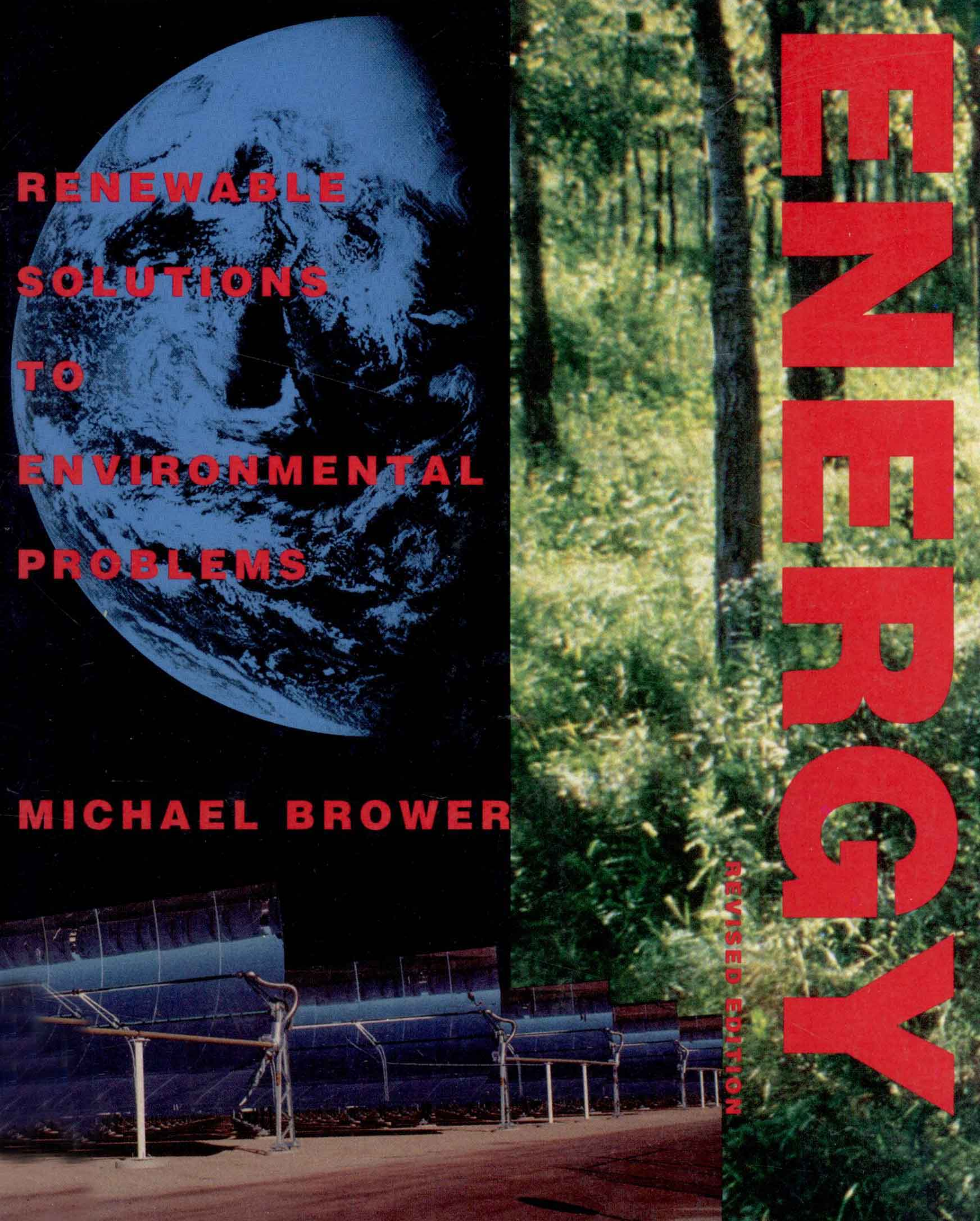
COOL ENERGY

RENEWABLE SOLUTIONS TO ENVIRONMENTAL PROBLEMS



MICHAEL BROWER

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Cool Energy

Renewable Solutions to Environmental Problems

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Michael Brower

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M.C.B.

