Introduction

In the beginning when God created the heavens and the earth, the earth was a formless void and darkness covered the face of the deep, while a wind from God swept over the face of the waters. Then God said, "Let there be light"; and there was light.

GENESIS 1:1-3

Wind. Light. Creation. To imagine the fullness of God is to talk about energy. From beginning to end, the Bible is replete with images of energy and divine activity. In the first verses of Genesis, "a wind from God swept over the face of the waters," inaugurating God's creation of the world (Genesis 1:2).[1] In the last chapter of Revelation, "the river of the water of life" flows from the throne of God to water the trees of life that grow along its banks, and whose twelve kinds of fruit are for the healing of the nations (Revelation 22).

Religious Understandings of Energy

Energy is central to God's work as Creator, Redeemer, and Sanctifier. In the first creation account, God works for six days to create the world, which God proclaims "very good" (Genesis 1:31). The second creation account emphasizes that the first human being *(Adam)* is created from energy-intensive and life-sustaining humus *(adamah)* (Genesis 2). God's redeeming and liberating work is also described in dramatic and energetic ways. After parting the Red Sea, God leads the freed Hebrew slaves in a pillar of cloud by day and a pillar of fire by night (Exodus 13:21). The prophet Amos compares God's quest for justice to the powerful force of a waterfall and the might of a raging river that clears everything from its path (Amos 5:24). Finally, God's gift of the Holy Spirit on the day of Pentecost is preceded by "a sound like the rush of a violent wind," after which "tongues, as of fire" rested on each of the disciples (Acts 2:1-3).

The authors of the Synoptic Gospels all discuss Jesus' ministry in terms of power. They utilize the Greek noun *δύναμισ* (*dunamis*) to describe the power with which Jesus performs miracles (Mark 6:2; 9:39), they associate this power with God (Mark 12:24; 14:62), and they emphasize that Jesus transfers this power to his disciples (Luke 9:1; Matt. 25:15). When a woman plagued by hemorrhages touches Jesus' cloak, it becomes clear that Jesus is filled with a redemptive and healing power because she is immediately healed of her disease. Sensing that "power had gone forth from him," Jesus praises the woman for her faith and blesses her (Mark 5:25-34). Divine power is redemptive energy.

God also provides energy in abundance for all whom God has made (Psalms 145:15). The birds of the air and the fish of the sea first receive the same blessing God bestows on human beings—to be fruitful and multiply (Genesis 1:22). As the people of God wander in the wilderness after the Exodus, God sends "enough" manna each day to sustain the community (Exodus 16). The jubilee legislation in Exodus and Leviticus stressed the needs of the poor and wild animals to eat from fields left fallow every seven years because all creatures are entitled to the energy they need to live. In the Gospel of John, Jesus proclaims that he has come so that all "may have life, and have it abundantly" (John 10:10). Jesus demonstrates this in the feeding of the five thousand, where all are fed and twelve baskets of food are left over (Mark 6:39-44). Paul summarizes, "God is able to provide you with every blessing in abundance, so that by always having enough of everything, you may share abundantly in every good work" (2 Corinthians 9:8). Abundance and sufficiency are linked.

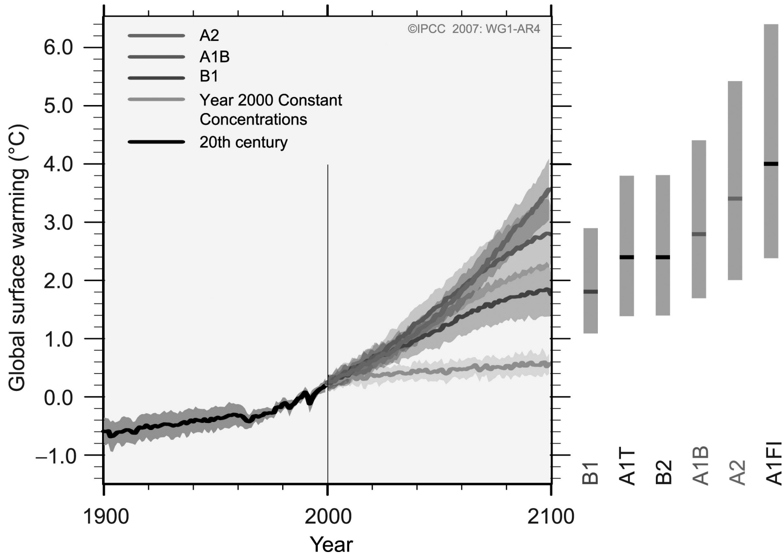
There can be no greater measure of God's abundant provision than the energy provided by Earth's sun. Each hour of every day, the sun delivers more energy to Earth than human beings consume in an entire year.[2] Renewable energy sources can provide almost six times more power than human communities currently consume from all energy sources.[3] Unlike virtually all other species, however, human beings in the modern era have not learned how to live in harmony with current solar energy that we receive each day from the sun. Instead, human communities have grown and some have prospered over the past three centuries by tapping into banked solar energy that has been buried for millions of years as fossil fuels beneath Earth's surface.

