Cornwall Alliance
For The Stewardship Of Creation

A Renewed Call to Truth, Prudence, and Protection of the Poor

An Evangelical Examination of the Theology, Science, and Economics of Global Warming

EXECUTIVE SUMMARY

The world is in the grip of an idea: that burning fossil fuels to provide affordable, abundant energy is causing global warming that will be so dangerous that we must stop it by reducing our use of fossil fuels, no matter the cost.

Is that idea true?

We believe not.

We believe that idea—we'll call it "global warming alarmism"—fails the tests of theology, science, and economics. It rests on poor theology, with a worldview of the Earth and its climate system contrary to that taught in the Bible. It rests on poor science that confuses theory with observation, computer models with reality, and model results with evidence, all while ignoring the lessons of climate history. It rests on poor economics, failing to do reasonable cost/benefit analysis, ignoring or underestimating the costs of reducing fossil fuel use while exaggerating the benefits. And it bears fruit in unethical policy that would destroy millions of jobs.

- cost trillions of dollars in lost economic production.
- slow, stop, or reverse economic growth.
- reduce the standard of living for all but the elite few who are well positioned to benefit from laws that unfairly advantage them at the expense of most businesses and all consumers.
- endanger liberty by putting vast new powers over private, social, and market life in the hands of national and international governments.
- condemn the world's poor to generations of continued misery characterized by rampant disease and premature death.

In return for all these sacrifices, what will the world get? At most a negligible, undetectable reduction in global average temperature a hundred years from now.

Our examination of theology, worldview, and ethics (Chapter One) finds that global warming alarmism wrongly views the Earth and its ecosystems as the fragile product of chance, not the robust, resilient, self-regulating, and self-correcting product of God's wise design and powerful sustaining. It rests on and promotes a view of human beings as threats to Earth's flourishing rather than the bearers of God's image, crowned with glory and honor, and given a mandate to act as stewards over the Earth—filling, subduing, and ruling it for God's glory and mankind's benefit. It either wrongly assumes that the environment can flourish only if humanity forfeits economic advance and prosperity or ignores economic impacts altogether. And in its rush

to impose draconian reductions in greenhouse gas emissions, it ignores the destructive impact of that policy on the world's poor.

Executive Summary

Our examination of the science of global warming (Chapter Two) finds that global warming alarmism wrongly claims that recent temperature changes have been greater and more rapid than those of the past and therefore must be manmade, not natural. It exaggerates the influence of manmade greenhouse gases on global temperature and ignores or underestimates the influence of natural cycles. It mistakenly takes the output of computer climate models as evidence when it is only predictions based on hypotheses that must be tested by observation. It falsely claims overwhelming scientific consensus in favor of the hypothesis of dangerous manmade warming (ignoring tens of thousands of scientists who disagree) and then falsely claims that such consensus proves the hypothesis and justifies policies to fight it. It seeks to intimidate or demonize scientific skeptics rather than welcoming their work as of the very essence of scientific inquiry: putting hypotheses to the test rather than blindly embracing them.

Our examination of the economics of global warming alarmism (Chapter Three) finds that it exaggerates the harms from global warming and ignores or underestimates the benefits not only from warming but also from increased atmospheric carbon dioxide. It grossly underestimates the costs and overestimates the benefits of policies meant to reduce carbon dioxide emissions. It exaggerates the technical feasibility and underestimates the costs of alternative fuels to replace fossil fuels in providing the abundant, affordable energy necessary for wealth creation and poverty reduction. It ignores the urgent need to provide cleaner energy to the roughly two billion poor in the world whose use of wood and dung as primary cooking and heating fuels causes millions of premature deaths and hundreds of millions of debilitating respiratory diseases every year. It fails to recognize that the slowed economic development resulting from its own policies will cost many times more human lives than would the warming it is meant to avert.

In light of all these findings, **we conclude** that

- human activity has negligible influence on global temperature,
- the influence is not dangerous,
- there is no need to mandate the reduction of greenhouse gas emissions, and
- environmental and energy policy should remove, not build, obstacles to the abundant, affordable energy necessary to lift the world's poor out of poverty and sustain prosperity for all.