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Introduction

The United States is rapidly approaching a new energy crisis. Consumption of energy is growing, but at the same time, Americans are increasingly demanding that the energy come from clean, safe sources that protect their health, environment, and quality of life. This sharpening conflict is seen in the virtual halt to nuclear power plant construction, strict new federal and state controls on pollution from fossil-fueled power plants, automobiles, and industry, and the high-profile debate over what to do about global warming.

Renewable energy sources such as wind, sunlight, plants, and geothermal energy could provide a way out of this emerging crisis. Although many in government and more than a few other Americans expect our nation's dependence on oil, coal, and natural gas to extend indefinitely into the future, much of the technology has already been developed to allow us to move in a different direction. This book makes the case that it is not only desirable but practical to make the transition from fossil fuels to "cool" renewable energy. By doing so, we will help preserve the environment and sustain our economy at the same time.

Renewable energy — that which is regenerated at the same rate it is used — was first widely considered as an alternative to fossil fuels in the seventies. In response to the decade's oil crises, it enjoyed a brief period of popularity. Under President Jimmy Carter's administration, funding for research and development in this area grew from almost nothing to more than $700 million in 1980. Tax credits and other programs made solar collectors, wind turbines, and other devices attractive business investments. So many families — from the Carters on down — placed solar collectors on the roofs of their houses that collector sales increased fivefold between 1975 and 1980.

Unfortunately, falling oil prices in the eighties put renewable energy on the back burner. A new administration under Ronald Reagan, deeply hostile to anything other than the energy status quo, drastically reduced funding for research and even removed the solar collectors from the White House roof.

Now, in the nineties, when there is greater awareness of the environmental problems caused by excessive dependence on fossil fuels, government officials, business leaders, and the media remain skeptical that renewable energy technologies can be deployed on a large enough scale to displace significant quantities of oil, coal, or natural gas. The brief boom in renewable energy did not last long enough to convince people that the future lies in wide-scale use of solar, wind, biofuels, or geothermal energy. In fact, because some of the crash implementation projects of the late seventies were poorly conceived — and in some cases the technologies simply were not ready for deployment — renewable energy earned a reputation for high cost and unreliability.

Renewable energy technologies nevertheless made dramatic strides while they were out of the public eye. The reliability and efficiency of equipment improved; the cost of installing, maintaining, and running it declined. Moreover, energy planners gained a better appreciation of how these technologies could be integrated efficiently and reliably into the existing energy system.

In the case of wind turbines, for example, more advanced designs, better choice of materials, and careful siting have made the cost of generating electricity from wind a fourth of what it was a decade ago. In many locations, a utility company can now build a wind-power facility that will produce electricity at a cost approaching that of a new fossil-fuel power plant. And, if such hidden costs of fossil fuels as air pollution and global warming are considered, wind can be a cheaper source of electricity than fossil fuels.

This book begins with a chapter describing some of the economic and environmental consequences of America's fossil-fuel-based economy. It makes the case that, despite some progress in reducing pollution from fossil fuels, no lasting cure for our deteriorating environment — in particular, the looming threat of global warming — is possible without developing alternative fuel sources. Just as important, America's economic security is becoming increasingly vulnerable to the actions of just a few oil-producing states, as the 1991 Persian Gulf war demonstrated. Reducing fossil-fuel use thus makes both environmental and economic sense.

That renewable energy can provide the bulk of the new supplies we need is the theme of the second chapter, which discusses the relative advantages of these resources compared to fossil fuels and nuclear power and evaluates their long-term potential. Yet the chapter also reveals that progress in commercializing renewable energy will be extremely slow unless the government acts to remove a number of market barriers. These barriers include, for example, a tax system that unfairly penalizes investments in renewable energy, utility regulations that encourage continued reliance on fossil fuels, and the failure of markets to account for the long-term economic, environmental, and social consequences of energy choices.