Moral Challenges in Energy Use

Today, heavy reliance on these fossil fuels (coal, oil, and natural gas) has produced grave threats to justice, peace, and the integrity of creation. The related challenges posed by global climate change are unprecedented in human history. If the world takes a business-as-usual approach and continues a fossil-fuel-intensive energy path during the twenty-first century, the Intergovernmental Panel on Climate Change (IPCC) projects current concentrations of greenhouse gases could more than quadruple by the year 2100. The last time Earth had such a level of greenhouse gases in the atmosphere was fifty million years ago, when no permanent ice existed anywhere on the planet, even in Antarctica.[4] If present trends continue, the IPCC's best estimate is that the global average surface temperature will increase 4.0°C (7.2°F) by the end of the twenty-first century (Fig. 0.1), but the upper range of this estimate projects warming could reach 6.4°C (11.5°F).[5] Putting these changes into perspective, the global average surface temperature has increased only 0.74°C (1.37°F) since 1850.[6]

This rapid rate of global warming will raise sea levels, endangering millions of people living in low-lying areas, despoil freshwater resources, widen the range of infectious diseases like malaria, reduce agricultural production, and increase the risk of extinction for 25 percent to 30 percent of all surveyed species.[7] The U.S. Climate Change Science Program claims, "We are very likely to experience a faster rate of climate change in the next 100 years than has been seen over the past 10,000 years."[8]

FIG. 0.1 Multimodel Averages and Assessed Ranges for Surface Warming



The solid lines are multimodel global averages of surface warming (relative to 1980–1999) for IPCC emission scenarios A2, A1B, and B1, shown as continuations of the twentieth-century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The gray bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the IPCC's six emission scenarios. Scenario A1F1 (far-right bar) reflects the consequence of "business as usual" emissions.

Source: Intergovernmental Panel on Climate Change, "Summary for Policymakers," in Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. S. Solomon et al. (New York: Cambridge University Press, 2007), fig. SPM.5, p. 14, accessed at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. Unfortunately, it was not possible to reprint this graph in its original color version.

These findings have prompted scientists all over the world to plead for reductions in greenhouse gas (GHG) emissions. James Hansen, the leading climate scientist in the United States, argues that following a business-as-usual approach for ten more years "guarantees that we will have dramatic climate changes that produce what I would call a different planet."[9] Hansen warns, "Recent greenhouse gas emissions place the Earth perilously close to dramatic climate change that could run out of our control, with great dangers for humans and other creatures."[10] To avoid ecological catastrophe, many scientists and policy makers are urging that global warming be held to less than 2°C (3.6°F) above preindustrial levels.[11]

Together with people all around the world, Christians at the outset of the twenty-first century must respond to this climate crisis by developing a new way of living in harmony with Earth's energy resources and in solidarity with all of God's creatures. This moral obligation involves our commitment to the poor and marginalized among the present generation, but it especially includes our responsibilities to future generations. Actions taken or not taken today will affect the welfare of the planet for centuries to come.

Those of us living in the United States have a unique moral responsibility to change our energy consumption practices in the face of global climate change. According to the World Resources Institute, the United States is responsible for nearly 30 percent of the carbon dioxide (CO_2) emissions produced by the combustion of fossil fuels from 1850 to 2002.[12] Even though China now leads the world in annual CO_2 emissions—with 24 percent of the total, compared with the United States at 21 percent—the United States still leads the world in CO_2 emissions on a per capita basis, according to a 2008 report issued by the Netherlands Environmental Assessment Agency. Each person in the United States produces 19.4 metric tons of carbon dioxide (t CO_2) per year, compared with 11.8 t CO_2 per person in Russia, 8.6 t CO_2 in the European Union, 5.1 t CO_2 in China, and only 1.8 t CO_2 per person in India.[13] Given statistics like these, there is no question that as a nation and as individuals, citizens of the United States must accept moral responsibility to deal with the negative consequences associated with fossil fuel consumption and global warming.

The challenges are daunting, and to many, they appear insurmountable. Certainly, several Christian traditions support a hard-eyed realism with regard to the nexus of issues related to energy policy and global climate change. Empowered, however, by a just, good, and gracious God, we must resist the temptation of despair. Among the wealthy and powerful, such despondency can be self-serving, because it leads to moral paralysis. This "cheap despair" changes nothing and preserves the status quo from which the wealthy and powerful currently benefit. Empowered by God's costly grace, Christians must work tirelessly with others as individuals, within church denominations, and as global citizens to live in harmony with the energy resources God has so abundantly provided.

The rest of this introductory chapter explores more fully various problems associated with reliance on fossil fuels and also examines in greater detail the recent findings of climate scientists.

Problems Related to Fossil Fuel Energy Sources

Energy is a key factor in advancing well-being and realizing human potential. Advances in the creative and efficient use of modern, fossil fuel energy sources have been at the heart of progress in affluent industrial nations, enabling advances in living standards to levels never experienced before in history. Energy is vital for growing and providing food for the world, for facilitating advances in health technologies, for powering transportation and industry, and for enabling the growth of the information and communications revolution. As technologies have advanced, energy costs as a share of economic output have tended to decline. This has created the foundation for sizable growth in living standards, reducing the burden of human toil and turning what were once conveniences into virtual necessities for those in the industrial and industrializing worlds.

