Furthermore, since it is very difficult to change the way a home is fundamentally constructed once it is already built, it would be a good idea to make the home as energy-efficient as possible when it first constructed. The same thing applies for installing an efficient geothermal heat pump. When compared to installing an integrated geothermal heat pump when a home is first constructed, it is much more costly to retrofit such a heating system and throw away a working natural gas heating system.

NUCLEAR ENERGY

Nuclear power, although not quite renewable, is often categorized as renewable energy. This is because nuclear power does not emit any air or water pollution, and most importantly, it is carbon-free. Nuclear power plants can also be built in any region of the country and provide power 24/7—independent of weather conditions. Nuclear power plants can be used to satisfy peak power demands, although they are not currently utilized in that manner.

A nuclear power plant is much like a coal-fired power plant. Water is heated to steam, steam turns a turbine, and electricity is generated. The used-up steam must then be converted back into water so the process can start all over again. Water-cooling towers are used in both nuclear and coal-fired power plants. The main difference between these two power plants is how the water is heated to steam. In a coal-fired power plant, coal burns and heats the water much like on a campfire; however, in a nuclear power plant the fission of uranium produces the heat that boils the water. This fission also produces lots of radiation, which can be very harmful. And of course, nuclear power generates radioactive waste that must then be contained for thousands of years. Several methods of storing this waste have been scientifically developed, but none has been fully accepted politically and socially.

The reason why nuclear power is not a renewable energy resource is that there is a limited amount of the uranium fuel on the planet. The fuel of choice is uranium 235 (U-235). At the current rate of consumption, there is only an 80-year supply of known U-235 in the world. Even if technology improves and other sources of uranium become feasible, the supply of uranium is still limited to about 250 years at today's rate of consumption. If nuclear power were to provide half of the entire world's energy, then that 250-year supply would be gone in just 25 short years. But that doesn't mean that nuclear can't provide most of the world's energy for centuries to come. After naturally occurring U-235 is used up, there is still more fuel. Abundant uranium 238 (U-238), which is not normally a fuel, can be converted into plutonium 239 (Pu-239), which is also nuclear fuel, but is used in a different style of reactor. This U-238–to–Pu-239 conversion is done in a special nuclear power plant called a breeder reactor, and it requires the reprocessing of spent nuclear fuel. By doing this, there would be enough fuel for nuclear power to provide all of the world's energy for at least 200 years.

Reprocessing the spent fuel is also an easy way to obtain nuclear bomb-grade plutonium, which is how many countries produced their first nuclear weapons, including the United States, the United Kingdom, North Korea, Russia (from the former Soviet Union), India, Pakistan, and so forth. Thus, by reprocessing spent fuel, it is possible to power the world for perhaps 500 years using nuclear power, but it also raises the risk of nuclear weapons proliferation.

Regardless of whether spent fuel is reprocessed or not, the world is staging a comeback of nuclear power. In the United States, no new nuclear plant has been proposed since 1979 (when the Three Mile Island accident occurred), that is, until 2007. During those 28 years, the only nuclear power plants to be built were already far into construction by 1979. In fact, many reactors that were under construction were abandoned after 1979. But today, in 2008, there are already 21 proposals to build new reactors in the United States, and it is expected that this number will continue to grow. Worldwide, there are nearly 40 nuclear plants already under construction in China, Russia, India, Canada, Japan, and so forth. There are more than 300 that are in pre-construction stages. At this rate, the use of nuclear power in the world will double within the next decade. But even after that, nuclear power will still provide less than 10 percent of the world's raw energy.

This rebirth of nuclear power is being driven by several factors (Deutch, 2009). Fossil fuels are becoming more costly, renewable fuels are usually too dependent upon weather, and nuclear technology has been reengineered so that power plants can now be built to be safer and faster with improved and more uniform designs. Today's nuclear power plants are based on standardized designs whose many components can be constructed in modular form in a specialized manufacturing facility. These modular units can then be shipped to the power plant site and assembled more quickly. In the future, nuclear power may even be developed to a point at which the entire plant is pre-constructed in an assembly line process and then returned to the manufacturer after a decade of use.

Safety of Nuclear Power

Nuclear power has already been shown to be very safe, and it is responsible for far fewer deaths and illnesses than either coal or natural gas. No deaths or injuries have ever been attributed to the nuclear aspects of a commercial nuclear plant in the United States. The worst U.S. commercial nuclear accident occurred at Three-Mile Island in 1979, and did not cause a single physical illness or death. Even worldwide, in over 50 years of commercial nuclear power generation, there has been only one fatal power plant accident at Chernobyl, which caused 31 immediate deaths and about 20,000 cancer deaths.

Nuclear power suffers from a skewed perception about its risk. In the United States alone, coal power plant pollution kills 20,000–30,000 people per year, and pollution from cars and trucks kills another 20,000 people every year. Auto accidents kill about 50,000 people every year in the United States. Many more are killed worldwide from these things. In general, most voluntary activities are more dangerous than involuntary exposure to risks that are wrongly perceived as more risky. For example, automobiles are one million times more risky than nuclear power plants. Even being stuck by lighting is about 1,000 times more likely to cause death than nuclear power plants.

ALTERNATIVE FOSSIL FUELS

In most conversations, when the phrase "alternative energy" is used, it is in the context that there is a source of energy that is somehow better than that which is currently used. This may be due to less pollution harming the environment and human health, less CO_2 emissions leading to climate change, less need for fresh water, less impact on land usage, and/or a new resource of energy that will not run out for at several centuries. However, there are two energy resources that are sometimes referred to as alternative, even though they don't meet the requirements above.

These two resources are oil shale and oil sands. As discussed below, both of these result in greater amounts of pollution, CO_2, and fresh water use than does the current use of petroleum. Methods of strip-mining oil shale and oil sands require a greater use of land than does petroleum production. And while oil shale and oil sands do increase the amount of petroleum resources that are available, the increase is only a few decades of use.

Oil Shale

Oil shale, sometimes called coal shale, is not coal at all, but rather kerogen. Kerogen has a slightly different molecular structure than petroleum, but when heated, kerogen transforms into petroleum. There is an estimated resource of 1,500 billion barrels of oil shale in the Green River formation of Colorado, Utah, and Wyoming. However, only about 600 billion barrels of that is considered practical for exploiting. Worldwide, there is about double this amount of oil shale.

To exploit oil shale as a fuel today, it must be mined and then distilled into petroleum. Although no commercial processing plants exist today, modern experimental processing dates back to the 1970s. Current techniques are problematic for two reasons. The process requires vast quantities of water (three barrels of water for each barrel of oil produced). Since the region where oil shale is found is a somewhat arid region, a lack of water supply limits the large-scale processing of oil shale. Another difficulty with this traditional method is that the volume of the excavated shale increases by 35 percent after being heat-treated. Thus, it is not possible to return the waste product to the same hole from which it was mined.

To put these problems into perspective, imagine if the United States were to obtain just 25 percent of its petroleum from this resource. This would require the mining of 10 million tons of shale per day, which is 3 times the amount of coal mined in the entire United States every day. It would also require the use of 10 percent of all water from the Colorado River watershed. Considering that this area is currently in a severe, long-term water shortage, it would be extremely difficult to obtain that much water. These problems have resulted in the failure to pursue, with any economic success, this traditional exploitation of oil shale.

It may be possible to heat the oil shale while it is still in the ground. This method is called "in situ" conversion, and it is being actively researched. To do this, a great number of holes are drilled in the ground, and electrical heaters are inserted deep into them. Electricity is used over several years to heat the buried shale artificially while using the natural geological pressure that exists inside the Earth. Several years of this high temperature will allow the oil shale to be converted into petroleum. The petroleum can then be extracted through one of the many wells that have already been drilled. However, as with regular oil drilling, only 50 percent of the oil can be recovered using even enhanced drilling techniques.

It is important to note that this in situ method is untested, and it is not known whether the technique will be successful or not. However, if successful, it solves several problems inherent in the old process. No fresh water is directly needed to create pressure or heat, although water may be needed for the generation of electricity to heat the buried oil shale. Also, massive amounts of earth no longer need to be moved, and the general topography can remain unaltered. There are some new problems with this process, most notably the massive electricity requirement. With either production method, oil sands result in a significant increase in the carbon footprint of petroleum and the emission of atmospheric pollutants, when compared to conventional sources of petroleum.

Oil Sands

Oil sands represent an oil resource of about 3–4 trillion barrels of oil worldwide, with about half of that found in Alberta, Canada and another very large deposit in Venezuela. However, extracting oil from oil sands is far more complicated, expensive, and energy-intensive than just pumping it from the deserts of the Middle East. The oil sands of Canada were formed when petroleum created millions of years ago migrated thousands of miles underground and became trapped in the shallow sand deposits of Athabasca and other nearby deposits. Once trapped in the sand, the originally high-grade crude oil began to break down into a low-grade heavy and viscous crude oil, bitumen, which exists today.

There are two methods to exploit oil sands. One method is to strip-mine the sand and clay in which the petroleum is located and then to separate the petroleum from the sand and clay. The other is an in situ method in which multiple wells are drilled into deep deposits so that steam can be pumped into the ground, which then releases the petroleum so that it can be pumped out of one of the other wells. In Canada, 20 percent of the oil sands can be strip-mined, yielding a high recovery rate, and the other 80 percent must be produced using a more expensive in-situ method that has a recovery rate of only 30 percent, similar to that for convention oil. Thus, only half of Canada's oil sands can ever be recovered, even with substantially improved technology and economic conditions. Nonetheless, oil sands may increase the total recoverable resources of petroleum worldwide from the currently estimated 2 trillion barrels of oil to about 3.5 trillion barrels of oil—about an extra 40 years' worth at the current rate of consumption.

The strip mine method of developing oil sands requires the removal of vast amounts of sand and clay that is impregnated with bitumen. Next, this soil is agitated in water with special chemicals so that all the soil is broken up into fine particles and the bitumen is released from the sand. This mixture is then allowed to settle so that the petroleum rises to the top, with the sand and clay sinking to the bottom. The separated petroleum is too heavy for most refineries and thus must be partially refined to convert it to a higher-grade crude that can then be transported to normal refineries. The water, sand, and clay mixture is then allowed to settle in a tailings pond to allow the water to evaporate. Unfortunately, much of the water will remain with the clay in a mixture that is stable enough that the clay and water will never separate naturally. This water would then be lost and the clay mixture would not form a solid soil. Remediation methods that can be used to separate this clay and water mixture are expensive and still being developed. Currently, there are far more clay and water tailings being produced than are being remediated. For this processing, four barrels of water are required per barrel of oil, which puts a large strain on the region's natural resources.

In addition to water requirements, energy is also needed for the mining, separation, and pre-refinement of the bitumen before usable petroleum is produced. Thus, the carbon and pollution footprint of petroleum from the Canadian oil sands is about 20 percent greater than the carbon footprint of petroleum from traditional sources. Nonetheless, in 2006, production of petroleum from the Canadian oil sands was 1.1 million barrels per day and expected to rise, since its production is cost-competitive with the production of conventional oil.

The in situ production of petroleum from the Canadian oil sands is much like the in situ production of oil shale in the United States. Injection wells must be drilled so that hot steam can be injected into the ground, which will loosen the petroleum from the clay and sand. Production wells must also be drilled in order to extract the loose petroleum. Using this method, about 30 percent of the oil can actually be extracted from the ground. In addition, vast quantities of water and fossil fuel energy to heat the water to steam must be used. This method does have the distinct advantage of not producing any mine tailings or requiring the remediation of strip-mined land. Less than one-half of the petroleum from the Canadian oil sands is produced using in situ methods today. However, the vast majority of the oil sand resources in Canada must ultimately be recovered using in situ methods.

CONCLUSION

There is no single best form of alternative energy technology. Each technology has advantages and disadvantages. Ultimately, it is likely that the United States will pursue most, if not all, of these technologies. Regardless of which combination of technologies is used, it is nearly certain that energy prices will continue to rise in the long term, with many roller-coaster dips and peaks along the way. The major issues that will need to be confronted along the way will include the following: providing a drastically updated national electrical grid, reducing CO_2 emissions in the face of global climate change, easing the environmental and health impacts of atmospheric pollutants, and society's acceptance—or not—of nuclear fission.

The role of consumers is critical. By demanding energy created by sustainable means, Americans can help shift away from the high-energy existence of the last century. Policies will likely need to use federal resources, including regulation, to steer the industry in more sustainable directions. It could be that consumers will find that doing the right thing costs them more in the short term, but yielding savings and steady access to energy for future generations.

