1 Global Warming and Climate Change

Ever since the Industrial Revolution, human activities have constantly changed the natural composition of Earth's atmosphere. Concentrations of trace atmospheric gases, nowadays termed "greenhouse gases," are increasing at an alarming rate. There is conclusive evidence that the consumption of fossil fuels, the conversion of forests to agricultural land, and the emission of industrial chemicals are the principal contributing factors to air pollution.

According to the National Academy of Sciences, the Earth's surface temperature has risen by about 1 degree Fahrenheit in the past century, with accelerated warming occurring in the past three decades. According to statistical reviews of the atmospheric and climatic records there is substantial evidence that global warming over the past 50 years is directly attributable to human activities.

Under normal atmospheric conditions, energy from the Sun controls the Earth's weather and climate patterns. Heating of the Earth's surface resulting from the Sun radiates energy back into space. Atmospheric greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), troposphere ozone (O_3), and water vapor (H_2O), trap some of this outgoing energy, retaining it in the form of heat, somewhat like a glass dome. This process is referred to as the GREENHOUSE EFFECT.

Without the Greenhouse Effect, the Earth's surface temperature would be roughly 30 degrees Celsius (54 degrees Fahrenheit) cooler than it is today – too cold to support life. Reducing greenhouse gas emissions is dependent on a reduction in the amount of fossil fuel–fired energy that we produce and consume.

Fossil fuels include coal, petroleum, and natural gas, all of which are used to fuel electric power generation and transportation. Substantial increases in the use of nonrenewable fuels have been a principal factor in the rapid increase in global greenhouse gas emissions. The use of renewable fuels can be extended to power industrial, commercial, residential, and transportation applications to reduce air pollution substantially.

Examples of zero-emission renewable fuels include solar, wind, geothermal, and renewably powered fuel cells. These fuel types, in conjunction with advances in energy-efficient equipment design and sophisticated energy management techniques, can reduce the risk of climate change and the resulting harmful effects on ecosystems. It should be kept in mind that natural greenhouse gases are a necessary

part of sustaining life on Earth. It is the anthropogenic, or human-caused, increase in greenhouse gases that is of concern to the international scientific community and governments around the world.

Since the beginning of the modern Industrial Revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases in greenhouse gas emissions have enhanced the heat-trapping capability of Earth's atmosphere.

Fossil fuels that are burned to operate electric power plants, run cars and trucks, and heat homes and businesses are responsible for about 98% of U.S. carbon dioxide emissions, 24% of U.S. methane emissions, and 18% of U.S. nitrous oxide emissions. Increased deforestation, landfills, large agricultural production, industrial production, and mining also contribute a significant share of emissions. In 2000, the United States produced about 25% of total global greenhouse gas emissions, the largest contribution by any country in the world.

Estimating future emissions depends on demographic, economic, technological, policy, and institutional developments. Several emissions scenarios based on differing projections of these underlying factors have been developed. It is estimated that by the year 2100, in the absence of emission control policies, carbon dioxide concentrations will be about 30–150% higher than they are today.

Increasing concentrations of greenhouse gases are expected to accelerate global climate change. Scientists expect that the average global surface temperature could rise an additional 1–4.5 degrees Fahrenheit within the next 50 years and 2.2–10 degrees Fahrenheit over the next century, with significant regional variation. Records show that the 10 warmest years of the 20th century all occurred in the last 15 years of that century. The expected impact of this warming trend includes the following:

Water Resources

Warming-induced decreases in mountain snowpack storage will increase winter stream flows (and flooding) and decrease summer flows. This, along with an increased evaporation and aspiration rate, is likely to cause a decrease in water deliveries.

Agriculture

The agricultural industry will be adversely affected by lower water supplies and increased weather variability, including extreme heat and drought.

Forestry

An increase in summer heat and dryness is likely to result in forest fires, an increase in the insect population, and disease.

Electrical Energy

Increased summer heat is likely to cause an increase in the demand for electricity, namely, increased reliance on air-conditioning. Reduced snowpack is likely to decrease the availability of hydroelectric supplies.

Regional Air Quality and Human Health

Higher temperatures may worsen existing air quality problems, particularly if there is a greater reliance on fossil fuel–generated electricity. Increased temperatures would also increase health risks for segments of the population.

Rising Ocean Levels

Thermal expansion of the ocean and glacial melting are likely to cause a 0.5 to 1.5 m (2 to 4 ft) rise in sea level by 2100.