Nevertheless, roughly one-third of the world's population (over two billion people) still lacks access to adequate supplies of energy, particularly electricity. This lack of access impairs human health and welfare, wastes environmental resources, and limits development in countless ways. For cooking, reliance on inefficient wood stoves leads to emission of large amounts of carbon monoxide and particulate matter, creating high levels of indoor air pollution that induce respiratory illness and shorten lives. Deforestation brings its own tragedies. Without electricity, there is no refrigeration to cool vaccines, no power for lights and computers needed to expand education, and limited connection to the wider world. This lack of access impairs human health and welfare, wastes environmental resources, and limits development in countless ways. Thomas Friedman argues persuasively, in his recent book *Hot, Flat, and Crowded,* that addressing "energy poverty" is one of the keys to reducing all forms of poverty around the world.[14]

While one-third of the world's population experiences serious problems associated with *too little access* to modern supplies of energy, all nations are grappling with various problems associated with *too much use* of fossil fuel energy sources by the rest of the world.

Social Problems

Even in the United States, where environmental regulations have slowed the rate of emissions related to the increasing use of fossil fuels, the American Lung Association estimates over 150 million people live in areas where the air quality puts their health at risk.[15] Vehicle emissions are the leading cause of this air pollution.[16] The 240 million cars, trucks, and buses on U.S. roads today emit a noxious cloud of pollutants consisting of large and fine particulate matter, volatile organic compounds, ozone, nitrogen oxide, and carbon monoxide.[17] These pollutants are a leading cause of asthma, lung cancer, and other respiratory diseases, cardiopulmonary disease, low-birth-weight babies, and increased infant mortality.[18] Each year, diesel exhaust alone is responsible for over 125,000 cancer cases in the United States, and nearly 100,000 Americans die annually from causes attributable to smog.[19] These health impacts are concentrated in cities all over the country, but they have a particularly harsh and unjust effect on vulnerable populations such as asthmatics, the elderly, the very young, and those who live near busy highways, refineries, and polluting industries. People who are poor and racial minorities bear a disproportionate and unjust share of this burden.[20] Around the world, the global toll from air pollution is much worse, likely exceeding a million deaths annually. This is particularly the case if we include indoor air pollution, which has a significant impact on women and children, who spend more time indoors.

Health issues associated with coal mining and the burning of coal to generate electricity are especially sobering. Next to petroleum, coal is the second largest source of energy in the world.[21] Each year, more than 6,000 coal miners are killed in China's coal mines.[22] Since 1900, more than 100,000 people have been killed in coal mine accidents in the United States, and black lung disease is estimated to have killed twice as many miners over the same period of time.[23] Accounting for nearly half of all electricity generation, coal-fired power plants in the United States produce two-thirds of all sulfur dioxide (the leading cause of acid rain), 22 percent of all nitrogen oxides (a major contributor to smog), approximately 40 percent of carbon dioxide (the principal greenhouse gas), and 40 percent of all emissions of mercury (a potent neurotoxin that accumulates in body tissues).[24] The Centers for Disease Control and Prevention (CDC) reports that one in twelve women in the United States have an unsafe level of mercury in their blood, and that as many as 630,000 babies per year could be at risk for health problems. The Environmental Protection Agency has issued advisories in forty-four of the fifty states regarding high mercury levels in various kinds of fish.[25]