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Redefining Alternatives

It can be unnerving to see the ridges of Pennsylvania's Allegheny Mountains lined with some of the largest propellers humans have ever constructed. We are used to spinning propellers lifting the cargo to which they are attached, whether it is the chassis of a helicopter or airplane. Therefore, one might feel compelled to ask: Will they be strong enough to lift the long, slight, tree-covered ridges? Is that the intention? In fact, after years of being mined to provide coal for energy production, these mountains may now have a respite—while still being a major component of America's energy future.

During the industrial era, Pennsylvania produced 20 billion tons of coal. It has been removed through a variety of means, including underground mining and, more recently, strip-mining and mountaintop removal. No matter how it was removed, though, the coal from these mountains was most often fed into long lines of railroad hopper cars and carried to sites all over the nation to be burned, its released power then used by industry or by utilities to make electricity for consumers. Today, Pennsylvania remains one of the nation's largest producers of anthracite, or hard coal. Now, however, this new energy crop has also crept into the state: hundreds of turbines have been built throughout the state, and a number of international manufacturers of wind turbines have made Pennsylvania their U.S. headquarters, all while coal production has declined there.

The turbine-decked mountains are one of many pieces of evidence that help to prove a fact about 2010: Americans are fully engaged in a significant and potentially seminal energy transition. The energy transition initiated in the 1970s did not bring immediate changes to American attitudes toward renewable energy. For many observers, this reality marks a failure of our species to pursue energy paths with less impact on planet Earth. Although this perspective is, on the whole, correct, it fails to appreciate the cultural and technical nuance of energy transitions. To complete an energy transition, technical advances are needed that require many years of research. This research began in earnest in the 1970s, so that by 2010, the mass production of thoroughly developed wind turbines was possible. From a historical standpoint—in terms of centuries and even millennia—a shift in the basic habits of the human species can drag on for decades and even centuries. Clearly, we are in the midst of an energy transition that very likely began thirty years ago during the 1970s. And it may continue for decades longer.

In hindsight, the temporary scarcity of the 1970s provided a catalyst for disrupting the paradigm that had classified most renewable sources as energy alternatives. More attention focused on these other ways of providing energy. Yet, when most American consumers continued business as usual in the late 20th century, any thoughts of a revolution in renewables seemed to be dashed. Life in the 21st century, though, suggests to us that this view of energy transitions might be oversimplified. While increasing supplies of cheap energy sources functioned to worsen patterns of American consumption in the 1980s and 1990s, ideas of a renewable future only went dormant in the public awareness. In areas of research and development, these ideas continued to evolve, percolating and developing until a moment arrived that was less deniable—when the public might be most receptive and the technology might arrive as a more fully developed manifestation.

The current energy transition seems to have reached a more clear-cut path into the future during 2007–2008, when spikes in energy prices suddenly seized the public's attention. This public, in addition, had changed a great deal from that seen in the 1970s. Energy prices, particularly for petroleum, but also for natural gas and electricity, rose steadily after the mid-1990s with little public reaction. But by the summer of 2008, the drumbeat of energy prices had become daily headlines. Of course, prices rose, primarily due to an increase in world demand for these finite resources. Unlike the false scarcity created by Middle East politics in the 1970s, 2007 brought a bona fide concern over scarcity. Stemming from the geological idea of peak oil, and the failure of worldwide energy production to keep pace with an increasingly competitive marketplace, the new energy economy must include players such as China and India that emerge as aspirants to industrial development.

In addition to higher prices for traditionally cheap fuels, increased scrutiny has been given to reliance on foreign supplies of energy, and to the pollution given off by these cheap fossil fuels. The increasing likelihood that carbon accounting (increasing prices to account for emissions, pollution, and other affects) in future years will cause prices to rise higher helps to make renewable energy sources more competitive than ever in the energy marketplace. When the full accounting of additional factors, like air pollution, climate change, and dependence on foreign oil, is taken into account, fossil fuels no longer seem so cheap.

In this fashion, the paradigm of cheap energy—created over the last few centuries—that forced the title "alternative" on renewables decades ago, has been shaken to the point of fracture. Our future energy paradigm, most experts agree, is in play, and possesses the potential to shift considerably. The following sections of this chapter will discuss the largest forces driving the change in our energy paradigm, as well as our forecast about what the future most likely holds.

RISING COSTS OF FOSSIL FUELS PROMOTES ALTERNATIVES

Energy costs in the early 21st century have risen at staggering rates. Since 2000, natural gas rates have risen by 80 percent, and gasoline has more than doubled in price. Even electricity rates have risen by nearly 40 percent after actually declining during most of the 1990s. For a typical household, direct expenditures on energy (gasoline, electricity, and home heating/cooling) increased a whopping $300 per month from 2000 to 2008, just prior to the economic collapse. It is no wonder that many households had financial trouble, especially when the accompanying increase in food prices is considered. This increased spending on energy was at least one of the reasons for the economic collapse that occurred just a few months later. Some argue that energy prices were the primary cause of this collapse.

Americans have found evidence of these increased costs in all types of related goods as well, particularly agriculture. Although agriculture begins with photosynthesis, most American food products are now dependent on petroleum and natural gas, which means that we rely on fossil fuels in order to eat. In the United States, in 2004, commercial farming accounted for 12 percent of our annual energy use, most of that being from natural gas used to make artificial fertilizer. After natural gas shortages develop, the artificial fertilizer plants shut down, or price their product so high that most farmers can't afford it. Food prices increase because of higher transportation costs as well as increased costs for herbicides and pesticides. Energy-related price increases are not limited to fruits, vegetables, and grains: they impact dairy and meat products as well. In fact, the energy required to produce meat is 100 times as much as the energy required to produce a similar diet of grains. Across the board, increased fossil fuel prices have trickled into the lives of American consumers and reminded them that we live an energy-intensive lifestyle. Based on cheap fuels, this lifestyle has defined American life for a century. As the prices now rise, the basic cost of living stresses many in the middle class to the breaking point.

Unfortunately, though, the rising costs of energy sources that are destined to expire is only one aspect of a high-energy life. Scientists have now demonstrated to us that burning fossil fuels has created emissions and pollution that imperil or at least corrupt Earth's natural systems. Many health and environmental problems that our country faces today, we have learned, are a result of our fossil-fuel dependence. The coal industry's most troublesome problem today is removing organic sulfur, a substance that is chemically bound to coal. All fossil fuels, such as coal, petroleum, and natural gas, contain sulfur. When these fuels are burned, the organic sulfur is released into the air, where it combines with oxygen to form sulfur dioxide. Sulfur dioxide is an invisible gas that has been shown to have adverse effects on the quality of air we breathe, and leads to the premature deaths of tens of thousands. It also contributes to acid rain, an environmental problem that adversely affects fish, wildlife, and forests.

In an effort to solve the problem, some coal-burning power plants are installing scrubbers to remove the sulfur in coal smoke. Scrubbers are installed at coal-fired electric and industrial plants, where a water and limestone mixture reacts with sulfur dioxide to form a sludge. Scrubbers eliminate up to 98 percent of the sulfur dioxide; and while they are expensive to build, they are far cheaper—in monetary value, not to mention in intrinsic value—than the healthcare problems caused by the release of the sulfur dioxide (Gelbspan, 1998). Efforts to create regulations to require the addition of scrubbers were resisted by the administration of President George W. Bush, particularly due to the increased cost to energy producers, and without regard to the increasing cost of dealing with the health problems caused by their absence.

Given the difficulty of establishing clean-coal regulation in the United States, one of the outcomes of this pollution deserves additional discussion. The combustion of fossil fuels, particularly coal, produces gaseous emissions of sulfur dioxide and nitrous oxides that cause a variety of harmful heath effects. A comprehensive study in 2000 and 2004 by the Clean the Air Task Force found that (Schneider, 2004):

- Fine particle pollution from U.S. power plants cuts short the lives of nearly 24,000 people each year, including 2,800 from lung cancer.
- Hundreds of thousands of Americans suffer each year from asthma attacks, cardiac problems, and respiratory problems associated with fine particles from power plants. These illnesses result in tens of thousands of emergency room visits, hospitalizations, and lost workdays each year.
- Power plant pollution is responsible for 38,200 non-fatal heart attacks per year.

In addition, this study also found that most of these lives (22,000 per year) could be saved just by having coal power plants install the best available technology to prevent the emission of these pollutants into the atmosphere. The task force noted that it would cost $34 billion to install this best technology at all the various power plants around the country, and while this may seem a staggering amount of money, it would then make possible a savings of $175 billion *per year* in healthcare costs. This illustrates how the U.S. society has indeed been penny-wise and pound-foolish for many years. We choose not to make a *one-time* commitment of $100 per person to clean up these power plants; instead, we opt to pay an extra $600 per person *each and every year,* in additional health-related costs, not to mention the sacrifice of one out of every 10,000 lives.

The environmental implications of sulfur dioxide and nitrous oxides are particularly problematic because they are transboundary issues: the air pollution from one area may create acid rain problems in other geographical areas. In addition, these pollution problems are difficult to trace to their exact source, and even more problematic to quantify. The new field of environmental accounting has attempted to create a rubric for such patterns, and this will be discussed a bit later under the section titled Carbon Counting. In more-developed countries, modern emission control technologies and the greater use of low-sulfur coal have greatly reduced acid rain. In the United States, despite continued growth in coal-fired electricity production, emissions of sulfur dioxide from utilities have fallen by only three percent per year since 1980, despite cost-effective existing technology that could prevent much more (Gelbspan, 1998).

Among the gases emitted when fossil fuels are burned, the most significant in the long term is carbon dioxide, a gas that traps heat in the earth's atmosphere. Over the last 150 years, burning fossil fuels has resulted in more than a 25 percent increase in the amount of carbon dioxide in our atmosphere. Fossil fuels are also implicated in the increased levels of atmospheric methane and nitrous oxide, although they have less importance as greenhouse gases when compared to carbon dioxide.

Finally, researchers have connected these changes in atmosphere to a global rise in temperature and ocean levels. Since reliable records began in the late 1800s, the global average surface temperature has risen 0.5–1.1 degrees Fahrenheit (0.3–0.6 degrees Celsius). Scientists with the Intergovernmental Panel on Climate Change (IPCC) concluded in a 2007 report what is now considered unequivocally true, that the Earth's climate is indeed warming and that "most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic [human] greenhouse gas concentrations" (IPCC, 2007a). Scientists from around the world who make up the IPCC panel unanimously support the conclusion that it is virtually certain that the Earth will continue to warm if carbon dioxide levels continue to rise. They also say that projected temperature increases will very likely result in an increased frequency of heat waves and severe rainfalls. These patterns will likely result in an increase in areas affected by drought, occurrences of intense tropical storms, and occurrences of extreme high sea events (IPCC, 2007a).

It is worth noting that the findings of the IPCC are inherently conservative because all of the members who make up the committee must unanimously support its conclusions. Many of the members believe that human-induced climate change is actually worse than what is indicated by the official committee findings (Pearce, 2007). In fact, the United Nations has recently reviewed all additional science which has occurred since the official IPCC report was drafted, and has concluded:

> Through its overview of the latest definitive science, this Climate Change Science Compendium reaffirms the strong evidence outlined in the IPCC's 4th Assessment Report that climate change is continuing apace.
>
> In fact, this report shows that climate change is accelerating at a much faster pace than was previously thought by scientists. New scientific evidence suggests important tipping points, leading to irreversible changes in major Earth systems and ecosystems, may already have been reached or even overtaken. (UNEP, 2009)

The warming of the planet will cause a variety of impacts. The warmth itself continues melting glaciers, ice sheets, and permafrost, as well as warming oceans and lakes. This will lead to the inundation of wetlands, river deltas, and even populated areas. The warmth will cause increased evaporation of moisture from both land and sea, resulting in more droughts. When weather conditions allow this atmospheric moisture to return to the surface, there will be more severe precipitation in the form of rain, freezing rain, and snow. Since parched dry land is less absorbent, run-off from heavy rains will be more likely to cause flooding. Many agricultural lands will be faced with this cycle of alternating droughts and floods.

Although there are environmental impacts from mining for any mineral, it appears that the greatest impact of the fossil fuel era will be the pollution that burning these resources for energy placed in our ecological commons, including the air and ocean that all humans need to survive. These are the costs of cheap energy use that are not contained in consumer utility or gas bills, nor are they paid for by the companies that produce or sell the energy. Instead, this cheap energy is paid for by the society and the surrounding environment with which we share the planet. It is paid for in health care costs and lost economic growth, but also in terms of the decreased well-being of countless individuals. Ultimately, these patterns result in the loss of tens of thousands of lives every year. If unchecked, the cost of this purportedly cheap energy will continue to rise, and could even cause the extinction of more than 40 percent of all plant and animal species on planet Earth by the end of this century (IPCC, 2007b).