Natural Habitat

Rising ocean levels and reduced summer river flow are likely to reduce coastal and wetland habitats. These changes could also adversely affect spawning fish populations. A general increase in temperatures and an accompanying increase in summer dryness could also adversely affect wild land plant and animal species.

Scientists calculate that without considering feedback mechanisms, a doubling of carbon dioxide would lead to a global temperature increase of 1.2 degrees Celsius (2.2 degrees Fahrenheit). However, the net effect of positive and negative feedback patterns appears to be substantially more warming than would be caused by the change in greenhouse gases alone.

Pollution Abatement Consideration

According to a 1999 study report by the U.S. Department of Energy (DOE), 1 kilowatt of energy produced by a coal-fired electrical power generating plant requires about 5 lb of coal. Likewise, the generation of 1.5 kWh of electrical energy per year requires about 7,400 lb of coal, which in turn produces 10,000 lb of carbon dioxide (CO_2).

Roughly speaking, the calculated projection of the power demand for the project totals about 2,500 to 3,000 kWh. This will require between 12 and 15 million pounds of coal, thereby producing about 16 to 200 million pounds of carbon dioxide. Solar power, if implemented as previously discussed, will substantially minimize the air pollution index. The Environmental Protection Agency (EPA) will soon be instituting an air pollution indexing system that will be factored into all future construction permits. All major industrial projects will be required to meet and adhere to these air pollution standards and offset excess energy consumption by means of solar or renewable energy resources.

Energy Escalation Cost Projection

According to an Energy Information Administration data source published in 1999, California consumes just as much energy as Brazil or the United Kingdom. The entirety of global crude oil reserves are estimated to last about 30 to 80 years, and more than 50% of the nation's energy is imported from abroad. It is thus inevitable that energy costs will surpass historical cost escalation averaging projections. The growth of fossil fuel consumption is illustrated in Figure 1.1. It is estimated that within

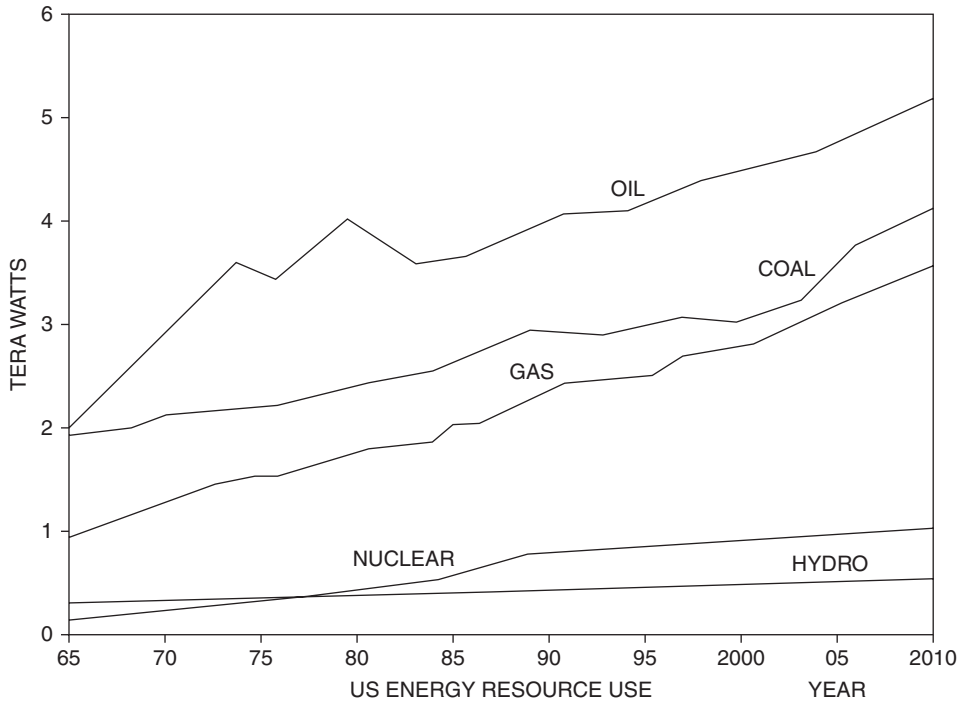

Figure 1.1. U.S. energy resources.
Source: DOE

the next decade producers will increase the cost of nonrenewable energy sources by approximately 4–5%.