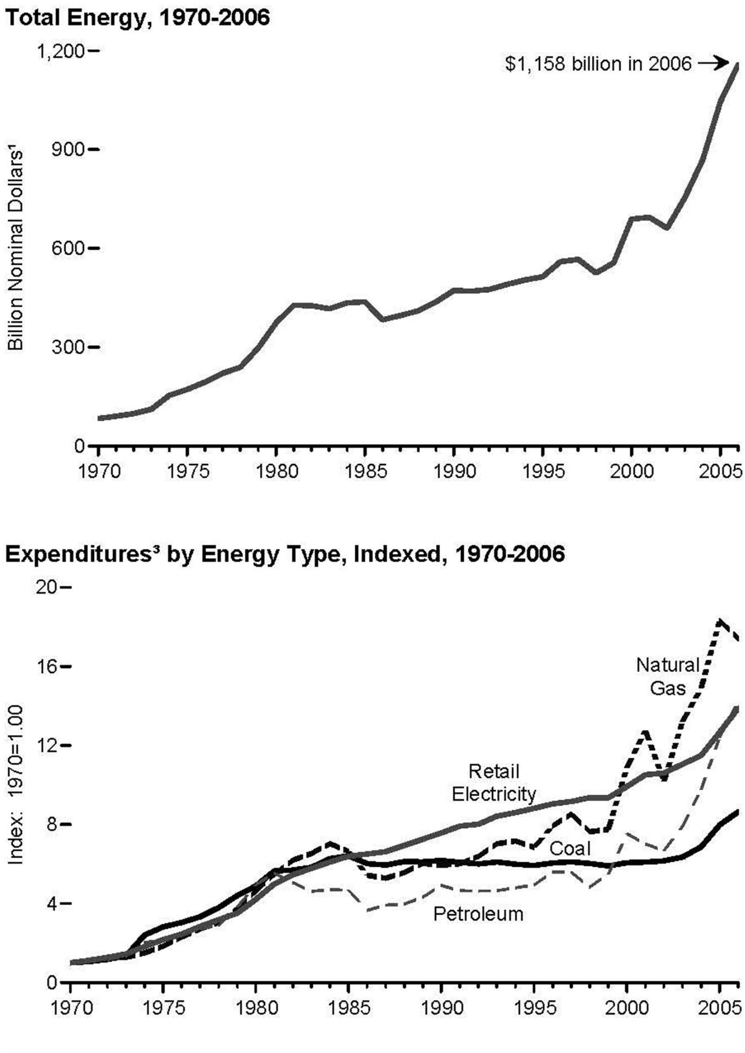
Economic Problems

For various reasons, energy prices have risen sharply in the United States over the past two decades (Fig. 0.2). Persons in low-income households (especially elderly residents, the disabled, and children) are most vulnerable to rising costs and often must choose between paying their energy bills or buying food and medicine. Congress created the Low Income Home Energy Assistance Program (LIHEAP) in 1981 precisely to address this need. Families receiving LIHEAP assistance must have income below 150 percent of the federal poverty level. Two-thirds of LIHEAP families earn less than $8,000 per year. Sadly, funding levels for the program have not kept pace with the growing number of households eligible for assistance. In recent years, Congress has authorized sufficient funding to provide LIHEAP assistance for only 15 percent of the eligible population.[26] The American Recovery and Reinvestment Act of 2009 that President Obama signed into law as a major economic stimulus bill provided only a 20 percent increase to LIHEAP's budget.[27]

The rising cost of petroleum fuels has affected all Americans. The average price of gasoline more than doubled from less than $2 a gallon in 2002 to over $4 a gallon in 2008.[28] This has had a disproportionate impact on people who are poor. Poor households with incomes below $15,000 a year typically spend more than 10 percent of their income on gasoline.[29] While prices dropped back to lower levels in 2009, many analysts believe this price reduction will be short-lived. U.S. oil production peaked in the 1970s, and ever since, imports have been rising steadily to meet demand. Today, the United States imports approximately two-thirds of the oil it consumes. Net imports of crude oil in 2008 cost $354 billion and represented over 52 percent of the nation's $677 billion international trade deficit in goods and services (Fig. 0.3).[30] These are dollars the United States could spend to reduce serious and unjust deficits in health care coverage or to invest in inner-city education and poverty alleviation. Instead, the rapidly increasing demand for oil in China and India is pushing the U.S. cost of imported oil even higher. As a result, the needs of the poor get shortchanged because the United States spends more and more money each year to purchase oil.

There are other significant costs related to U.S. oil supplies. Various studies estimate the United States spends between $55 billion and nearly $100 billion each year on the military to secure its oil supplies

FIG. 0.2. U.S. Consumer Energy Expenditures



[1] See "Nominal Dollars" in Glossary.
[2] Wood and waste; excludes ethanol and biodiesel.
[3] Based on nominal dollars.
[4] Liquefied petroleum gases.

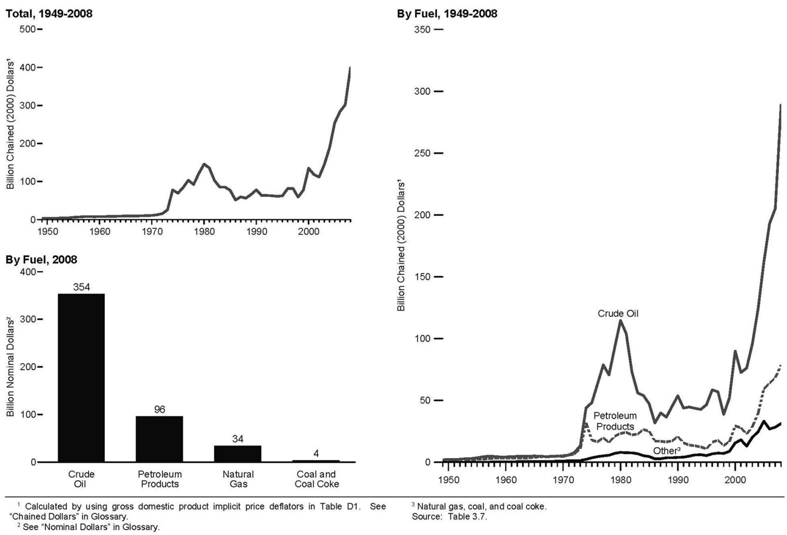
Source: Energy Information Administration, Annual Energy Review 2008, DOE/EIA-0384(2008) (Washington, D.C.: EIA, June 2009), fig. 3.5, p. 76, accessed online at http://www.eia.doe.gov/aer/pdf/aer.pdf.

around the world.[31] These estimates do not include more than $100 billion spent each year since 2003 for the war in Iraq, which has the world's third largest proven reserves of oil.[32] With the number of civilian and military deaths in Iraq at or above 100,000 people, those who mourn the loss of their loved ones are a reminder that the human toll far exceeds the economic costs of this war.[33] Nevertheless, when these costs are added to the cost of federal and state subsidies to the oil industry, and combined with estimates of health care costs related to fossil fuel pollution, some analysts argue that the true cost of a gallon of gasoline at the pump ranges from $8 to $11 per gallon.[34]

Political Problems

Recently, the National Petroleum Council warned that international energy development and trade are more likely to be influenced by geopolitical considerations and less by market factors.[35] President Bush acknowledged this reality in his 2006 State of the Union address when he remarked, "America is addicted to oil, which is often imported from unstable parts of the world."[36] More recently, President

Fig. 0.3. Value of U.S. Fossil Fuel Imports



Source: Energy Information Administration, Annual Energy Review 2008, DOE/EIA-0384(2008) (Washington, D.C.: EIA, June 2009), fig. 3.7, p. 80, accessed online at http://www.eia.doe.gov/aer/pdf/aer.pdf. For definitions of "chained" and "nominal" dollars, see the glossary at the end of *Annual Energy Review* 2008.