By the early 21st century, the price of fossil fuels was evident in both the pollution they produced and the rapidly increasing cost to consumers. Although the economic collapse of 2008–09 gave consumers a break from high energy costs, prices are expected to soar once global consumption of energy resources has righted itself. If, in the meantime, society does not adapt by using more alternative energy and with much greater efficiency and conservation, the energy prices that will result will certainly dwarf those seen prior to the economic collapse.

But the prices we pay for energy use do not include the harmful effects on human health, the damage to the land from mining, or the environmental degradation caused by global warming, acid rain, and water pollution. When we begin fully accounting for our high-energy existence, then these related environmental and financial costs of pollutants must be included in the cost of cheap fossil fuels. Additionally, it has also become increasingly clear that protecting our access to foreign sources of oil has become the primary threat to national security—even meriting the use of military force and the risk of worldwide conflict. Thus, the military cost of securing our access to these foreign supplies of oil must also be included in the cost of cheap fossil fuels. When these additional costs are accounted for, fossil fuels are no longer cheap, and they certainly are not without detrimental effects.

Estimates have been made that when energy producers prevent these harmful emissions or otherwise pay for their effects, the cost of fossil fuels doubles. When the retail price of electricity from a coal power plant rises to 20 cents per kilowatt-hour, the cost of solar, wind, and geothermal energy isn't so much after all. And when the price of gasoline is six dollars per gallon, the higher price of a hybrid vehicle, or even the limited range of an electric vehicle, seems worthwhile.

Consumers have already been taking a leading role in demanding more energy-efficient products. For example, in the fall of 2005, *Consumer Reports* reported that fuel efficiency had just become more important than cup-holder placement when considering buying a new car. For some among this new breed of consumers, their ethic grows from a modern environmentalist commitment to lead a lower energy existence. However, others simply cannot stomach the high economic cost of such an existence. Regardless of which category a consumer fits into, companies have responded by reconsidering their methods, priorities, and products with an eye to energy consumption. Many companies have added language or accentuated significant details to attract green consumers. Certainly, as the accounting of fossil fuels more fully includes their harmful effects, costs will continue to rise and the mass consumer will begin to adopt a lower-energy existence.

METHODS FOR A FULL ACCOUNTING OF ENERGY PRODUCTION

With the full accounting of fossil fuel, energy sources, and their impacts on human health, the environment, and climate change, alternative energy sources have become mainstream. This full accounting of the price of fossil fuels can be done in a variety of ways. Ideally, the producer of a certain type of energy should be required to pay for its production and all its detrimental effects to society and the environment. Were this done, the producer would then pass this cost along to the consumer. The consumer would then be able to reap the financial benefit if they were to choose a low energy-existence life.

Without this production-side accounting, a well-meaning consumer who chooses to live off the grid in a solar-powered home with electric vehicles will not reap the benefits of their lifestyle. Although they would not be responsible for the daily emission of pollution, they would still be forced to breathe the same air as their neighbor living in an inefficient home with a 10,000-pound SUV. Thus, without production-side accounting of energy, there is no way for those with a low-energy life to reap the full benefits of their lifestyle. Of course, the owner of that 10,000-pound SUV will also unfairly reap the clean air rewards of all the other people who drive around in hybrids.

Even without a complete production-side accounting, the government plays an important role in energy accounting by using several different methods. The government can provide incentives to those who use renewable energy and purchase more efficient products. These incentives are nearly always financial in nature, so they don't technically provide for cleaner air or a cleaner environment. And while these incentives have not been valued highly enough in relation to the health and environmental impacts of the use of fossil energy, these incentives have promoted alternative energy and conservation.

Another way for the government to promote a full accounting of energy production is to establish a carbon tax or carbon-trading scheme. The emission of carbon dioxide is the leading cause of global climate change and will have an impact of massive proportions on future generations. By enacting a carbon tax, the government doesn't stop the emission of carbon dioxide and the accompanying climate change, but it does make those emissions more expensive. The producer of energy that emits carbon dioxide must then pass this cost along to the consumer. This is similar to production-side accounting, and encourages energy use from producers who don't emit carbon dioxide.

A third way for the government to be involved is to pass laws to prevent the emission or release of harmful pollutants. This is sometimes called a command and control structure by those opposed to it. With this legal requirement, an energy producer must take the necessary steps, at whatever cost, to prevent the harmful pollution. This cost is then passed on to the consumer. This type of accounting is production-side accounting. If this were done, it would not be necessary for renewable incentives or carbon taxes to be provided. However, this type of legal requirement to prevent harmful pollution has proven very difficult to enact and enforce.

The Clean Air Act was designed to prevent the emission of harmful pollutants. However, this act was not enforced with older plants that already were polluting the air. In some cases, lawsuits were brought against older power plants by the government to mandate more pollution controls. In one such successful lawsuit, which took nearly a decade to pursue, the Ohio-based company American Electric Power Co. settled with the government and agreed to update its older power plants in 2007 (U.S. EPA, 2007). What was ironic about the settlement of this successful lawsuit was that while the company did have to install $4.6 billion-worth of pollution controls to prevent future pollution, it only paid $75 million dollars in fines and damages for years of unlawful pollution. During those years of unlawful pollution, the company caused an estimated $32 billion dollars *per year* in human health and environmental damage, not to mention an unknown number of people dead from the pollution.

This particular lawsuit illustrates how relatively inexpensive it is to clean up power-plant pollution, compared to the economic damage caused by that pollution. And yet with fines that are so cheap compared to the damages caused, it is not difficult to understand why the private industry is loath to shoulder the burden of installing these pollution controls voluntarily. It is simply cheaper for the industry to pollute and pay the fine. Such has been the public's demand for seemingly cheap electricity, without regard to the consequences.

In practice, the government employs a mix of these accounting schemes, and they have had the effect of making alternative energy production cost-competitive. As more of these schemes are employed to account for additional harmful pollution from the use of fossil fuels, alternative energy will continue to become more cost-effective, and perhaps fossil fuels will soon be cost-prohibitive.

DRIVEN TO CHANGE ENERGY PATTERNS

One of the first sources of evidence of the seriousness of our energy change was the shift in automobiles demanded by the U.S. consumer starting in 2005 and reaching a fever pitch by 2008. The steady increase in gasoline prices to the $4-per-gallon range irreparably altered the auto marketplace and demonstrated just how much influence consumers could have on the auto industry. Toyota and Honda led the way by making hybrid vehicles widely available. However, as Americans' love affair with large vehicles gave way to thoughts of efficiency, drivers chose smaller vehicles. American manufacturers were left very near to being in complete ruin due to their emphasis on manufacturing larger vehicles, including SUVs and full-size pickup trucks. One by one, the American Big 3 released plans for their future that grew from their reading of American consumers' views of their own future.

In the case of America's Big 3—those companies that delivered 10 thousand-pound large vehicles for middle-class consumers—entire plants dedicated to manufacturing SUVs and trucks have been shut down, or have shifted to making smaller cars. The biggest losers in the market are the big pickups and SUV's that Ford and its domestic rivals, General Motors and Chrysler, rely on for much of their profits. "We saw a real change in the industry demand in pickups and SUV's in the first two weeks of May [2008]," Ford's chief executive, Alan R. Mulally, said Thursday. "It seems to us we reached a tipping point" (BW). Last year, pickups accounted for about 14 percent of the overall U.S. market, but they now represent 9 percent. Mr. Mulally said the striking shift by consumers from trucks and SUV's to smaller cars and crossovers now appears to be structural in nature rather than a short-term reaction to gas prices. "We needed to act now," he said.

In the case of Ford, they had few designs on the table for such vehicles. In order to get vehicles to consumers as quickly as possible, Ford is transforming a Mexican large-truck plant to make the European-designed, small-car, Fiesta for North America, beginning from early 2010. The Cuautitlan facility near Mexico City will be converted from its current production of F-Series pickups for Mexico—future supplies will be imported from the United States—to small cars for all North America. "Ford is absolutely committed to leveraging our global assets to accelerate the shift to more fuel-efficient small cars and powertrain technologies that people really want and value," said Ford's Mulally. "Customers responded very positively after seeing both the sedan and hatchback versions of the Verve small-car concept [at motor shows]," noted Mark Fields, Ford's president of the Americas. "We know the market is headed toward more small cars and crossovers. With our product and manufacturing flexibility, we will be able to offer both models and add production capacity" (BW).

This contrasts with Toyota and Honda, which already had manufacturing facilities for very efficient vehicles like the Fit and Yaris, as well as the Prius and Civic hybrids. Prior to 2006, the Fit and Yaris had been manufactured for many years already, but never sold in the United States All Honda and Toyota had to do was make minor modifications and begin shipping them to the United States beginning in 2006, as well as to boost their production of hybrids to meet the increasing demand.

Overall, the momentum in small-car sales is outpacing industry growth worldwide, the automaker said. Globally, small-car sales are expected to grow from 23 million in 2002 to an estimated 38 million in 2012. Driving the growth in the North American market is a group of young people aged 13 to 28 years—dubbed "millennials." Today, this group numbers approximately one billion worldwide and will represent 28 percent of the total U.S. population by 2010. These consumers, who have grown up entirely in a world of high-priced gasoline, realize that alternatives are a must.

Over the summer of 2008, which saw prices remain over four dollars per gallon, the Big 3 U.S. automakers—General Motors, Ford Motor, and the Chrysler Group unit that is being sold by DaimlerChrysler—reported a 19 percent decline in sales in July versus a year earlier, compared to the single-digit declines or even modest gains reported by most overseas automakers during that period. This decline left the domestic brands with only 48.1 percent of U.S. sales, down 4 percentage points from a year earlier and below the previous low, set in June of this year, of 50.2 percent. As a group, Asian brands posted a 5.6 percent drop in U.S. sales, but that was enough to capture 44.6 percent of U.S. sales (BW). The European brands' sales were off only 2.4 percent, good enough for 7.3 percent of the market.

In addition to shrinking the types of vehicles comprising its fleet, manufacturers also stepped up efforts to create commercially available hybrids and alternatively fueled vehicles. First in 2006 and again in 2008, Honda and Toyota were being forced to employ waiting lists for their commercially available hybrids. Each American company advertised hybrid models, but few of them actually made it to the road. Instead, GM and Ford each strategically elected to develop plug-in, all-electric vehicles that were supposed to be available commercially by 2010. It is now known that these will only be available in limited quantities. They also made their fleet appear greener (in the conservationist sense) by selling vehicles able to use more biofuels.

The larger economic collapse of 2008–09 took a bad situation for American manufacturers and made it grave. At the time of this writing, only Ford thought that it could survive without government assistance. And the federal government was poised to take over American auto manufacturing in order to stem the tide of job losses, particularly in the Midwestern states. The long-term future of worldwide automobile manufacturing will probably depend on the speed with which companies can emerge from the current economic downturn with the successful mass-production of mid-transition, alternatively fueled vehicles.

The transition that will occur for vehicles will be even more drawn out than the general energy transition for society. This is odd, since the primary fuel powering vehicles, petroleum, is the fuel of which there is the greatest shortage today, and the one fuel whose peak production the United States has long since passed. Having reached the peak production of petroleum in 1970, the United States is in an irreversible trend of having to import more and more of its petroleum. However, despite the undeniable trend toward a greater reliance on foreign oil that will become increasingly expensive, Americans in the mainstream are still wedded to the once great symbol of American independence—the gasoline-powered automobile.

The energy transition for vehicles began in the 1990s, two decades after the start of the general energy transition, because vehicles represent a more difficult technological challenge. In the 1990s, manufacturers began a short-lived, failed attempt to develop purely electric vehicles. But this was not a total failure, the technology that was developed morphed into the gasoline-electric hybrid vehicles that are so successful, albeit in small numbers, today. These hybrids and other vehicles that have been made smaller and lighter for better fuel efficiency without sacrificing safety represent the current state of the transition in vehicles. But as advanced as they are, all of these gasoline and gasoline-electric hybrid dinosaurs are still marked for extinction, possibly within the lifetimes those reading this book.

The only reprieve for the current lack of available alternative-fueled vehicles lies in the uncertain success of advanced cellulosic and algae biofuels. Without those successes, vehicles must be re-engineered to use an alternative energy source such as electricity or hydrogen from a variety of other primary sources. Even natural gas is not much of an option for mainstream use, as there is no long-term surplus of natural gas supplies to handle an entirely new sector of consumption. Unfortunately, viable electric cars are still years away, and hydrogen vehicles are even further. Thus, while the automobile industry is undergoing a transformation to produce much more efficient vehicles today, the industry still has not truly begun the transition away from gasoline altogether.