When compounded with a general inflation rate of 3%, over the next decade average energy costs could be expected to rise at a rate of about 10–12% per year. This cost increase does not take into account other inflation factors, such as regional conflicts, embargoes, and natural catastrophes.

Solar power cogeneration systems, if designed and monitored properly, require minimal maintenance and are more reliable than any manmade power generation devices. The systems have an actual life span of 35 to 50 years and are guaranteed by the manufacturers for a period of 25 years. It is my opinion that in a near-perfect geographic setting, the integration of these systems into mainstream architectural design will not only enhance design aesthetics but also generate considerable savings and mitigate adverse effects on the ecosystem and global warming.

Social and Environmental Concerns

Nowadays, we do not think twice about leaving lights on or turning off the television or computers, which oftentimes run for hours. Most people believe that energy is infinite, but in fact, that is not the case. The global consumption of fossil fuels, which supply us with most of our energy, is steadily rising. In 1999, it was discovered that of 97 quads of energy used (a quad is $3 \times 1{,}011$ kWh), 80 quads were from coal, oil, and natural gas. The imminent depletion of fossil fuel sources within a few generations requires us to be prepared with novel and alternative sources of energy. In reality, as early as 2020, we could witness serious energy deficiencies (see Figure 1.2 for

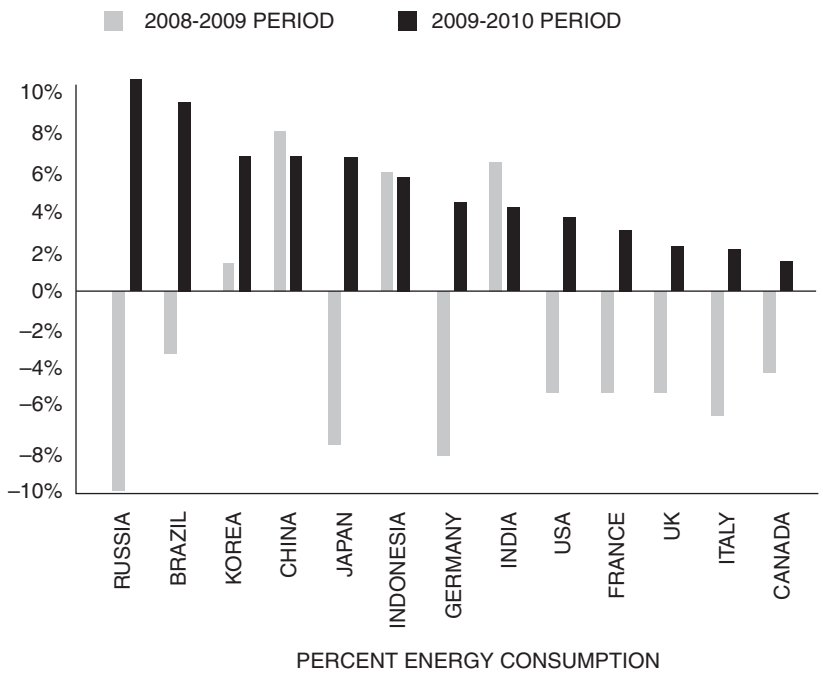

Figure 1.2. Energy consumption trends in major G20 countries.
Source: Enerdata

energy consumption trends in major G20 countries). Therefore, interest in renewable sources of energy, including wind, solar, and hydropower, has become a hot topic.

Although they may seem novel, renewable fuels are by no means a recent phenomenon. In fact, the Industrial Revolution was launched with renewable fuels. Until energy conferences in 1973 and 1974, the United States and the rest of the world had been using energy without serious concern for years. This was when energy conservation issues were brought to the attention of the industrialized world. Ever since, we have been forced to realize that the global supply of fossil fuels would one day run out and that we would have to find alternate sources of energy.

An extensive report published by the DOE in 1999 disclosed that by the year 2020, there will be a 60% increase in carbon dioxide emissions, which will create a serious strain on the environment and further aggravate the dilemma with greenhouse gasses. Figure 1.3 shows carbon dioxide generation by various industries and Figure 1.4 shows the growth of carbon dioxide in the atmosphere over a period of two centuries.

A reduction in energy consumption may seem a simple solution. However, this would not be feasible. There is a correlation between high electricity consumption (4,000 kWh per capita) and a high Human Development Index (HDI), which measures quality of life. In other words, there is a direct correlation between quality of life and amount of energy used. This is one of the reasons that the standard of living in industrialized countries is better than it is in third world countries, where there is very little access to electricity. In 1999, the United States possessed 5% of the world's population and produced 30% of the gross world product. The U.S. also consumed 25% of the world's energy and emitted 25% of its carbon dioxide.