The bulk of the book considers five broad categories of renewable energy sources: solar, wind, biomass (plant matter), rivers and oceans, and geothermal. For each of these sources, the book describes its current application, discusses its costs, analyzes new technologies under development, and assesses its positive and negative environmental impacts. Because conventional wisdom holds that inherently fluctuating renewable resources like solar and wind cannot make significant inroads into world supply without energy storage, the book devotes a chapter to the energy storage issue. It concludes with a chapter on policies that could help speed the transition to a renewable energy economy.

Taken as a whole, this book shows the vital role renewable sources can and should play in America's energy future. It cites studies indicating that, with the right policies, renewable energy could provide as much as half of America's energy within 40 years, and an even larger fraction down the road. Such a rapid shift from existing energy sources would be dramatic but not unprecedented. In 1920, coal supplied 70 percent of U.S. energy, but within 40 years its share had dropped to just 20 percent as oil and natural gas use increased.

Sooner or later, oil and natural gas will also fade in importance. The real question is when. This book makes the case that the time to move decisively toward a renewable energy economy has arrived.

1 The Energy Challenge

From almost the start of the industrial revolution, the engine of Western civilization has run on fossil fuels. In the United States, coal emerged as the dominant energy source several decades after it did in Europe, but by the end of the 19th century it was providing fully 50 percent of U.S. energy needs. Oil and natural gas came into wide use in the 20th century, helping to reduce the cost and improve the quality of transportation, industry, residential heating, and other energy services. Today, close to 85 percent of U.S. energy needs are met in one manner or another by fossil fuels.

Yet this dependence cannot continue without putting the U.S. economy and the global environment at risk. Even before the threat of global warming attracted wide attention in the late eighties, it was clear that U.S. and world oil and natural gas reserves would not last indefinitely, and that prudence called for gradually reducing our dependence on these energy sources. At present rates of consumption, proven U.S. oil reserves will last just 10 years, and world oil reserves will last barely 40 years. To be sure, new reserves are being discovered all the time, but even if total reserves prove to be double current estimates, the world will begin running short on oil and natural gas by the middle of the next century. Well before then, prices are likely to rise sharply because of the increasing difficulty and cost of discovering and extracting oil. The growing concentration of oil production in a small number of countries is also cause for alarm. By 2020, if present trends continue, over two-thirds of world oil will be pumped from the Middle East, compared to just a quarter today — a deeply troubling prospect, considering the instability and conflict that continue to plague that region (Flavin and Lenssen 1990).

Given these trends, the world seems destined to experience another period of sharply rising energy prices like that which struck in the seventies, this one possibly far more severe and enduring than the last.

The potential impact of the next oil crisis on the U.S. economy cannot be overstated. About 40 percent of U.S. energy comes from oil. Even though half of this is domestically produced (a fraction certain to fall over the next several years as domestic reserves are depleted), the oil market knows no national boundaries. If the world oil price rises, then all of the oil we consume will become more expensive. Even more distressing is the possibility of a complete cutoff of Persian Gulf oil, resulting perhaps from war, which would shut down much of American industry and cause crippling shortages of gasoline and heating oil.

The Greenhouse Connection

All of these dangers were widely recognized in the seventies. What is new today is the growing appreciation by both scientists and the public at large of the role fossil fuels play in damaging the global environment. To be sure, Americans have long been troubled by air pollution, which continues to affect the health and comfort of millions of city dwellers. Even our rural and wilderness areas are not immune to this problem: High levels of ozone (a component of smog) are damaging crops and reducing agricultural productivity, while acid rain and clouds are strongly suspected of damaging forests and poisoning lakes and streams in parts of the eastern United States and Canada (WRI 1990, MacKenzie and El-Ashry 1988).