EMERGING ALTERNATIVE TECHNOLOGIES

Since most alternative energy sources received serious attention in the 1970s, much advancement has been made in their technology. Driven only with government research and development, the application of these energy sources was demonstrated on small scales so that potential problems could be found and solutions could be engineered. After 30 years, many alternative energy technologies have reached a very mature level of development, waiting for the time when economic and social conditions were right for large-scale application.

Smart Grids

The successful deployment of any renewable electricity generation beyond the 20 percent threshold will require the development of a national smart grid to replace the currently outdated electrical transmission grid. A smart grid will allow for active load-balancing, to better manage peak power demand. This load balancing uses Internet technology to allow electricity suppliers to control consumers' use of that electricity, usually in exchange for a discounted price. An example of the desired effect of this load balancing is to prevent *all* the air-conditioners in one city from running at the exact same time. By spreading out which air-conditioners run, and when, in an organized way, the usable capacity of the electric grid is increased. Similarly, some electrical use, such as dishwashing and clothes washing, can be delayed by automatic control until nighttime, when electricity is in lower demand.

Many details of a smart grid are things that already can be and are done by consumers who pay peak utility rates to conserve money by shifting their purchases from on-peak to off-peak rates. A smart grid makes all of these efforts work synchronously to allow a greater utilization of power-plant capacity. When wind and solar are being used much more than they are now, the weather will begin to dictate when peak and off-peak periods will be. Conditions could change rapidly as an isolated cloud passes over a large industrial photovoltaic site. Thus, a smart grid will manage the various consumers of electricity in real time to make sure that electricity is available for those who need it, and is not used without thought about weather conditions and the electrical demand of consumers around them.

A smart grid will also allow a fleet of plug-in electric vehicles (EVs) to be effectively used as renewable energy sources for peak power demands. When drivers come home at about 5 P.M., instead of the car's charging system being added to an already overloaded grid, the car's batteries could be used to offset a home's use of energy from the grid. Thus, EVs connected to a smart grid have the potential not only to decrease consumption during times of peak demand, but also to increase the supply of electricity during these peak hours.

Many aspects of this smart grid are already being utilized by large consumers and energy producers. The future energy transition will certainly bring the incorporation of smart-grid technology into the home as well.

Wind Energy

New electricity production in many states is now more likely to be from wind turbines than from any other source of energy. This surge in new wind construction is only the result of technological advances begun in the 1970s having made wind energy the cheapest form of electricity in wind-favorable locations. Most of this expansion has been by utility-scale wind farms. In most areas, this new energy source has been welcomed, but in some areas, mostly mountaintop locations, it has not been welcomed by all.

Although there are enough wind resources in the United States to provide all of the nation's electrical and transportation energy demands, there are practical considerations that limit the use of wind much more than this. Using the current electrical grid, it is estimated that wind can supply about 20 percent of the nation's electricity. Beyond this, transmission lines will become overloaded trying to get additional wind-generated electricity to more distant consumers, or bringing in backup sources of electricity on non-windy days. However, a greatly expanded electrical grid with smart controls could be used to increase the amount of wind energy that can be utilized.

T. Boone Pickens' Plan for Breaking Wind in Texas

The bizarre scene of our energy transition reached a new level when an actor entered who had been a major player in the previous transition. Texas oil tycoon T. Boone Pickens unleashed a national series of television commercials during the summer of 2008 that scolded Americans for not having an energy plan. In the place of government leadership, Pickens offered his own plan on July 18, 2008, which called for huge investments in the development of alternatives, particularly wind, and the shifting of natural gas from electricity generation to powering vehicles. His plan, clearly, was about everything but the petroleum that had made Pickens wealthy. The online description of the plan concludes this way:

> The Pickens Plan is a bridge to the future—a blueprint to reduce foreign oil dependence by harnessing domestic energy alternatives, and buy us time to develop even greater new technologies.
>
> Building new wind generation facilities and better utilizing our natural gas resources can replace more than one-third of our foreign oil imports in 10 years. But it will take leadership.
>
> On January 20, 2009, a new President will take office.
>
> We're organizing behind the Pickens Plan now to ensure our voices will be heard by the next administration.
>
> Together we can raise a call for change and set a new course for America's energy future in the first hundred days of the new presidency—breaking the hammerlock of foreign oil and building a new domestic energy future for America with a focus on sustainability.
>
> You can start changing America's future today by supporting the Pickens Plan. (Pickens)

The centerpiece of the plan is wind development on the Texas Plains that is, in Texas style, gargantuan. The construction of a wind future on the Plains of Texas, of course, possesses some of the irony of the wind turbines atop Pennsylvania's Appalachian Mountains, which were discussed above. The complaints leveled against wind development in other areas of the United States have little traction in West Texas, a sparsely populated region also pockmarked with oil drilling and exploration equipment.

Texas already generates about 5,000 megawatts of wind power, more than any other state. Most of Texas' wind-energy production is in petroleum-producing West Texas, where nearly 4,000 wind turbines tower over oil-pump jacks and capture the breeze that blows across the flat and largely barren landscape. The new plan would not only build a slew of new turbines, but would also add transmission lines capable of moving electricity all over the country. State funds have been directed at building transmission lines that would carry wind-developed power to other regions. The economic stimulus bill of 2009 provides $4.5 billion for improvements to the national electric grid, thus manufacturing the opportunity for turbine developers to enter the picture.

Pickens' company, Mesa Power, is purchasing hundreds of wind turbines to eventually cover 400,000 acres near Pampa, Texas, and generate enough power for more than 1.3 million homes. "We are making Pampa the wind capital of the world," Pickens commented on his website. Pickens said it would be the world's largest wind farm, at a cost that could grow to $12 billion before its scheduled completion in 2014. "It's clear that landowners and local officials understand the economic benefits that this renewable energy can bring not only to landowners who are involved with the project, but also in revitalizing an area that has struggled in recent years," he said. (Pickens)

Rebirth of Nuclear Power

Perhaps the clearest sign of a sea change in public acceptance of nuclear power was during the 2008 U.S. presidential campaign. During this campaign, the candidates of both major parties made clear their support for the use of nuclear power as part of the energy mix in America. Prior to this, such public support for nuclear power would often mark the end of a political career. Even before this, the company Areva began a national advertising campaign for nuclear power. This sea-change was also evident in the actions of many different companies within the energy industry, as they have submitted applications for 26 new reactors in the United States (Deutch, 2009). Prior to 2007, there had been no such proposals made for nearly 30 years.

The driving force behind this desire for more nuclear power is varied. For some it just represents the lesser of two evils (coal and nuclear), while for others it represents a steady, clean, and relatively cheap source of energy; and of course there are those who remain opposed to nuclear power under any circumstances. Regardless, nuclear power does solve many of the problems associated with both fossil fuel and renewable energy sources, and presents a set of new problems. There are no emissions of any pollutants like there are with fossil fuels. The nuclear waste that is generated is completely contained and not released into the environment. It is the steadiest of all the sources of energy and is independent of weather (as well as, for the most part, of geography). New problems presented include the long-term storage of waste and the proliferation of nuclear weapons. Proponents of nuclear power say that these problems have been solved from a technological viewpoint, but just not acted upon for political purposes.

The reemergence of nuclear power has been decades in the making. Plant designs have been made more advanced and fail-safe than those of decades ago. Also, designs allow for faster construction, which reduces costs. But, perhaps most of all, nuclear power plants are cost-competitive, if not cheaper, than the full accounting of fossil fuel power plants. Because nuclear power is now viewed as cost-competitive, industry is now choosing to invest in this technology, and it appears that nuclear power will meet a larger portion of our electricity needs in the future.

In addition, nuclear power is viewed as a replacement for coal and natural gas electricity generation. Nuclear power plants now operate with a duty cycle of over 90 percent, which is much greater than any other type of power plant. They also run independent of weather conditions, making them ideal for base-load power. These factors have led to the rebirth of nuclear power, and time will tell how completely nuclear power will be embraced by society.

But nuclear power cannot be the single solution to our energy crisis, at least not in the form currently used in the United States. There is not enough uranium in the world to supply a vastly expanded use of nuclear power for a time period of a century or so. In order for uranium to be a lasting part of our energy mix, it will become necessary for the science of breeder reactors and reprocessing nuclear waste into new plutonium and thorium fuel to take precedent over the politics of not wanting to reprocess nuclear waste. This reprocessing of nuclear waste is sometimes called a "closed fuel cycle," to indicate that fuel is used to make more fuel and not as much waste needs to be generated. Although other nations such as Japan, France, and Russia currently reprocess their nuclear waste, the United States has had a policy for over 30 years to not reprocess nuclear waste. This political policy was adopted in the hope of stopping the spread of nuclear weapons around the world. However, as is evidenced by North Korea, Pakistan, India, Israel, and South

Africa, this policy has failed. Many of the latest reactor designs being pursued internationally allow for the reprocessing of nuclear waste, so that nuclear power can provide energy for centuries more while reducing the amount of high-level waste that must be stored long-term.

The Increasing Use of Biofuels

Possibly the most significant change in the energy transition of 2008 was the broadening of production and use of biofuels. In 2006, when President George W. Bush castigated Americans for their addiction to oil, he called for the use of alternatives to produce biofuels, including switchgrass. Most experts expect that in the first decade of the 21st century there will appear a mad rush to biofuels, homegrown gasoline, and diesel substitutes made from crops like corn, soybeans, and sugarcane. These technologies had been around for a century, but now were thrust forward as the most effective transitional energy source as humans considered other ways to power transportation. Although most were never intended for use on a massive scale, biofuels became major players in the energy sector with high gas prices.

The image is enticing to many Americans: not only liberating Americans from Middle East oil but also pumping that revenue into the declining rural economy of the United States. The entire industry, though, remains based in speculation and uncertainty. Biofuels as currently rendered in the United States are doing great things for some farmers and for agricultural corporations, including Archer Daniels Midland and Cargill. Most Americans see ethanol as a green alternative, ethanol plants burn natural gas or, increasingly, coal, to create the steam that drives the distillation. Additionally, diesel farm machinery is used to tend the fields, and natural gas-based fertilizers and herbicides are used to maximize the crop yield, leading to substantial use of fossil fuels to make ethanol. “Biofuels are a total waste and are misleading us from getting at what we really need to do: conservation,” says Cornell University’s David Pimentel, who is one of ethanol’s harshest critics. “This is a threat, not a service. Many people are seeing this as a boondoggle” (National Geographic).

Fortunately, with improvements in technology, the ethanol yield has improved and is now approaching 500 gallons per acre for corn, and the energy content of that yield is approaching a 50 percent increase over the total fossil energy required to produce the ethanol. Perhaps even more important is that most of the fossil energy put into ethanol production is in the form of natural gas and coal. Thus, ethanol effectively serves as a method of converting natural gas and coal into a somewhat larger amount of liquid fuel for transportation.

Three factors came together in the early 2000s to make ethanol less an alternative fuel and to move it into the mainstream, which included record high prices for petroleum, the phaseout of the MTBE gasoline additive, and society's desire to become more energy independent. Ethanol production has responded to these factors, going from 50 million barrels in 2002 to over 200 million barrels in 2008. Continued increases in production will be limited by the ability to grow suitable feedstock for biofuels. For instance, experts estimate that even if we turned our entire corn and soybean crop into biofuels, together they would replace only 12 percent of our gasoline and 6 percent of our diesel. And getting just to this point would require replacing each of these crops in their other roles as feed to various animals (including pork, beef, and poultry).

The push to produce more ethanol has quickly revealed some of the problems associated with biofuels. The growth in ethanol production has pushed corn demand to heights not seen in years, affecting food prices and spurring U.S. growers to plant the largest crops since World War II. Around a fifth of the harvest will be brewed into ethanol—more than double the amount only five years ago. Corn is not the only crop that is problematically being made into fuel. From an environmental perspective, biodiesel from soybeans fares only slightly better. Rising prices for both crops pushed farmers to plow up more land than in previous years—approximately 35 million acres of marginal farmland now set aside for soil and wildlife conservation and in areas too arid for farming without depleting subsurface aquifers. But most disturbing of all is the impact upon global trade as the United States exports less corn and soybeans. This lack of U.S. food exports has led to increased crop production elsewhere in the world, namely Brazil and Indonesia, where rainforests were clear-cut and plowed into new farmland. The carbon footprint of an acre of rainforest being turned into cropland, effectively for biofuel production, is much worse than if fossil fuels had been used in the first place.