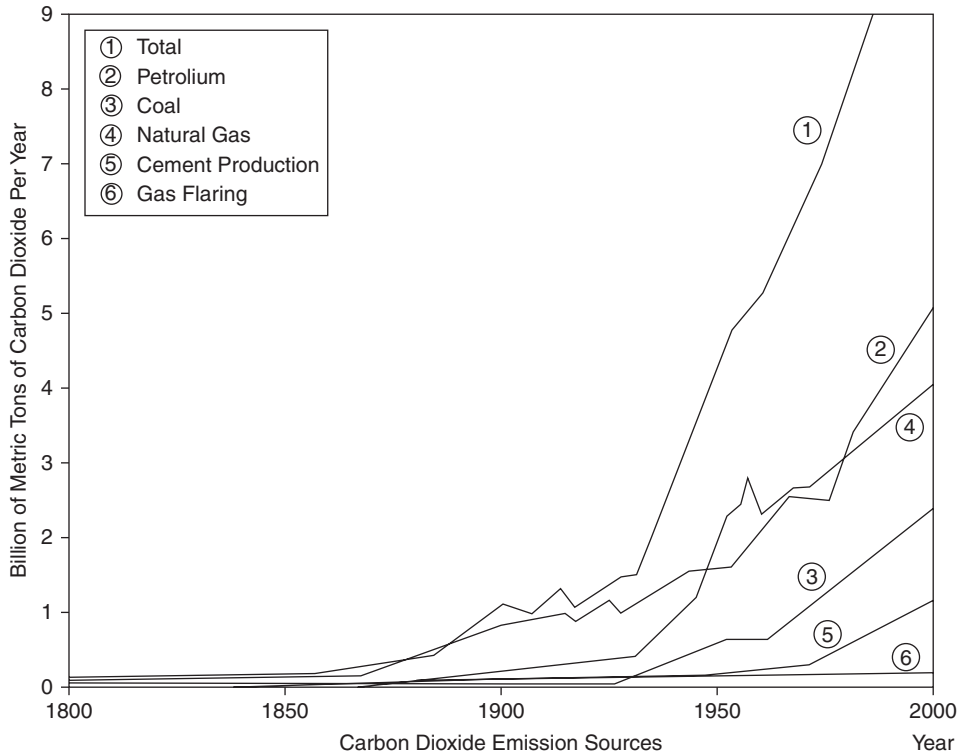

Figure 1.3. CO_2 generation by various industries.

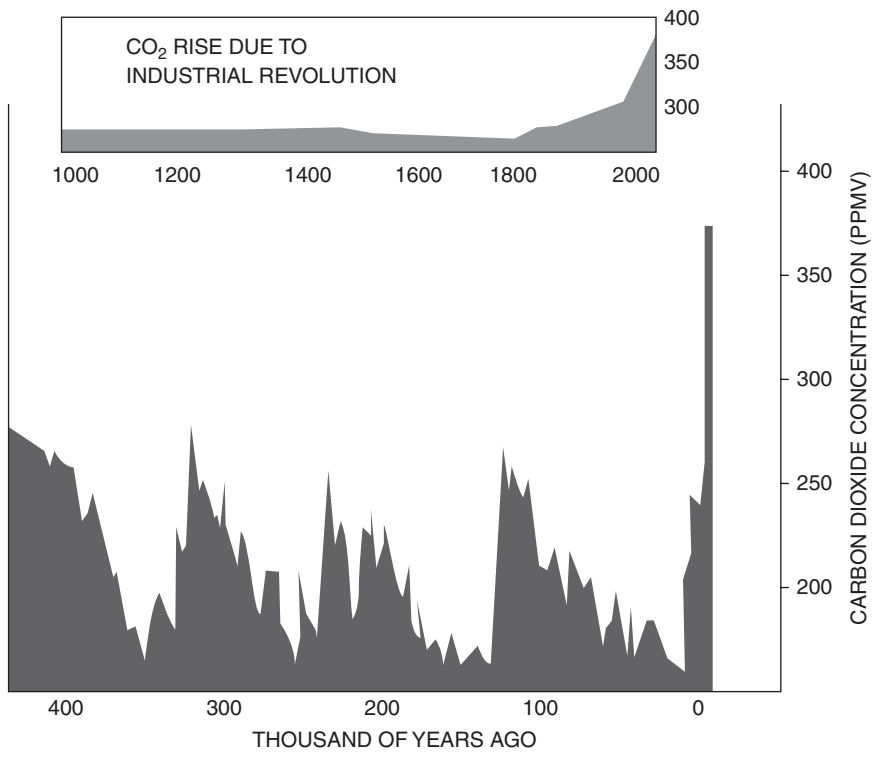

Figure 1.4. CO_2 generation over thousands of years.