Obama lamented in his 2009 Address to the Joint Session of Congress that "we import more oil today than ever before."[37] In recent years, over half of U.S. oil imports have come from four leading suppliers: Canada (19 percent), Saudi Arabia (12 percent), Mexico (11 percent), and Venezuela (10 percent). Nigeria, Algeria, Angola, Iraq, Brazil, and Kuwait round out the other top ten suppliers.[38] While the United States enjoys primarily positive foreign relations with its neighbors, Canada and Mexico, it has strained relationships with Saudi Arabia and Venezuela. In addition, the relationship between blood and oil is all too clear in Iraq's civil strife, and it is becoming more apparent as the level of violence and civil unrest grows in nations like Nigeria and Angola, where oil wealth is not being spread broadly to all residents of these oil-exporting nations. A recent report by Amnesty International claims the exploitation of oil reserves in the Niger Delta has produced a "resource curse" for the 31 million people in the region who suffer from pollution related to the production and from human rights abuses related to its control.[39]

Once oil has been extracted from beneath the ground, transporting the oil can lead to another set of political problems. More than half the world's oil passes through a few potential "choke points," including the Suez Canal, the Bosporus, and the Straits of Hormuz and Malacca.[40] A significant disruption of oil shipments through any of these points could wreak havoc on the world's economy. Nine out of the last ten recessions in the United States were preceded by oil price shocks related to supply disruptions.[41] Many analysts fear that Iran may lay siege to tankers in the Strait of Hormuz if the United States or Israel attacks the facilities Iran has built to enrich uranium.

With demand for natural gas rising around the world, Russia's control of natural gas supplies raises concerns for many nations in Europe and Central Asia. Recently Russia signed a deal to build a pipeline from Turkmenistan through Kazakhstan, which will feed Russia's network of pipelines to Europe. The deal seeks to thwart efforts by the United States and other European nations to build oil and gas pipelines that would avoid Russia by connecting to Europe through Azerbaijan and Turkey. Recently, Russia reduced the flow of natural gas to Georgia, which reduced supplies for countries in Eastern Europe that are fed by the same pipeline. Many European nations fear Russia will use its virtual monopoly over natural gas resources for political purposes.[42]

This brief overview reveals a host of social, economic, and political problems associated with heavy reliance by the United States on fossil fuels. There are also serious environmental problems. Oil spills around the world despoil waters and harm wildlife. Mountaintop coal mining in Appalachia erodes hillsides, ruins scenic lands, and degrades surface streams and groundwater supplies. Emissions of nitrogen oxides and particulate matter from fossil fuel combustion play havoc with respiratory systems. Volatile organic compounds in petroleum fuels produce cancers and other diseases. Sulfur dioxide emissions from the burning of coal produce acid rain that destroys forests and significantly reduces agricultural production around the world.

Global Warming and Climate Change

While these are all serious problems, they pale in comparison to the unprecedented perils posed by global warming and climate change. After nearly two decades of intensive study, scientists around the world have reached a much greater consensus about these phenomena, their causes, and likely impacts. The United Nations established the Intergovernmental Panel on Climate Change (IPCC) in 1988 to review and assess the most recent scientific, technical, and socioeconomic information relevant to climate change. The IPCC has issued periodic reports and issued its Fourth Assessment Report in four installments during 2007. Over 1,200 authors contributed to the report, and their work was reviewed by more than 2,500 scientific experts.[43] Since each report for policy makers is approved line by line in plenary sessions, the IPCC's findings are arguably the least controversial and most accepted assessments of climate change in the scientific community. As a result, their findings are also relatively conservative.

The IPCC Fourth Assessment Report in 2007 finally persuaded many that global warming is real, that it is caused by human activity, and that it will very likely produce climate change in the twenty-first century that will be unprecedented in human history. The following are some of the key findings reprinted directly from the IPCC reports.

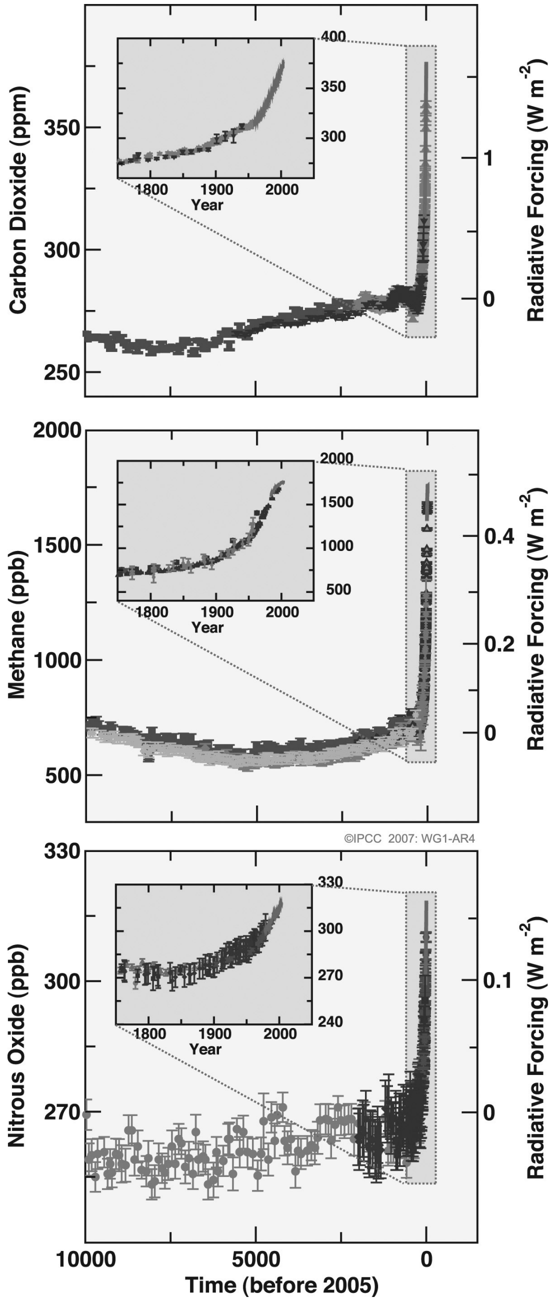
Human and Natural Drivers of Climate Change[44]

- Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed preindustrial values determined from ice cores spanning many thousands of years (see fig. 0.4).
- Carbon dioxide is the most important anthropogenic greenhouse gas. The global atmospheric concentration of CO_2 has increased from a preindustrial value of about 280 ppm to 379 ppm in 2005. The atmospheric concentration of CO_2 in 2005 exceeded by far the natural range over the past 650,000 years (180 to 300 ppm) as determined from ice cores.
- The primary source of the increased atmospheric concentration of CO_2 since the preindustrial period results from fossil fuel use, with land use change providing another significant but smaller contribution.
- The understanding of anthropogenic warming and cooling influences on climate has improved since the Third Assessment Report, leading to *very high confidence* (greater than 90 percent probability) that the globally averaged net effect of human activities since 1750 has been one of warming.

Direct Observations of Recent Climate Change[45]

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level (see fig. 0.5).
- Eleven of the past twelve years (1995 to 2006) rank among the twelve warmest years in the instrumental record of global surface temperature.
- At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather, including droughts,

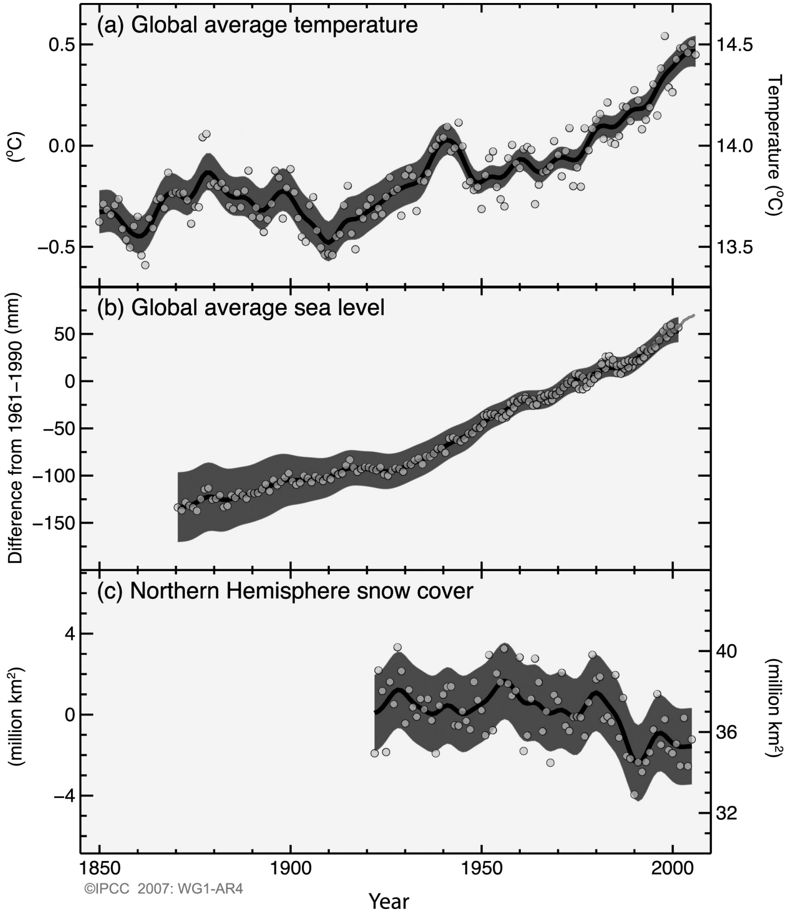
FIG 0.4 Changes in Greenhouse Gases from Ice Core and Modern Data



Atmospheric concentrations of carbon dioxide, methane, and nitrous oxide over the past 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colors for different studies and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right axes of the large panels.

Source: Intergovernmental Panel on Climate Change, "Summary for Policymakers," in Climate Change 2007: *The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon et al. (New York: Cambridge University Press, 2007), fig. SPM.1, p. 3, accessed at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. Unfortunately, it was not possible to reprint this graph in its original color version.

Fig. 0.5. Changes in Temperature, Sea Level, and Northern Hemisphere Snow Cover.



Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data, and (c) Northern Hemisphere snow cover for March through April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values, while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c).

Source: Intergovernmental Panel on Climate Change, "Summary for Policymakers," in *Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. S. Solomon et al. (New York: Cambridge University Press, 2007), fig. SPM.3, p. 6, accessed at http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf. Unfortunately it was not possible to reprint this graph in its original color version.

heavy precipitation, heat waves, and the intensity of tropical cyclones.
- Average Arctic temperatures increased at almost twice the global average rate in the past 100 years.