These considerations have led pilot projects in the United States to experiment with making ethanol from cellulose acquired from non-crop biomass (switchgrass, wood). One ton can be converted into 70 gallons of ethanol in about a week. Overall, the current process is about half as efficient as that of deriving the energy from crude oil. If the technology is improved, non-crop biomass feedstock can be grown on land without displacing current crops. Furthermore, switchgrass and fast-growing trees can also be grown with a much lower environmental impact when the actual planting, tending, and harvesting procedures are taken into account. Another potential plant that scientists are experimenting with as a biofuel feedstock is one that is much simpler: algae—single-celled pond scum.

Since the plant does not require farmable land resources and can instead be grown even in wastewater, many experts believe algae-based fuels are the only feedstock with the potential to reach the supply levels required to make a significant impact on our energy use.

Giving Solar a Chance

Another slice of the new energy supply pie will likely derive from the oldest source of power. New, large-scale efforts to put solar power to work have recently taken shape in California. Two separate companies are constructing solar plants that will be ten times bigger than those now in use. Spurred by state mandates to derive 20 percent of its electricity from renewable sources by 2010, Pacific Gas and Electric will purchase the plants' electricity.

Each plant uses photovoltaic technology, which turns sunlight directly into electricity instead of using it to heat water. OptiSolar, a company that has just begun to make thin-film solar panels—with a layer of semiconductor material thinner than a human hair on the back of a glass panel—will install 550 megawatts in San Luis Obispo County, in central California. And the SunPower Corporation, which uses crystalline cells, will build 250 megawatts in the same county. The OptiSolar plant will cover about nine square miles, and the SunPower plant about 3.5, although the actual cell area will be smaller. Together, these plants will generate a total of 800 megawatts.

A megawatt is enough power to run a large Wal-Mart. At peak hours, together the plants will produce as much power as a large coal or nuclear power plant. But they will run far fewer hours of the year, so output will be at least a third less than that of a coal plant of the same size. SunPower's panels are mounted at a 20-degree angle, facing south, and pivot over the course of the day so they continuously face the sun. OptiSolar's panels are installed at a fixed angle. They are larger and less efficient, but much less costly, so that the cost per watt of energy is similar, company executives said. (OptiSolar)

Solar energy, both photovoltaic and thermal, which uses the sun's heat to make steam, is bounding ahead, driven mostly by state quotas and government incentives. California requires that 20 percent of the kilowatt-hours sold by investor-owned utilities come from renewable sources by 2010, a goal that some companies are struggling to meet. Pacific Gas and Electric expects that when these two solar plants are completed, their total will rise to 24 percent, but that will not be until 2013.

The planned California installations raise questions about the idea that solar power is best deployed on the roofs of houses and businesses. Although building units near their point of use can help avoid transmission expenses, the companies said that by building on a gargantuan scale, they expected to achieve economies of scale in the cost of design, installation, and connection to the grid, as well as marketing and overhead. A typical home installation is several thousandths of a megawatt, while these proposed units are in the hundreds of megawatts. Boosting the solar manufacturing base with such large projects is an important step toward lowering the cost of solar energy, for both large commercial projects and for smaller distributed rooftop systems, for future generations.

CONCLUSION: MAKING ALTERNATIVES PRIMARY

It would appear that the lifecycle of alternative fuels has arrived at a new juncture in human history. Just as wind turbines, a symbol of alternative approaches to power production, are appearing along the ridgelines of Central Pennsylvania, they can now be found revitalizing one of their primary points of origin: the Netherlands. In chapter 2, we explored the early years of energy use—when almost all the power available derived from renewable sources. The windmills of early industry in places such as the Netherlands were private or community enterprises. Today's efforts are most often developed by private companies, but as part of, or with the help of, large government initiatives.

In the Netherlands, for instance, the government has invested more than $80 million to restore some of the 1,040 older mills already in existence. Many of them have been retrofitted to generate electricity instead of to grind grain. In addition, the government has constructed one large-scale wind farm off the coast and has plans for others. Making the Netherlands' adoption of alternative power easier, of course, is the nation's small population, size, and, commensurately, footprint. Such changes are more complicated in nations that have allowed themselves to grow more dependent on fossil fuels.

The United States, ground-zero for humans' high-energy lifestyle in the 20th century, has been slower than the Netherlands and many European nations in creating effective government stimuli for the development of wind power and other alternative energy. One of the most recent developments in our energy transition, though, has been a clear sea change in Americans' interest in and openness toward deriving their energy from sources other than fossil fuels. Linked to the ethic of modern environmentalism, green power options moved to the mainstream in the 21st century, including incorporation into the economic stimulus initiatives of 2009 that grew from the business potential of these new opportunities. Again, we recall the 2008 speech of Nobel Laureate Al Gore, cited in the Introduction, when he urged his listeners:

> What could we do instead for the next 10 years? What should we do during the next 10 years? Some of our greatest accomplishments as a nation have resulted from commitments to reach a goal that fell well beyond the next election: the Marshall

Plan, Social Security, and the interstate highway system. But a political promise to do something 40 years from now is universally ignored because everyone knows that it's meaningless.

Ten years is about the maximum time that we as a nation can hold a steady aim and hit our target. When President John F. Kennedy challenged our nation to land a man on the moon and bring him back safely in 10 years, many people doubted we could accomplish that goal. But eight years and two months later, Neil Armstrong and Buzz Aldrin walked on the surface of the moon. . . .

On July 16, 1969, the United States of America was finally ready to meet President Kennedy's challenge of landing Americans on the moon. I will never forget standing beside my father a few miles from the launch site, waiting for the giant Saturn 5 rocket to lift Apollo 11 into the sky. I was a young man, 21 years old, who had graduated from college a month before and was enlisting in the United States Army three weeks later.

I will never forget the inspiration of those minutes. The power and the vibration of the giant rocket's engines shook my entire body. As I watched the rocket rise, slowly at first and then with great speed, the sound was deafening. We craned our necks to follow its path until we were looking straight up into the air. And then four days later, I watched along with hundreds of millions of others around the world as Neil Armstrong took one small step to the surface of the moon and changed the history of the human race. We must now lift our nation to reach another goal that will change history.

Our entire civilization depends upon us now embarking on a new journey of exploration and discovery. Our success depends on our willingness as a people to undertake this journey and to complete it within 10 years. Once again, we have an opportunity to take a giant leap for humankind. (See Appendix 4)

How does one lead an energy transition forward? Although each candidate for U.S. President has always discussed initiatives in this area, President Jimmy Carter demonstrated the difficulty of the Oval Office's attempting to lead technological innovation. It appears that the Obama administration has adopted a more integrated approach than that of Carter or any other U.S. President. Such initiatives, though, succeed or fail based on the public reaction to them.

In order to further this transition, we must return to some of the basic roots of Americans' 20th-century high-energy binge: the culture of consumption. With informed consumption, consumers might play the most critical role in America's energy future. Since Americans first considered energy conservation to be part of their lifestyle in the 1970s, modern environmentalism has bred an entirely new genre of consumption, referred to as "green consumerism." In fact, across the board, mass consumption contains a thread of greenness—conservation thought—that runs diametrically opposed to the ethic behind our expansion into the high-energy lifestyle of the mid-20th century. History has taught us that such revisionary shifts in lifestyle do not fare well when presented to Americans from the top down; instead, we now operate in an information era in which well-informed consumers might steer producers toward more sustainable and, often, economical uses of energy.

A one-size-fits-all energy strategy neither can nor should be mandated by the U.S. federal government. However, neither can society wait for a perfect solution to present itself as the path to a new energy future. By waiting for a perfect solution, America will fail to move forward and will ultimately rely on technologies developed in nations that have more actively pursued alternative sources of energy. The successful freeway to America's energy future will have many lanes representing a variety of energy sources; including even the clean use of the remaining fossil fuels. Each energy source will have its own set of imperfections. Perhaps the only technology that must be pursued is an expanded and modernized smart grid, which benefits all sources of power by helping to more efficiently meet the demands of society. A smart grid will allow the many energy sources to both compete and coordinate with each other. Such a competitive energy economy, including the consideration of the full life cycles of each energy source, holds the most promise for American society. No more fear of dwindling supplies, high prices, and reliance on other nations. The United States should move forward on many fronts to a diversified energy future.

In such an energy market, alternative sources of energy can no longer remain in their current status. As our energy transition proceeds, the most likely outcome is a diverse energy mix built upon the backbone of a modernized, smart electrical grid that draws power from a wide variety of sources, prioritizing those that are sustainable and even renewable, and sends that power along to the consumer. Government must play an even more significant role in regulating and enforcing a fuller accounting of all energy sources, because individuals are too far removed by both geography and generations from observing the negative impacts of using cheap energy. When the entire life cycle of energy sources are priced correctly and Americans are given a more honest choice of various energy sources, the alternatives with which humans began a few centuries ago rise to the top. These sources of power demand innovation and mainstream use.

Let the next phase of our energy transition begin with educated consumers valuing energy in this profoundly new fashion.

Appendix 1

Summaries of U.S. Legislation Provisions Related to Alternative Energy

This appendix contains summaries of some of the legislation pertinent to alternative fuels since the late 1970s.

1978: THE ENERGY TAX ACT OF 1978 (ETA) (P.L. 95–618)

Residential energy (income) tax credits for solar and wind energy equipment expenditures: 30 percent of the first $2,000 and 20 percent of the next $8,000.

Business energy tax credit: 10 percent for investments in solar, wind, geothermal, and ocean thermal technologies (in addition to standard 10 percent investment tax credit available on all types of equipment, except for property that also served as structural components, such as some types of solar collectors; e.g., roof panels). In sum, investors were eligible to receive income tax credits of up to 25 percent of the cost of the technology.

Percentage depletion for geothermal deposits: depletion allowance rate of 22 percent for 1978–1980 and 15 percent after 1983.

1980: THE CRUDE OIL WINDFALL PROFITS TAX ACT OF 1980 (WPT) (P.L. 96–223)

Increased the ETA residential energy tax credits for solar, wind, and geothermal technologies from 30 percent to 40 percent of the first $10,000 in expenditures.

Increased the ETA business energy tax credit for solar, wind, geothermal, and ocean thermal technologies from 10 percent to 15 percent, and extended the credits from December 1982 to December 1985.

Expanded and liberalized the tax credit for equipment that either converted biomass into a synthetic fuel, burned the synthetic fuel, or used the biomass as a fuel.

Allowed tax-exempt interest on industrial development bonds for the development of solid waste-to-energy (WTE) producing facilities, for hydroelectric facilities, and for facilities for producing renewable energy.

1981: THE ECONOMIC RECOVERY TAX ACT OF 1981 (ERTA) (P.L. 97–34)

Allowed accelerated depreciation of capital (five years for most renewable energy-related equipment), known as the Accelerated Cost Recovery System (ACRS); public utility property was not eligible.

Provided for a 25 percent tax credit against the income tax for incremental expenditures on research and development (R&D).

1982: THE TAX EQUITY AND FISCAL RESPONSIBILITY ACT OF 1982 (TEFRA) (P.L. 97–248)

Canceled further accelerations in ACRS mandated by ERTA, and provided for a basis adjustment provision that reduced the cost basis for ACRS purposes by the full amount of any regular tax credits, energy tax credits, and rehabilitation tax credits.

1982–85: THE TERMINATION OF ENERGY TAX CREDITS

In December 1982, the 1978 ETA energy tax credits terminated for the following categories of non-renewable energy property: alternative energy property such as synfuels equipment and recycling equipment, equipment for producing gas from geopressurized brine, shale-oil equipment, and cogeneration equipment. The remaining energy tax credits, extended by the WPT, terminated on December 31, 1985.

1986: THE TAX REFORM ACT OF 1986 (P.L. 99–514)

Repealed the standard 10 percent investment tax credit.

Eliminated the tax-free status of municipal solid waste (MSW) power plants (WTE) financed with industrial development bonds, reduced accelerated depreciation, and eliminated the 10 percent tax credit (P.L. 96–223).

Extended the WPT business energy tax credit for solar property through 1988 at the rates of 15 percent for 1986, 12 percent for 1987, and 10 percent for 1988; for geothermal property through 1988 at the rates of 15 percent for 1986, and 10 percent for 1987 and 1988; for ocean thermal property through 1988 at the rate of 15 percent; and for biomass property through 1987 at the rates of 15 percent for 1986, and 10 percent for 1987. (The business energy tax credit for wind systems was not extended and, consequently, expired on December 31, 1985.)

Public utility property became eligible for accelerated depreciation.