Until very recently, however, such problems were believed to be largely local, or at worst regional, phenomena. For the public, the first inkling of the error in this thinking came when scientists announced discovery, in 1986, of the now-famous "hole" in the stratospheric ozone layer over Antarctica, which vividly demonstrated that localized emissions of pollutants could cause global environmental damage. This hole is caused not by fossil-fuel combustion but by the release of a class of chemicals known as chlorofluorocarbons, or CFCs, long-lived substances used in refrigerators, air conditioners, solvents, and other applications. Stratospheric ozone — not to be confused with tropospheric, or near-ground-level, ozone — blocks the sun's harmful ultraviolet rays from reaching the earth's surface. Consequently, a decrease in stratospheric ozone results in an increase in the exposure of people to ultraviolet radiation, and thus very likely an increase in the incidence of afflictions such as skin cancer and cataracts. The destruction of ozone is now observed to be spreading to temperate regions and has become the object

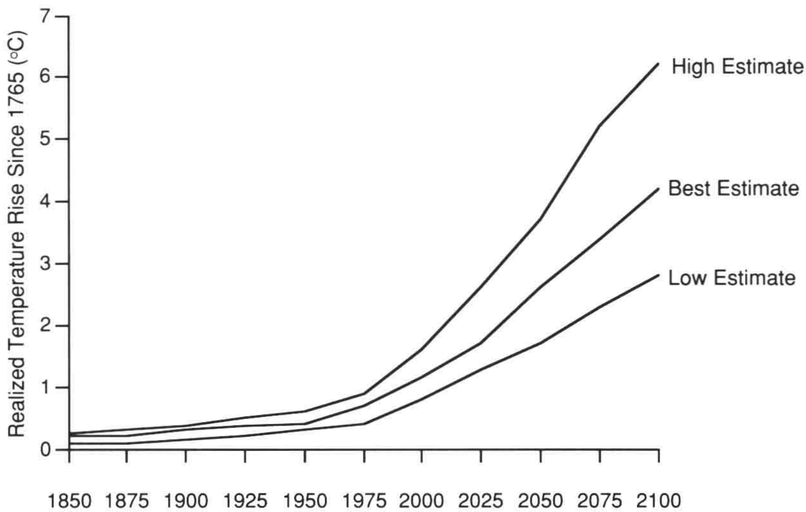

Figure 1.1
Computer models of the earth's climate indicate that the global average temperature has risen 0.5°C – 1.5°C since 1765, and that it is likely to rise an additional 2.5°C – 4.5°C by the end of the next century, because of emissions of greenhouse gases (IPCC 1990).

of international agreements to reduce and eventually eliminate production of CFCs.

More recently, attention has been focused on the threat of global warming. Scientists have long known that certain gases in the atmosphere absorb heat (infrared light) radiating from the earth's surface. Most of these gases, such as water vapor, carbon dioxide, and methane, exist naturally, and without their warming influence — the greenhouse effect — the earth would be much colder and uninhabitable. Various human activities are believed to be aggravating the greenhouse effect, however, by adding ever-greater quantities of these gases to the atmosphere. From direct measurements since 1958, and before then from gas samples taken from ice cores, we know that the atmospheric concentration of carbon dioxide is up 25 percent since preindustrial times. The concentrations of other greenhouse gases such as methane and CFCs[1] are also rising (IPCC 1990, Bolin et al. 1986, Ramanathan 1988).

Global warming first came to the public's attention in the summer of 1988, when droughts and heat waves gripped much of the United States causing crops to fail and rivers to dry up. In a dramatic announcement, a leading climatologist, James Hansen, told a Congressional committee he was "98 percent" sure that a significant global temperature rise was occurring, although whether this was directly the result of accumulating greenhouse gases he could not say. Indeed, the temperature trend is alarming: An increase of 0.3°C to 0.6°C (0.5°F to 1.0°F) in the earth's average temperature has been observed in meteorological records going back over 100 years. What is most striking is that the seven warmest years on record have all occurred since 1980. These facts cannot be ascribed unambiguously to an artificial increase in the greenhouse effect, however, since many other factors (such as variations in solar radiation and changes in ocean currents) can also influence climate.