Projections of Future Changes in Climate[46]

- Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the twenty-first century that would *very likely* be larger than those observed during the twentieth century.
- This assessment gives best estimates and likely ranges for globally average surface air warming in six emissions scenarios. For example, the best estimate for the low scenario is 1.8°C (3.2°F), and the best estimate for the high scenario is 4.0°C (7.2°F).
- Past as well as future anthropogenic CO_2 emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the timescales required for removal of this gas from the atmosphere.

Current Knowledge of Future Impacts[47]

- Drought-affected areas will likely increase in extent. Heavy-precipitation events, which are very likely to increase in frequency, will augment flood risk.
- In the course of the century, water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives.
- The resilience of many ecosystems is likely to be exceeded this century by an unprecedented combination of climate change, associated disturbances (for example, flooding,

Impact of Climate Change on the United States

The U.S. Global Change Research Program published a major report in 2009 on the impact of global climate change on the United States. What follows are some of the key findings excerpted directly from the study:

- The U.S. average temperature has risen more than 2°F over the past 50 years and is projected to rise more in the future; how much more depends primarily on the amount of heat-trapping gases emitted globally and how sensitive the climate is to those emissions.
- Precipitation has increased an average of about 5 percent over the past 50 years. Projections of future precipitation generally indicate that northern areas will become wetter, and southern areas, particularly in the West, will become drier.
- The amount of rain falling in the heaviest downpours has increased approximately 20 percent on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places.
- Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past forty to fifty years.
- The destructive energy of Atlantic hurricanes has increased in recent decades. The intensity of these storms is likely to increase in this century.
- In the eastern Pacific, the strongest hurricanes have become stronger since the 1980s, even while the total number of storms has decreased.
- Sea level has risen along most of the U.S. coast over the past fifty years and will rise more in the future.
- Cold-season storm tracks are shifting northward, and the strongest storms are likely to become stronger and more frequent.
- Arctic sea ice is declining rapidly, and this is very likely to continue.

Source: Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, eds., *Global Climate Change Impacts in the United States* (New York: Cambridge University Press, 2009), 27, accessed at http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf.

drought, wildfire, insects, ocean acidification), and other global change drivers (for example, land use change, pollution, over-exploitation of resources).

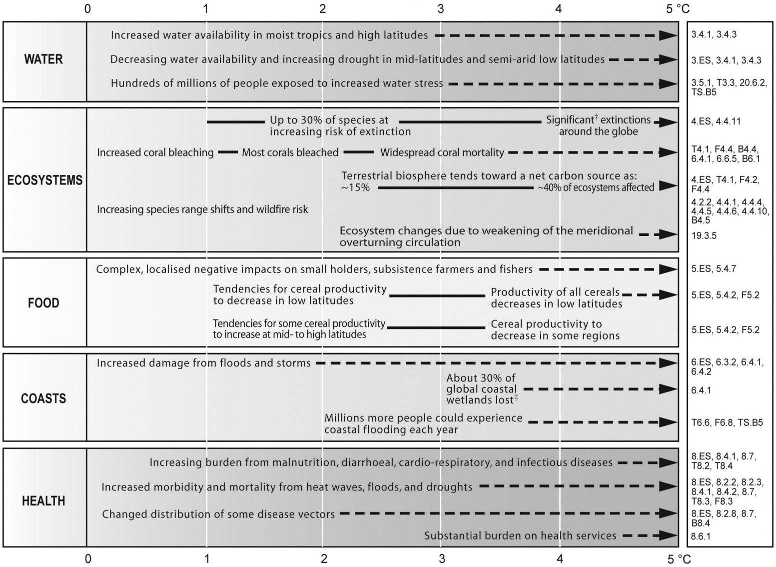
- Approximately 20 to 30 percent of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5°C to 2.5°C (see Fig. 0.6).
- Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1°C to 3°C, but above this it is projected to decrease.
- Many millions more people are projected to be flooded every year due to a rise in sea level by the 2080s. The numbers affected will be largest in the mega-deltas of Asia and Africa, while small islands are especially vulnerable.
- Poor communities can be especially vulnerable, particularly those concentrated in high-risk areas. They tend to have more limited adaptive capacities and are more dependent on climate-sensitive resources such as local water and food supplies.[48]

In summary, the IPCC's Fourth Assessment Report concluded that the scientific evidence of global warming is "unequivocal" and that that panel has "very high confidence" that human activities have contributed to this warming since 1750.[49] The Earth's global average surface temperature has increased 0.74°C (1.37°F) since 1850, and the rate of temperature increase has been accelerating since 1970.[50] The IPCC reported that the concentration of the principal greenhouse gas, CO_2, increased from preindustrial levels of 280 parts per million by volume (ppm) to 379 ppm in 2005. At the end of 2008, atmospheric concentrations of CO_2 stood at 386 ppm, and the concentration of all six greenhouse gases stood at over 460 ppm of carbon dioxide equivalent (CO_2eq).[51]

Climate Sensitivity Thresholds

After the IPCC issued its Third Assessment Report in 2001, many scientists believed that limiting CO_2 concentrations to 450 ppm and all greenhouse gases to 550 ppm CO_2eq would be sufficient to forestall the worst consequences of climate change. In fact, the U.S. Global Change Research Program published a major report in 2009 on the impact of

Fig. 0.6. Key Impacts as a Function of Increasing Global Average Temperature Change



Source: Intergovernmental Panel on Climate Change, "Summary for Policymakers," in Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovermental Panel on Climate Change, ed. M. L. Parry et al. (Cambridge: Cambridge University Press, 2007), fig. SPM.2, p. 16, accessed at http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf.