1992: THE ENERGY POLICY ACT OF 1992 (EPACT) (P.L. 102–486)

Established a permanent 10 percent business energy tax credit for investments in solar and geothermal equipment.

Established a 10-year, 1.5 cents per kilowatt-hour (kWh) production tax credit (PTC) for privately owned as well as investor-owned wind projects and biomass plants using dedicated crops (closed-loop) brought on-line between 1994 and 1993, respectively, and on June 30, 1999.

Instituted the Renewable Energy Production Incentive (REPI), which provides an incentive of 1.5 cents per kWh (subject to annual congressional appropriations (section 1212)), for generation from biomass (except municipal solid waste), geothermal (except dry steam), wind, and solar by tax-exempt, publicly owned utilities and rural cooperatives.

Indefinitely extended the 10 percent business energy tax credit for solar and geothermal projects.

1999: THE TAX RELIEF EXTENSION ACT OF 1999 (P.L. 106–170)

Extends and modifies the production tax credit (PTC in EPACT) for electricity produced by wind and closed-loop biomass facilities. The tax credit is expanded to include poultry waste facilities, including those that are government-owned. All three types of facilities are qualified if placed in service before January 1, 2002. Poultry waste facilities must have been in service after 1999.

A nonrefundable tax credit of 20 percent is available for incremental research expenses paid or incurred in a trade or business.

Notes: The residential energy credit provided a credit (offset) against tax due for a portion of taxpayer expenditures for energy conservation and renewable energy sources. The general business credit is a limited nonrefundable credit (offset) against income tax that is claimed after all other nonrefundable credits.

2001: The Economic Security and Recovery Act of 2001 (P. 107–104), which was signed into law in early 2002, includes a two-year extension of the production tax credit (PTC) for new wind, closed-loop biomass, and poultry waste facilities. The production tax credit, created originally in the Energy Policy Act of 1992, provided an inflation-adjusted tax credit of 1.5 cents per kilowatt-hour for electricity generated from qualifying projects. Under the new law, the production tax credit is now extended retroactively from the end of 2001 to December 31, 2003.

Source: DOE, http://www.eia.doe.gov/cneaf/solar.renewables/page/legisla tion/impact.html.

Note: Transportation: "FLEX FUEL" description introduced through AMFA with this language:

A "dual energy" vehicle is defined by AMFA as one:

i) Which is capable of operating on alcohol and on gasoline or diesel fuel;
ii) Which provides equal or superior energy efficiency, as calculated for the applicable model year during fuel economy testing for the Federal Government, while operating on alcohol as it does while operating on gasoline and diesel fuel; and
iii) Which, for model years 1993 through 1995 and, if the Administrator of the Environmental Protection Agency determines that an extension of this clause is warranted, for an additional period ending not later than the end of the last model year for which sections 513(b) and (d) apply, provides equal or superior energy efficiency, as calculated for the applicable model year during fuel economy testing for the Federal Government, while operating on a mixture of alcohol and gasoline or diesel fuel containing exactly 50 percent gasoline or diesel fuel as it does while operating on gasoline or diesel fuel . . .

Similarly, a "natural gas dual energy" vehicle is one:

i) Which is capable of operating on natural gas and on gasoline or diesel fuel; and
ii) Which provides equal or superior energy efficiency as calculated for the applicable model year during fuel economy testing for the Federal Government, while operating on natural gas as it does while operating on gasoline or diesel fuel . . .

AMFA directed NHTSA to establish two minimum driving ranges: one specification for the alcohol/gasoline or diesel dual-energy vehicles when operating on alcohol and the other for natural gas dual-energy vehicles while operating on natural gas. In establishing these criteria, AMFA directed the agency to consider consumer acceptability, economic practicability, technology, environmental impact, safety, driveability, performance, and other factors considered relevant. The minimum driving range for alcohol vehicles was set at 200 miles, and natural gas vehicle range was required to meet or exceed 100 miles. EPACT amended the natural gas dual-energy driving range to 200 miles. NHTSA codified this requirement in April 1996. EPACT also revised the terminology of the AMFA-qualified fuels. Section 301.8(A) of EPACT revised the definitions in Section 513h.1.C of the Motor Vehicle Information and Cost Savings Act by redefining both "dual-energy" and "natural gas dual-energy" vehicles as "dual-fuel" vehicles. In addition, a broader category of "alternative-fuel" vehicles was established that would also include vehicles capable of operating on liquefied petroleum gas, hydrogen, coal-derived liquefied petroleum, and fuels derived from biological materials. It also would include electric vehicles, which included those deriving power from battery sources and solar energy, ethers, and any other materials that the Secretary of Energy deemed to be substantially non-petroleum in origin, and which delivered substantial energy security and environmental benefits.

Section 6 of AMFA amended the fuel economy provisions of Title V of the Motor Vehicle Information and Cost Savings Act through the addition of section 513, which provides CAFE incentives for vehicles capable of operating on alternative fuels. Beginning in May 1993, manufacturers of alternative-fuel vehicles could qualify for special treatment in the calculation of their CAFE by computing the weighted average of the fuel economy while operating on gasoline or diesel fuel, and when operating on alcohol after dividing the alcohol fuel economy by a factor of 0.15. As an example, a dedicated alternative-fuel vehicle that would achieve a 15 mpg fuel economy while operating on alcohol would have a CAFE calculated as follows:

$$FE = (1/0.15)(15) = 100 \text{ mpg.}$$

For alternative dual-fuel vehicles, an assumption is made that the vehicles would operate 50 percent of the time on the alternative fuel and 50 percent of the time on conventional fuel, resulting in a fuel economy that is based on a harmonic average of alternative fuel and conventional fuel. The fuel economy for an alternative dual-fuel model is calculated by dividing 1.0 by the sum of 0.5 divided by the fuel economy as measured for the conventional fuel, and 0.5 divided by the fuel economy as measured for the alternative fuel, using the 0.15 volumetric conversion factor. For example, for an alternative dual-fuel model that achieves 15 mpg operating on an alcohol fuel and 25 mpg on the conventional fuel, the resulting CAFE would be:

$$FE = 1/(0.5/25) + (0.5/100) = 40 \text{ mpg.}$$

Calculation of fuel economy for natural gas vehicles is performed in a similar fashion. For the purposes of this calculation, the fuel economy is equal to the weighted average of the fuel economy while operating on natural gas and while operating on either gasoline or diesel fuel. AMFA specifies that the energy equivalency of 100 cubic feet of natural gas be equal to 0.823 gallons of gasoline, with the gallon equivalency of natural gas to be considered to have a fuel content, similar to that for alcohol fuels, equal to 0.15 gallons of fuel (49 U.S.C. §329059(c)). Calculations to determine the adjusted CAFE values for natural gas alternative-fuel vehicles are performed in similar fashion. For example, under this conversion and gallon equivalency, a dedicated natural gas vehicle that achieves 25 miles per 100 cubic feet of natural gas would have a CAFE value as follows:

$$FE = (25/100) \times (100/0.823)(1/0.15) = 203 \text{ mpg}.$$

These calculation procedures, along with the fuel economy testing procedures for alternative-fuel vehicles, were codified by the EPA in 1994 (59 FR 39638; August 3, 1994).

AMFA also limits the extent to which these special considerations can improve a manufacturer's average fuel economy. For model years 1993 through 2004, the maximum increase that can be attributed to this program is 1.2 mpg for each category of automobiles (domestic and import passenger car fleets and light truck fleets). The incentive program can be extended at the approval of the Secretary of Transportation for up to four years beyond MY 2004, but at a ceiling reduced from 1.2 mpg to 0.9 mpg. In the event that the Secretary of Transportation reduces the current CAFE requirement from 27.5 mpg for any model year, any increase of CAFE resulting from the AMFA calculation will be reduced by the CAFE standard, but may not be reduced to yield less than 0.7 mpg (49 U.S.C. §32906(b)).

Appendix 2

President Jimmy Carter's Speech Concerning Energy, April 18, 1977

Tonight I want to have an unpleasant talk with you about a problem unprecedented in our history. With the exception of preventing war, this is the greatest challenge our country will face during our lifetimes. The energy crisis has not yet overwhelmed us, but it will if we do not act quickly.

It is a problem we will not solve in the next few years, and it is likely to get progressively worse through the rest of this century.

We must not be selfish or timid if we hope to have a decent world for our children and grandchildren.

We simply must balance our demand for energy with our rapidly shrinking resources. By acting now, we can control our future instead of letting the future control us.

Two days from now, I will present my energy proposals to the Congress. Its members will be my partners and they have already given me a great deal of valuable advice. Many of these proposals will be unpopular. Some will cause you to put up with inconveniences and to make sacrifices.

The most important thing about these proposals is that the alternative may be a national catastrophe. Further delay can affect our strength and our power as a nation.

Our decision about energy will test the character of the American people and the ability of the President and the Congress to govern. This difficult effort will be the "moral equivalent of war"—except that we will be uniting our efforts to build and not destroy.

I know that some of you may doubt that we face real energy shortages. The 1973 gasoline lines are gone, and our homes are warm again. But our energy problem is worse tonight than it was in 1973 or a few weeks ago in the dead of winter. It is worse because more waste has occurred, and more time has passed by without our planning for the future. And it will get worse every day until we act.

The oil and natural gas we rely on for 75 percent of our energy are running out. In spite of increased effort, domestic production has been dropping steadily at about six percent a year. Imports have doubled in the last five years. Our nation's independence of economic and political action is becoming increasingly constrained. Unless profound changes are made to lower oil consumption, we now believe that early in the 1980s the world will be demanding more oil that it can produce.

The world now uses about 60 million barrels of oil a day and demand increases each year about 5 percent. This means that just to stay even we need the production of a new Texas every year, an Alaskan North Slope every nine months, or a new Saudi Arabia every three years. Obviously, this cannot continue.

We must look back in history to understand our energy problem. Twice in the last several hundred years there has been a transition in the way people use energy.

The first was about 200 years ago, away from wood—which had provided about 90 percent of all fuel—to coal, which was more efficient. This change became the basis of the Industrial Revolution.

The second change took place in this century, with the growing use of oil and natural gas. They were more convenient and cheaper than coal, and the supply seemed to be almost without limit. They made possible the age of automobile and airplane travel. Nearly everyone who is alive today grew up during this age and we have never known anything different.

Because we are now running out of gas and oil, we must prepare quickly for a third change, to strict conservation and to the use of coal and permanent renewable energy sources, like solar power.

The world has not prepared for the future. During the 1950s, people used twice as much oil as during the 1940s. During the 1960s, we used twice as much as during the 1950s. And in each of those decades, more oil was consumed than in all of mankind's previous history.

World consumption of oil is still going up. If it were possible to keep it rising during the 1970s and 1980s by 5 percent a year as it has in the past, we could use up all the proven reserves of oil in the entire world by the end of the next decade.

I know that many of you have suspected that some supplies of oil and gas are being withheld. You may be right, but suspicions about oil companies cannot change the fact that we are running out of petroleum.

All of us have heard about the large oil fields on Alaska's North Slope. In a few years when the North Slope is producing fully, its total output will be just about equal to two years' increase in our nation's energy demand.

Each new inventory of world oil reserves has been more disturbing than the last. World oil production can probably keep going up for another six or eight years. But some time in the 1980s it can't go up much more. Demand will overtake production. We have no choice about that.

But we do have a choice about how we will spend the next few years. Each American uses the energy equivalent of 60 barrels of oil per person each year. Ours is the most wasteful nation on earth. We waste more energy than we import. With about the same standard of living, we use twice as much energy per person as do other countries like Germany, Japan and Sweden.

One choice is to continue doing what we have been doing before. We can drift along for a few more years.

Our consumption of oil would keep going up every year. Our cars would continue to be too large and inefficient. Three-quarters of them would continue to carry only one person—the driver—while our public transportation system continues to decline. We can delay insulating our houses, and they will continue to lose about 50 percent of their heat in waste.

We can continue using scarce oil and natural to generate electricity, and continue wasting two-thirds of their fuel value in the process.

If we do not act, then by 1985 we will be using 33 percent more energy than we do today.

We can't substantially increase our domestic production, so we would need to import twice as much oil as we do now. Supplies will be uncertain. The cost will keep going up. Six years ago, we paid $3.7 billion for imported oil. Last year we spent $37 billion—nearly ten times as much—and this year we may spend over $45 billion.

Unless we act, we will spend more than $550 billion for imported oil by 1985—more than $2,500 a year for every man, woman, and child in America. Along with that money we will continue losing American jobs and becoming increasingly vulnerable to supply interruptions.

Now we have a choice. But if we wait, we will live in fear of embargoes. We could endanger our freedom as a sovereign nation to act in foreign affairs. Within ten years we would not be able to import enough oil—from any country, at any acceptable price.