It is not hard to imagine what countries like China and India, with their burgeoning populations and economic growth, can do to the state of global ecology.

The most significant feature of solar energy is that it is clean energy that does not harm the environment. Solar power use does not emit any of the extremely harmful greenhouse gases that contribute to global warming. A small amount of pollution is generated when solar panels are produced, but it is minuscule in comparison to the pollution associated with fossil fuels. The Sun is also a free source of energy. As technology advances, solar energy will become ever more economically feasible because the price of photovoltaic modules will decrease. One of the primary concerns with solar power is that it is not energy on demand and that it only works during the day and during very sunny weather. The only way to overcome this problem is to build storage facilities that save up some of the energy in batteries. However, this adds more to the cost of solar energy.

A Few Facts about Coal-Based Electric Power Generation

Presently, the most abundant fossil fuel resource available in the United States is coal. Coal-based electric power generation represents about 50% of energy used and is the largest source of environmental pollution. Coal burned in boilers generates an abundance of CO_2, SO_2 (sulfur dioxide), NO_2 (nitrogen dioxide), arsenic, cadmium, lead, mercury, soot particles, and tons of coal ash, which pollute the atmosphere and water. At present, 40% of the world's CO_2 emissions are from coal burning power plants.

The coal industry in the United States has recently developed the advertising slogan "Opportunity Returns" as part of an attempt to convey an unsubstantiated message to the public that a new clean coal gasification technology, assumed to be superclean, is on the horizon and will provide safe energy for the next 250 years. Whatever the outcome of the promised technology, at present coal-fired electric power generation plant construction is on the rise and 120 power generation plants are currently under construction.

So-called clean coal Integrated Gasification Combined Cycle (IGCC) technology converts coal into synthetic gas, which is supposed to be as clean as natural gas and 10% more efficient when used to generate electricity. The technology is expected to increase plant power efficiency by 10%, produce 50% less solid waste, and reduce water pollution by 40%. Despite all of the coal power energy production improvements, the technology will remain a major source of pollution.

Coal Power Generation Industry Facts

- By the year 2030, it is estimated that coal-based electrical power generation will represent a very large portion of the world's power and provide 1,350 thousand megawatts of electric energy, which in turn will inject 572 billion tons of CO_2 into the atmosphere. This is equal to the amount of pollution generated over the past 250 years.
- In the United States, it takes 20 pounds of coal to generate sufficient energy requirements per person. In total, this represents approximately 1 billion tons of coal. The percentage of coal-based energy production in the United States will be 50%, as compared to 40% in China and 10% in India.