Nevertheless, there is a strong consensus among scientists that the earth is likely to get warmer in the future. A recent international study sponsored by several governments (including the United States) and involving some 300 scientists from various disciplines concluded the following:

> We are certain [that] there is a natural greenhouse effect which already keeps the Earth warmer than it would otherwise be [and that] emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases. . . .These increases will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. (IPCC 1990)

If present trends continue, the concentrations of all greenhouse gases will rise to the equivalent of double the preindustrial concentration of carbon dioxide by around 2020. According to the best climate models available, such a rise will cause the earth to warm anywhere from 2.5°C to 4.5°C (4.5°F to 8.1°F) by the end of the next century. (The earth would actually be *committed* to a greater increase than that, but the warming would be delayed several decades by the thermal inertia of the oceans.)

Predicting future warming with any accuracy is difficult because many complex climate-related processes are either poorly understood or difficult to simulate with existing computer capabilities. For example, scientists cannot identify or quantify all of the natural sources and "sinks" of carbon dioxide and so cannot predict accurately how much carbon-dioxide levels will increase in the future, even if human carbon-dioxide emissions could be predicted perfectly. There are also significant scientific uncertainties concerning cloud formation and dissipation, the exchange of energy between the oceans and the atmosphere, and the behavior of polar ice sheets, all of which have an important impact on warming predictions. In addition, today's computer models do not have the capacity to predict small-scale or regional climate variations with any accuracy.

Yet if the model predictions hold true, the temperature increase will be more sustained and rapid than anything modern humans have ever experienced. To put it in perspective, today's global average temperature is only about 5°C (9°F) warmer than it was at the peak of the last Ice Age 18,000 years ago, when much of the Northern Hemisphere was covered by ice sheets kilometers thick (Schneider and Londer 1984). The effects of an equally large — and far more rapid — future warming would be profound and irreversible, and very likely adverse to the human race.

In 1988 the Environmental Protection Agency released a study of the potential impacts of global warming on the United States. It suggested, among other things, that forest systems would begin to decline within a few decades and a number of species of plants and animals would die out because they could not migrate north quickly enough or their paths of migration would be blocked by urban sprawl. Most of the country's coastal wetlands — many of them irreplaceable wildlife refuges — would be lost to rising seas (caused by the melting of land-based polar ice and the thermal expansion of seawater). Coastal communities would have to spend large sums to protect against flooding. Agricultural output would be affected, as forecasters predict increased summer dryness in the American breadbasket and a higher frequency of droughts and heat waves (although increased levels of atmospheric carbon dioxide could at least partially offset these changes by aiding plant growth). In some parts of the country, water for drinking, irrigation, and industry would become more scarce (EPA 1988).

Striking a somewhat more optimistic note, a 1991 National Academy of Sciences study concluded that because of its rich natural and human resources, the United States "is well situated to respond to greenhouse warming," although the cost would be high (NAS 1991). Yet even if the United States can adapt to global warming without extreme disruptions, its effects could well take on tragic proportions in other parts of the world, particularly in less-developed countries ill-equipped to cope with rapidly changing climate conditions. Famines could occur as heavily populated, food-producing coastal regions are inundated by rising seas and the interiors of continents are afflicted by more frequent droughts. Increased stress on natural ecosystems could lead to mass refugee movements and possibly even wars over scarce resources. Considering the ever-growing interdependency of world economies, it seems unlikely that the United States could remain wholly removed from such disasters.