If we wait, and do not act, then our factories will not be able to keep our people on the job with reduced supplies of fuel. Too few of our utilities will have switched to coal, our most abundant energy source.

We will not be ready to keep our transportation system running with smaller, more efficient cars and a better network of buses, trains and public transportation.

We will feel mounting pressure to plunder the environment. We will have a crash program to build more nuclear plants, strip-mine and burn more coal, and drill more offshore wells than we will need if we begin to conserve now. Inflation will soar, production will go down, people will lose their jobs. Intense competition will build up among nations and among the different regions within our own country.

If we fail to act soon, we will face an economic, social and political crisis that will threaten our free institutions.

But we still have another choice. We can begin to prepare right now. We can decide to act while there is time.

That is the concept of the energy policy we will present on Wednesday. Our national energy plan is based on ten fundamental principles.

The first principle is that we can have an effective and comprehensive energy policy only if the government takes responsibility for it and if the people understand the seriousness of the challenge and are willing to make sacrifices.

The second principle is that healthy economic growth must continue. Only by saving energy can we maintain our standard of living and keep our people at work. An effective conservation program will create hundreds of thousands of new jobs.

The third principle is that we must protect the environment. Our energy problems have the same cause as our environmental problems—wasteful use of resources. Conservation helps us solve both at once.

The fourth principle is that we must reduce our vulnerability to potentially devastating embargoes. We can protect ourselves from uncertain supplies by reducing our demand for oil, making the most of our abundant resources such as coal, and developing a strategic petroleum reserve.

The fifth principle is that we must be fair. Our solutions must ask equal sacrifices from every region, every class of people, every interest group. Industry will have to do its part to conserve, just as the consumers will. The energy producers deserve fair treatment, but we will not let the oil companies profiteer.

The sixth principle, and the cornerstone of our policy, is to reduce the demand through conservation. Our emphasis on conservation is a clear difference between this plan and others which merely encouraged crash production efforts. Conservation is the quickest, cheapest, most practical source of energy. Conservation is the only way we can buy a barrel of oil for a few dollars. It costs about $13 to waste it.

The seventh principle is that prices should generally reflect the true replacement costs of energy. We are only cheating ourselves if we make energy artificially cheap and use more than we can really afford.

The eighth principle is that government policies must be predictable and certain. Both consumers and producers need policies they can count on so they can plan ahead. This is one reason I am working with the Congress to create a new Department of Energy, to replace more than 50 different agencies that now have some control over energy.

The ninth principle is that we must conserve the fuels that are scarcest and make the most of those that are more plentiful. We can't continue to use oil and gas for 75 percent of our consumption when they make up seven percent of our domestic reserves. We need to shift to plentiful coal while taking care to protect the environment, and to apply stricter safety standards to nuclear energy.

The tenth principle is that we must start now to develop the new, unconventional sources of energy we will rely on in the next century.

These ten principles have guided the development of the policy I would describe to you and the Congress on Wednesday.

Our energy plan will also include a number of specific goals, to measure our progress toward a stable energy system.

These are the goals we set for 1985:

—Reduce the annual growth rate in our energy demand to less than two percent.
—Reduce gasoline consumption by ten percent below its current level.
—Cut in half the portion of United States oil which is imported, from a potential level of 16 million barrels to six million barrels a day.
—Establish a strategic petroleum reserve of one billion barrels, more than six months' supply.
—Increase our coal production by about two thirds to more than 1 billion tons a year.
—Insulate 90 percent of American homes and all new buildings.
—Use solar energy in more than two and one-half million houses.

We will monitor our progress toward these goals year by year. Our plan will call for stricter conservation measures if we fall behind.

I can't tell you that these measures will be easy, nor will they be popular. But I think most of you realize that a policy which does not ask for changes or sacrifices would not be an effective policy.

This plan is essential to protect our jobs, our environment, our standard of living, and our future.

Whether this plan truly makes a difference will be decided not here in Washington, but in every town and every factory, in every home an don every highway and every farm.

I believe this can be a positive challenge. There is something especially American in the kinds of changes we have to make. We have been proud, through our history of being efficient people.

We have been proud of our leadership in the world. Now we have a chance again to give the world a positive example.

And we have been proud of our vision of the future. We have always wanted to give our children and grandchildren a world richer in possibilities than we've had. They are the ones we must provide for now. They are the ones who will suffer most if we don't act.

I've given you some of the principles of the plan.

I am sure each of you will find something you don't like about the specifics of our proposal. It will demand that we make sacrifices and changes in our lives. To some degree, the sacrifices will be painful—but so is any meaningful sacrifice. It will lead to some higher costs, and to some greater inconveniences for everyone.

But the sacrifices will be gradual, realistic and necessary. Above all, they will be fair. No one will gain an unfair advantage through this plan. No one will be asked to bear an unfair burden. We will monitor the accuracy of data from the oil and natural gas companies, so that we will know their true production, supplies, reserves, and profits.

The citizens who insist on driving large, unnecessarily powerful cars must expect to pay more for that luxury.

We can be sure that all the special interest groups in the country will attack the part of this plan that affects them directly. They will say that sacrifice is fine, as long as other people do it, but that their sacrifice is unreasonable, or unfair, or harmful to the country. If they succeed, then the burden on the ordinary citizen, who is not organized into an interest group, would be crushing.

There should be only one test for this program: whether it will help our country.

Other generation of Americans have faced and mastered great challenges. I have faith that meeting this challenge will make our own lives even richer. If you will join me so that we can work together with patriotism and courage, we will again prove that our great nation can lead the world into an age of peace, independence and freedom.

Source: Originally published in a slightly different form in April 18, 1977. In *Vital Speeches of the Day*, vol. XXXXIII, no. (14, May 1, 1977), 418–420. Reprinted by permission of the author and the publisher.

Appendix 3

President Jimmy Carter: The "Crisis of Confidence" Speech, July 15, 1979

Good evening. This is a special night for me. Exactly three years ago, on July 15, 1976, I accepted the nomination of my party to run for president of the United States.

I promised you a president who is not isolated from the people, who feels your pain, and who shares your dreams and who draws his strength and his wisdom from you.

During the past three years I've spoken to you on many occasions about national concerns, the energy crisis, reorganizing the government, our nation's economy, and issues of war and especially peace. But over those years the subjects of the speeches, the talks, and the press conferences have become increasingly narrow, focused more and more on what the isolated world of Washington thinks is important. Gradually, you've heard more and more about what the government thinks or what the government should be doing and less and less about our nation's hopes, our dreams, and our vision of the future.

Ten days ago I had planned to speak to you again about a very important subject—energy. For the fifth time I would have described the urgency of the problem and laid out a series of legislative recommendations to the Congress. But as I was preparing to speak, I began to ask myself the same question that I now know has been troubling many of you. Why have we not been able to get together as a nation to resolve our serious energy problem?

It's clear that the true problems of our Nation are much deeper—deeper than gasoline lines or energy shortages, deeper even than inflation or recession. And I realize more than ever that as president I need your help. So I decided to reach out and listen to the voices of America. . . .

After listening to the American people, I have been reminded again that all the legislation in the world can't fix what's wrong with America. So, I want to speak to you first tonight about a subject even more serious than energy or inflation. I want to talk to you right now about a fundamental threat to American democracy.

I do not mean our political and civil liberties. They will endure. And I do not refer to the outward strength of America, a nation that is at peace tonight everywhere in the world, with unmatched economic power and military might.

The threat is nearly invisible in ordinary ways. It is a crisis of confidence. It is a crisis that strikes at the very heart and soul and spirit of our national will. We can see this crisis in the growing doubt about the meaning of our own lives and in the loss of a unity of purpose for our nation. . . .

We are at a turning point in our history. There are two paths to choose. One is a path I've warned about tonight, the path that leads to fragmentation and self-interest. Down that road lies a mistaken idea of freedom, the right to grasp for ourselves some advantage over others. That path would be one of constant conflict between narrow interests ending in chaos and immobility. It is a certain route to failure.

All the traditions of our past, all the lessons of our heritage, all the promises of our future point to another path, the path of common purpose and the restoration of American values. That path leads to true freedom for our nation and ourselves. We can take the first steps down that path as we begin to solve our energy problem.

Energy will be the immediate test of our ability to unite this nation, and it can also be the standard around which we rally. On the battlefield of energy we can win for our nation a new confidence, and we can seize control again of our common destiny.

In little more than two decades we've gone from a position of energy independence to one in which almost half the oil we use comes from foreign countries, at prices that are going through the roof. Our excessive dependence on OPEC has already taken a tremendous toll on our economy and our people. This is the direct cause of the long lines which have made millions of you spend aggravating hours waiting for gasoline. It's a cause of the increased inflation and unemployment that we now face. This intolerable dependence on foreign oil threatens our economic independence and the very security of our nation. The energy crisis is real. It is worldwide. It is a clear and present danger to our nation. These are facts and we simply must face them.

What I have to say to you now about energy is simple and vitally important.

Point one: I am tonight setting a clear goal for the energy policy of the United States. Beginning this moment, this nation will never use more foreign oil than we did in 1977—never. From now on, every new addition to our demand for energy will be met from our own production and our own conservation. The generation-long growth in our dependence on foreign oil will be stopped dead in its tracks right now, and then reversed as we move through the 1980s, for I am tonight setting the further goal of cutting our dependence on foreign oil by one-half by the end of the next decade—a saving of over four and a half million barrels of imported oil per day.

Point two: To ensure that we meet these targets, I will use my presidential authority to set import quotas. I'm announcing tonight that for 1979 and 1980, I will forbid the entry into this country of one drop of foreign oil more than these goals allow. These quotas will ensure a reduction in imports even below the ambitious levels we set at the recent Tokyo summit.

Point three: To give us energy security, I am asking for the most massive peacetime commitment of funds and resources in our nation's history to develop America's own alternative sources of fuel—from coal, from oil shale, from plant products for gasohol, from unconventional gas, from the sun. . . .

Point four: I'm asking Congress to mandate, to require as a matter of law, that our nation's utility companies cut their massive use of oil by 50 percent within the next decade and switch to other fuels, especially coal, our most abundant energy source.

Point five: To make absolutely certain that nothing stands in the way of achieving these goals, I will urge Congress to create an energy mobilization board which, like the War Production Board in World War II, will have the responsibility and authority to cut through the red tape, the delays, and the endless roadblocks to completing key energy projects.

We will protect our environment. But when this nation critically needs a refinery or a pipeline, we will build it.

Point six: I'm proposing a bold conservation program to involve every state, county, and city and every average American in our energy battle. This effort will permit you to build conservation into your homes and your lives at a cost you can afford.

I ask Congress to give me authority for mandatory conservation and for standby gasoline rationing. To further conserve energy, I'm proposing tonight an extra $10 billion over the next decade to strengthen our public transportation systems. And I'm asking you for your good and for your nation's security to take no unnecessary trips, to use carpools or public transportation whenever you can, to park your car one extra day per week, to obey the speed limit, and to set your thermostats to save fuel. Every act of energy conservation like this is more than just common sense—I tell you it is an act of patriotism.

Source: American Rhetoric, http://www.americanrhetoric.com/speeches/jimmycarter crisisofconfidence.htm.

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Appendix 4

Former Vice President Al Gore at New York University, July 17, 2008

There are times in the history of our nation when our very way of life depends upon dispelling illusions and awakening to the challenge of a present danger. In such moments, we are called upon to move quickly and boldly to shake off complacency, throw aside old habits and rise, clear-eyed and alert, to the necessity of big changes. Those who, for whatever reason, refuse to do their part must either be persuaded to join the effort or asked to step aside. This is such a moment. The survival of the United States of America as we know it is at risk. And even more—if more should be required—the future of human civilization is at stake.

I don't remember a time in our country when so many things seemed to be going so wrong simultaneously. Our economy is in terrible shape and getting worse, gasoline prices are increasing dramatically, and so are electricity rates. Jobs are being outsourced. Home mortgages are in trouble. Banks, automobile companies and other institutions we depend upon are under growing pressure. Distinguished senior business leaders are telling us that this is just the beginning unless we find the courage to make some major changes quickly.

The climate crisis, in particular, is getting a lot worse—much more quickly than predicted. Scientists with access to data from Navy submarines traversing underneath the North polar ice cap have warned that there is now a 75 percent chance that within five years the entire ice cap will completely disappear during the summer months. This will further increase the melting pressure on Greenland. According to experts, the Jakobshavn glacier, one of Greenland's largest, is moving at a faster rate than ever before, losing 20 million tons of ice every day, equivalent to the amount of water used every year by the residents of New York City.