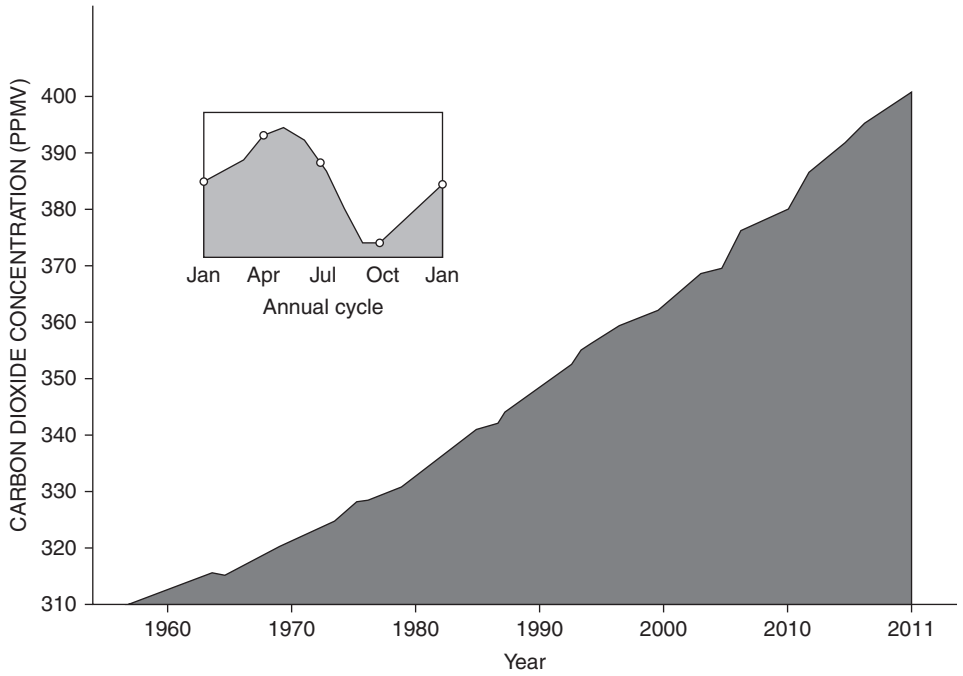

Figure 1.5. CO_2 generation over 60 years.

- By the year 2030, global energy demand is projected to double.
- Worldwide coal resources are estimated to be at 1 trillion tons. The United States holds 25% of these total resources, or about 270 billion tons. China has 75 billion tons of coal, which is expected to provide 75 years of coal-based electric energy.
- Cheap electric power generated from coal will require large national expenditures to mitigate environmental pollution and related public health problems, which will translate into medical bills for treating asthma, emphysema, heart attacks, and cancer. Pollution will also lead to global ecological demise and genetic changes in plant and animal life.
- According to a study conducted by Princeton University, the effects of U.S. coal-fired electric power generation plants on public health would add $130 billion per megawatt hour of energy. At a cost of $0.12/ kWh per megawatt of power, this is equal to $120.00
- The Kyoto Protocol, which has been ratified by 162 nations, calls for cutting greenhouse gases by 5.2% by 2012. China and developing nations like India, which are exempt, are estimated to generate twice the expected amount of atmospheric pollution. The United States and Australia have not ratified the Kyoto Protocol. See Figure 1.5 for CO_2 generation over 60 years.

In conclusion, it should be noted that as responsible citizens considering investment in solar power or renewable energy systems, we should also consider the negative effects of indirect cost burdens on the global economy, which would be required to mitigate the deterioration of the global ecosystem and the consequences of environmental pollution on human health, welfare, and lifestyle for present and future generations.

To be a skeptic without expert knowledge about a subject is always easier than to be knowledgeable, since acquiring knowledge requires one to expend considerable time studying, exploring, and analyzing a subject, which requires an inquisitive and alert mind and perseverance in discovering the truth. It is only the few who can measure up to such standards, and they are the ones whom we call scholars. However, skepticism based on a solid foundation is the essence of every new human intellectual discovery.

2 Solar Power and Sustainable Energy Technologies and Their Impact on Global Economy

Introduction

In the past couple of decades, solar power as well as sustainable energy system deployment have been misunderstood and largely dismissed as viable sources of sustainable energy. More specifically, the valuation of solar power system technology as a viable source of clean energy has in some instances been hampered, mainly by a lack of appreciation of the technology's impact on the national and global economy and its significant long-term benefits to human welfare and global ecology.

When considering the trade-off of inexpensive power generated by coal and other fossil fuels versus degradation of the ecosystem, which is essential to the sustenance of human and animal life, we must also measure the costs of sustainable energy and its significance in relation to the survival of life itself.

Unfortunately, competing business interests and market forces have recently flooded the news and television media with negative opinions and notions in regard to the viability of sustainable energy systems. These reports are frequently inaccurate and wholly misrepresentative of technologies that hold great promise for significant long-term benefits to the global ecology and economy. As a result, alternative energy systems, and more specifically *solar power technologies,* have been dismissed and labeled as expensive and inefficient solutions unable to meet the ever-increasing demand for global energy. Yet coal-fired electrical energy advertisements have taken center stage and have been branded as "clean energy" that could solve today's and tomorrow's world energy shortcomings.

In a book entitled *Solar Power in Building Design*, recently published by McGraw-Hill, I wrote a forward discussing the implications of global dependency on fossil fuels and their contribution to global warming. In it, I attempted to illustrate a number of concerns that urgently require further discussion. Without a profound appreciation of the dire ecological consequences of continued fossil fuel energy use, and lacking the validation of sustainable energy generation technologies as *essential* in their impact on the human lifestyle, it is highly unlikely that we will be able to achieve an equitable balance to maintain a reasonably viable lifestyle for future generations.