†"Significant" is defined here as more than 40 percent.

‡Based on average rate of sea level rise of 4.2 mm/yr from 2000 to 2080.

global climate change that focused on this 450 ppm CO_2 threshold, though it noted that scenarios that stabilize emissions below that level "offer an increased chance of avoiding dangerous climate change."[52] Today, an increasing number of scientists and policy makers are urging that global concentrations of CO_2 be reduced from their current level and stabilized at 350 ppm or lower, in order to limit the total increase in global surface temperature from preindustrial levels to no more than 2°C.[53]

Converting greenhouse gas (GHG) concentrations to future temperature changes is currently limited by scientific uncertainty about the sensitivity of the planet's climate system. Climate sensitivity is defined as the global mean temperature increase that would result in the long run if CO_2 concentrations were to double from their preindustrial level of approximately 278 ppm. If climate sensitivity is low, then a doubling of carbon dioxide levels to 550 ppm might produce only 1°C of warming. If climate sensitivity is high, then 4.5°C of warming might result from the doubling of CO_2 concentrations. The IPCC Fourth Assessment Report estimates climate sensitivity "*likely* to be in the range 2°C to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C."[54] According to the Worldwatch Institute, there is about a 75 percent risk that stabilizing greenhouse gas concentrations at 550 ppm CO_2eq would lead to warming exceeding 2°C. If concentrations are stabilized at 475 CO_2eq, the risk of exceeding 2°C is reduced to 50 percent.[55] That amounts to flipping a coin.

The IPCC Fourth Assessment Report reviews a variety of GHG emission scenarios and related temperature stabilization levels. For the best chance of limiting the temperature increase to 2.0°C to 2.4°C, the IPCC emphasizes that global GHG emissions must peak before 2015 and then fall 85 percent by 2050 to within a range of 350 to 400 ppm for CO_2 and 445 to 490 ppm CO_2eq for all greenhouse gases.[56]

Research published after the IPCC's Fourth Assessment Report has raised concerns that these recommended temperature and GHG concentration thresholds may be too high to forestall dangerous climate change. In 2008, the most famous climate scientist in the United States, James Hansen, made the following recommendation in a coauthored article published in the *Open Atmospheric Science Journal:* "If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm, but likely less than that."[57]

Across the Atlantic, in England, the former cochair of the IPCC, Sir John Houghton, expressed his concern that "the 2°C target as currently pursued will almost certainly turn out to be inadequate."[58] Houghton arrived at this conclusion after observing record-low summer sea ice volume during 2008 in the Arctic Ocean. Some climate scientists now predict the Arctic Ocean could be completely ice free by 2015, eighty years ahead of the IPCC's most recent projections.[59] In 2009, a group of scientists at the International Scientific Congress on Climate Change presented findings that sea levels may rise twice as much by the end of the century as was projected in the IPCC's Fourth Assessment Report. One of the scientists remarked, "We are at the very least in the worst-case scenario of the IPCC. There's no good news here."[60]

In July 2009, the Commonwealth Scientific and Industrial Research Organization (CSIRO), an Australia-based research group, published a report that shows the amount of carbon stored in frozen soils at high latitudes is double previous estimates and could, if emitted as carbon dioxide and methane, lead to a significant increase in the global average surface temperature by the end of this century. The scientists warn that if only 10 percent of the permafrost melts, an additional 80 ppm CO_2eq would be released into the atmosphere, resulting in an additional 0.7°C of global warming. The scientists warn that rapid thawing of the permafrost will create a negative feedback loop, which will only spur even greater warming.[61]

Virtually all climate scientists agree that global warming is real and that the concentration of greenhouse gases in the atmosphere poses unprecedented challenges from climate change for human communities.[62] A recent study in the United States published in the prestigious *Proceedings of the National Academy of Sciences* notes warming will take place for a thousand years even after GHG emissions stop. The report concludes, "Irreversible climate changes due to carbon dioxide emissions have already taken place, and future carbon dioxide emissions would imply further irreversible effects on the planet, with attendant long legacies for choices made by contemporary society."[63]

Conclusion

Clearly, global warming and related climate change brought on by the combustion of fossil fuels and some land use practices pose grave threats to justice, peace, and the integrity of creation. The information provided by the IPCC raises at least two fundamental ethical issues. The first is an *inter*generational question: What are our obligations to future generations with regard to reducing or mitigating the challenges posed by climate change? The second is an *intra*generational question: How do we equitably distribute the burdens associated with mitigating greenhouse gas emissions and adaptation to global climate change among present generations? A recent report of the United Nations Development Programme reframes these questions in a more provocative way:

> Climate change demands urgent action now to address a threat to two constituencies with little or no political voice: the world's poor and future generations. It raises profoundly important questions about social justice, equity and human rights across countries and generations . . . . Dangerous climate change is the avoidable catastrophe of the 21st Century and beyond. Future generations will pass a harsh judgment on a generation that looked at the evidence on climate change, understood the consequences, and then continued on a path that consigned millions of the world's most vulnerable people to poverty and exposed future generations to the risk of ecological disaster.[64]

This book grapples with these issues of climate justice and focuses primarily on the ethical responsibilities of industrialized nations, especially the United States. The first chapter offers biblical and ethical resources for grappling with these ethical questions. The subsequent chapters use these resources to assess the ethics of diverse energy options as well as international and U.S. climate policy proposals.