Two major studies from military intelligence experts have warned our leaders about the dangerous national security implications of the climate crisis, including the possibility of hundreds of millions of climate refugees destabilizing nations around the world.

Just two days ago, 27 senior statesmen and retired military leaders warned of the national security threat from an "energy tsunami" that would be triggered by a loss of our access to foreign oil. Meanwhile, the war in Iraq continues, and now the war in Afghanistan appears to be getting worse.

And by the way, our weather sure is getting strange, isn't it? There seem to be more tornadoes than in living memory, longer droughts, bigger downpours and record floods. Unprecedented fires are burning in California and elsewhere in the American West. Higher temperatures lead to drier vegetation that makes kindling for mega-fires of the kind that have been raging in Canada, Greece, Russia, China, South America, Australia and Africa. Scientists in the Department of Geophysics and Planetary Science at Tel Aviv University tell us that for every one degree increase in temperature, lightning strikes will go up another 10 percent. And it is lightning, after all, that is principally responsible for igniting the conflagration in California today.

Like a lot of people, it seems to me that all these problems are bigger than any of the solutions that have thus far been proposed for them, and that's been worrying me.

I'm convinced that one reason we've seemed paralyzed in the face of these crises is our tendency to offer old solutions to each crisis separately—without taking the others into account. And these outdated proposals have not only been ineffective—they almost always make the other crises even worse.

Yet when we look at all three of these seemingly intractable challenges at the same time, we can see the common thread running through them, deeply ironic in its simplicity: our dangerous over-reliance on carbon-based fuels is at the core of all three of these challenges—the economic, environmental and national security crises.

We're borrowing money from China to buy oil from the Persian Gulf to burn it in ways that destroy the planet. Every bit of that's got to change.

But if we grab hold of that common thread and pull it hard, all of these complex problems begin to unravel and we will find that we're holding the answer to all of them right in our hand.

The answer is to end our reliance on carbon-based fuels.

In my search for genuinely effective answers to the climate crisis, I have held a series of "solutions summits" with engineers, scientists, and CEOs. In those discussions, one thing has become abundantly clear: when you connect the dots, it turns out that the real solutions to the climate crisis are the very same measures needed to renew our economy and escape the trap of ever-rising energy prices. Moreover, they are also the very same solutions we need to guarantee our national security without having to go to war in the Persian Gulf.

What if we could use fuels that are not expensive, don't cause pollution and are abundantly available right here at home?

We have such fuels. Scientists have confirmed that enough solar energy falls on the surface of the earth every 40 minutes to meet 100 percent of the entire world's energy needs for a full year. Tapping just a small portion of this solar energy could provide all of the electricity America uses.

And enough wind power blows through the Midwest corridor every day to also meet 100 percent of U.S. electricity demand. Geothermal energy, similarly, is capable of providing enormous supplies of electricity for America.

The quickest, cheapest and best way to start using all this renewable energy is in the production of electricity. In fact, we can start right now using solar power, wind power and geothermal power to make electricity for our homes and businesses.

But to make this exciting potential a reality, and truly solve our nation's problems, we need a new start.

That's why I'm proposing today a strategic initiative designed to free us from the crises that are holding us down and to regain control of our own destiny. It's not the only thing we need to do. But this strategic challenge is the lynchpin of a bold new strategy needed to re-power America.

Today I challenge our nation to commit to producing 100 percent of our electricity from renewable energy and truly clean carbon-free sources within 10 years.

This goal is achievable, affordable and transformative. It represents a challenge to all Americans—in every walk of life: to our political leaders, entrepreneurs, innovators, engineers, and to every citizen.

A few years ago, it would not have been possible to issue such a challenge. But here's what's changed: the sharp cost reductions now beginning to take place in solar, wind, and geothermal power—coupled with the recent dramatic price increases for oil and coal—have radically changed the economics of energy.

When I first went to Congress 32 years ago, I listened to experts testify that if oil ever got to $35 a barrel, then renewable sources of energy would become competitive. Well, today, the price of oil is over $135 per barrel. And sure enough, billions of dollars of new investment are flowing into the development of concentrated solar thermal, photovoltaics, windmills, geothermal plants, and a variety of ingenious new ways to improve our efficiency and conserve presently wasted energy.

And as the demand for renewable energy grows, the costs will continue to fall. Let me give you one revealing example: the price of the specialized silicon used to make solar cells was recently as high as $300 per kilogram. But the newest contracts have prices as low as $50 a kilogram.

You know, the same thing happened with computer chips—also made out of silicon. The price paid for the same performance came down by 50 percent every 18 months—year after year, and that's what's happened for 40 years in a row.

To those who argue that we do not yet have the technology to accomplish these results with renewable energy: I ask them to come with me to meet the entrepreneurs who will drive this revolution. I've seen what they are doing and I have no doubt that we can meet this challenge.

To those who say the costs are still too high: I ask them to consider whether the costs of oil and coal will ever stop increasing if we keep relying on quickly depleting energy sources to feed a rapidly growing demand all around the world. When demand for oil and coal increases, their price goes up. When demand for solar cells increases, the price often comes down.

When we send money to foreign countries to buy nearly 70 percent of the oil we use every day, they build new skyscrapers and we lose jobs. When we spend that money building solar arrays and windmills, we build competitive industries and gain jobs here at home.

Of course there are those who will tell us this can't be done. Some of the voices we hear are the defenders of the status quo—the ones with a vested interest in perpetuating the current system, no matter how high a price the rest of us will have to pay. But even those who reap the profits of the carbon age have to recognize the inevitability of its demise. As one OPEC oil minister observed, “The Stone Age didn't end because of a shortage of stones.”

To those who say 10 years is not enough time, I respectfully ask them to consider what the world's scientists are telling us about the risks we face if we don't act in 10 years. The leading experts predict that we have less than 10 years to make dramatic changes in our global warming pollution lest we lose our ability to ever recover from this environmental crisis. When the use of oil and coal goes up, pollution goes up. When the use of solar, wind and geothermal increases, pollution comes down.

To those who say the challenge is not politically viable: I suggest they go before the American people and try to defend the status quo. Then bear witness to the people's appetite for change.

I for one do not believe our country can withstand 10 more years of the status quo. Our families cannot stand 10 more years of gas price increases. Our workers cannot stand 10 more years of job losses and outsourcing of factories. Our economy cannot stand 10 more years of sending $2 billion every 24 hours to foreign countries for oil. And our soldiers and their families cannot take another 10 years of repeated troop deployments to dangerous regions that just happen to have large oil supplies.

What could we do instead for the next 10 years? What should we do during the next 10 years? Some of our greatest accomplishments as a nation have resulted from commitments to reach a goal that fell well beyond the next election: the Marshall Plan, Social Security, the interstate highway system. But a political promise to do something 40 years from now is universally ignored because everyone knows that it's meaningless. Ten years is about the maximum time that we as a nation can hold a steady aim and hit our target.

When President John F. Kennedy challenged our nation to land a man on the moon and bring him back safely in 10 years, many people doubted we could accomplish that goal. But 8 years and 2 months later, Neil Armstrong and Buzz Aldrin walked on the surface of the moon.

To be sure, reaching the goal of 100 percent renewable and truly clean electricity within 10 years will require us to overcome many obstacles. At present, for example, we do not have a unified national grid that is sufficiently advanced to link the areas where the sun shines and the wind blows to the cities in the East and the West that need the electricity. Our national electric grid is critical infrastructure, as vital to the health and security of our economy as our highways and telecommunication networks. Today, our grids are antiquated, fragile, and vulnerable to cascading failure. Power outages and defects in the current grid system cost U.S. businesses more than $120 billion a year. It has to be upgraded anyway.

We could further increase the value and efficiency of a Unified National Grid by helping our struggling auto giants switch to the manufacture of plug-in electric cars. An electric vehicle fleet would sharply reduce the cost of driving a car, reduce pollution, and increase the flexibility of our electricity grid.

At the same time, of course, we need to greatly improve our commitment to efficiency and conservation. That's the best investment we can make.

America's transition to renewable energy sources must also include adequate provisions to assist those Americans who would unfairly face hardship. For example, we must recognize those who have toiled in dangerous conditions to bring us our present energy supply. We should guarantee good jobs in the fresh air and sunshine for any coal miner displaced by impacts on the coal industry. Every single one of them.

Of course, we could and should speed up this transition by insisting that the price of carbon-based energy include the costs of the environmental damage it causes. I have long supported a sharp reduction in payroll taxes with the difference made up in CO_2 taxes. We should tax what we burn, not what we earn. This is the single most important policy change we can make.

In order to foster international cooperation, it is also essential that the United States rejoin the global community and lead efforts to secure an international treaty at Copenhagen in December of next year that includes a cap on CO_2 emissions and a global partnership that recognizes the necessity of addressing the threats of extreme poverty and disease as part of the world's agenda for solving the climate crisis.

Of course the greatest obstacle to meeting the challenge of 100 percent renewable electricity in 10 years may be the deep dysfunction of our politics and our self-governing system as it exists today. In recent years, our politics has tended toward incremental proposals made up of small policies designed to avoid offending special interests, alternating with occasional baby steps in the right direction. Our democracy has become sclerotic at a time when these crises require boldness.

It is only a truly dysfunctional system that would buy into the perverse logic that the short-term answer to high gasoline prices is drilling for more oil ten years from now.

Am I the only one who finds it strange that our government so often adopts a so-called solution that has absolutely nothing to do with the problem it is supposed to address? When people rightly complain about higher gasoline prices, we propose to give more money to the oil companies and pretend that they're going to bring gasoline prices down. It will do nothing of the sort, and everyone knows it. If we keep going back to the same policies that have never ever worked in the past and have served only to produce the highest gasoline prices in history alongside the greatest oil company profits in history, nobody should be surprised if we get the same result over and over again. But the Congress may be poised to move in that direction anyway because some of them are being stampeded by lobbyists for special interests that know how to make the system work for them instead of the American people.

If you want to know the truth about gasoline prices, here it is: the exploding demand for oil, especially in places like China, is overwhelming the rate of new discoveries by so much that oil prices are almost certain to continue upward over time no matter what the oil companies promise. And politicians cannot bring gasoline prices down in the short term.

However, there actually is one extremely effective way to bring the costs of driving a car way down within a few short years. The way to bring gas prices down is to end our dependence on oil and use the renewable sources that can give us the equivalent of $1 per gallon gasoline.

Many Americans have begun to wonder whether or not we've simply lost our appetite for bold policy solutions. And folks who claim to know how our system works these days have told us we might as well forget about our political system doing anything bold, especially if it is contrary to the wishes of special interests. And I've got to admit, that sure seems to be the way things have been going. But I've begun to hear different voices in this country from people who are not only tired of baby steps and special interest politics, but are hungry for a new, different and bold approach.

We are on the eve of a presidential election. We are in the midst of an international climate treaty process that will conclude its work before the end of the first year of the new president's term. It is a great error to say that the United States must wait for others to join us in this matter. In fact, we must move first, because that is the key to getting others to follow; and because moving first is in our own national interest.

So I ask you to join with me to call on every candidate, at every level, to accept this challenge—for America to be running on 100 percent zero-carbon electricity in 10 years. It's time for us to move beyond empty rhetoric. We need to act now.

This is a generational moment. A moment when we decide our own path and our collective fate. I'm asking you—each of you—to join me and build this future. Please join the WE campaign at wecansolveit.org. We need you. And we need you now. We're committed to changing not just lightbulbs, but laws. And laws will only change with leadership.

On July 16, 1969, the United States of America was finally ready to meet President Kennedy's challenge of landing Americans on the moon. I will never forget standing beside my father a few miles from the launch site, waiting for the giant Saturn 5 rocket to lift Apollo 11 into the sky. I was a young man, 21 years old, who had graduated from college a month before and was enlisting in the United States Army three weeks later.

I will never forget the inspiration of those minutes. The power and the vibration of the giant rocket's engines shook my entire body. As I watched the rocket rise, slowly at first and then with great speed, the sound was deafening. We craned our necks to follow its path until we were looking straight up into the air. And then four days later, I watched along with hundreds of millions of others around the world as Neil Armstrong took one small step to the surface of the moon and changed the history of the human race.

We must now lift our nation to reach another goal that will change history. Our entire civilization depends upon us now embarking on a new journey of exploration and discovery. Our success depends on our willingness as a people to undertake this journey and to complete it within 10 years. Once again, we have an opportunity to take a giant leap for humankind.

Source: Al Gore's blog space, http://blog.algore.com/2008/07/a_generational_challenge_to_re.html.

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