Taken together, the possible effects of global warming present a frightening threat to future generations. Some of the effects, moreover, may not be anticipated, just as scientists failed to anticipate the Antarctic ozone hole. Most studies assume, for example, that whatever climate changes occur will be gradual, but there are indications — in the cyclical history of ice ages, for example — that the earth's climate can change abruptly and radically in response to unknown factors. As the 1988 EPA study noted, predictions are "inherently limited by our imaginations. . . . Until a severe event occurs . . . we fail to recognize the close links between our society, the environment, and climate."

The Role of Fossil Fuels

A variety of human activities is contributing to the release of greenhouse gases into the atmosphere. They include the destruction of tropical rainforests and the associated release of carbon dioxide, methane, and other gases; agricultural practices, such as the use of nitrogen-rich fertilizers, which generates nitrous oxide, and the growing of rice in flooded paddies, which produces methane; and emissions of CFCs.

The chief source of greenhouse gases, however, is the combustion of fossil fuels. Worldwide, fossil-fuel combustion accounts for more than 70 percent of all human carbon-dioxide emissions — approximately 20 billion metric tons annually — and carbon dioxide accounts for 55 percent of world contributions to global warming (IPCC 1990, Houghton and Woodwell 1989). Fossil fuels are also a source of nitrous oxide, methane, and, indirectly, tropospheric (low-altitude) ozone, which is not only a pollutant but a greenhouse gas. Nitrous oxide is produced in combustion, methane through leaks from natural-gas wells, pipelines, and coal mines, and ozone through photochemical reactions involving methane, nitrogen oxides, and other compounds. All told, fossil-fuel use accounts for about half of the warming that is estimated to have occurred in the 1980s and over half of the warming predicted for the next 100 years (EPA 1990).

All countries contribute to global warming to some degree, but the United States bears an especially heavy responsibility. Although it has just 5 percent of the world's population, the United States contributes about 24 percent of world carbon-dioxide emissions from fossil fuels. When the cumulative effects of past emissions are considered, the U.S. contribution is even greater — 30 percent for the period 1950 to 1987 (WRI 1990). Within the U.S. economy, fossil fuels consumed to generate electricity are the largest source of carbon dioxide, emitting about 35 percent of the total, followed by fossil-fuel use for transportation, industry, and residential and commercial buildings. Electricity's share is so large in part because about 60 percent of electricity is generated from coal. For each unit of energy obtained in combustion, coal emits some 40 percent more carbon dioxide than oil and almost 100 percent more carbon dioxide than natural gas.

In recent decades, several countries, including the United States, have taken steps to limit emissions of various types of air pollution caused by fossil fuels. Lead was phased out from gasoline in the seventies and eighties, automobiles were required to be equipped with catalytic converters, and power plants were subject to increasingly stringent controls on emissions. More recently, in 1990, amendments to the U.S. Clean Air Act required major additional reductions in sulfur and other emissions from various sources, to be phased in over the next several years. And most encouraging of all, the world community has reached agreement to phase out production of CFCs (although because of the long atmospheric lifetime of these chemicals, stratospheric ozone will continue to be depleted for decades to come).

For all of this, however, few concrete steps have been taken to limit carbon dioxide and other greenhouse gases (aside from CFCs). World fossil-fuel consumption and carbon-dioxide emissions have almost quadrupled since 1950, and without major changes in energy policies they are likely to continue expanding, possibly as much as doubling by 2025 (EPA 1990). Fossil-fuel consumption in the United States is predicted to increase 15 to 25 percent by 2010, if present trends continue (EIA 1991a). Even without the threat of global warming, it will be difficult to sustain these trends without causing excessive damage to the environment. As fossil-fuel use grows, it will become increasingly costly for communities to meet clean-air goals through conventional pollution-control strategies, necessary though they will be. Moreover, such strategies will do little or nothing to reduce emissions of greenhouse gases. A new approach to protecting the global environment is necessary, one that goes to the root of the problem: our society's addiction to fossil fuels.