We also gladly join others in embracing *An Evangelical Declaration on Global Warming*.

Chapter One

Theology, Worldview, and Ethics of Global Warming Policy

Executive Summary

Earth and all its subsystems—of land, sea, and air, living and nonliving—are the good products of the wise design and omnipotent acts of the infinite, eternal, and unchangeable Triune God of the Bible. As such they reveal God's glory. Mankind, created in God's image, is the crown of creation. Human beings have the divine mandate to multiply and to fill, subdue, and rule the Earth, transforming it from wilderness into garden. They act as stewards under God to cultivate and guard what they subdue and rule. Calling them to be His vicegerents over the Earth, God requires obedience to His laws—in Scripture and imprinted in the human conscience—in their stewardship. Although sin, universal among mankind, deeply mars this stewardship, God's redemptive act in Jesus Christ's death on the cross and His instructive activity through Scripture, communicating the nature of creation and human responsibility for it, enable people to create wealth and decrease poverty at the same time that they pursue creation stewardship and, even more important, the true spiritual wealth of knowing their Creator through Jesus Christ.

The Biblical worldview contrasts sharply with the environmentalist worldview—whether secular or religious—in many significant ways. Among these, four are particularly germane:

- Environmentalism sees Earth and its systems as the product of chance and therefore fragile, subject to easy and catastrophic disruption. The Biblical worldview sees Earth and its systems as robust, self-regulating, and self-correcting, not immune to harm but durable.
- Environmentalism sees human beings principally as consumers and polluters who are only quantitatively, not qualitatively, different from other species. The Bible sees people as made in God's image, qualitatively different from all other species, and designed to be producers and stewards who, within a just and free social order, can create more resources than they consume and ensure a clean, healthful, and beautiful environment.
- Environmentalism tends to view nature untouched by human hands as optimal, while the Bible teaches that it can be improved by wise and holy human action.
- Environmentalism tends to substitute subjective, humanist standards of environmental stewardship for the objective, transcendent standards of divine morality.

This Biblical vision anticipates the development of environmentally friendly prosperity through the wise application of knowledge and skill to the raw materials of this world and the just ordering of society. That is, it anticipates the achievement of high levels of economic development and the reduction of poverty along with reductions in resource scarcity, pollution, and other environmental hazards.

The providence and promises of God inform a Christian understanding of creation stewardship, helping to avert irrational or exaggerated fears of catastrophes—fears that are rooted, ultimately, in the loss of faith in God. Those who do trust God are able to assess and respond to risks rationally. God's wisdom, power, and faithfulness justify confidence that Earth's ecosystems are robust and will, by God's providence, accomplish the purposes He set for them. Sound policymaking requires

both moral and prudential (cost/benefit) analysis. In this, a high priority for the church should be the welfare of the poor, since environmental policies often adversely affect them. That is the case with policies intended to reduce global warming by reducing the use of fossil fuels. For example, such fuels are currently the most abundant and affordable alternatives to dirty fuels, like wood and dung, which are now used by two billion people and cause millions of deaths and hundreds of millions of illnesses from respiratory diseases contracted by breathing their smoke. Insisting on the use of more expensive alternative fuels because of global warming fears means depriving the poor of the abundant, affordable energy they need to rise from abject poverty and its attendant miseries. Such policies fail both moral and prudential tests.

Environmental policies the world's poor most need will aim not at reducing global temperature (over which human action has little control) but at reducing specific risks to the poor regardless of temperature: communicable diseases (especially malaria), malnutrition and hunger, and exclusion from worldwide markets by trade restrictions. Money diverted from these goals to fight global warming will be wasted, while the poor will suffer increased and prolonged misery. Overall economic policy toward the poor should focus on promoting economic development, including making low-cost energy available, through which they can lift themselves out of poverty. It should not focus on wealth redistribution, which fosters dependency and slows development. Above all, the poor—and all other persons—need the gospel of salvation by grace alone through faith alone in Christ alone.

INTRODUCTION: THE CREATOR AND HIS CREATION

God, the Creator of all things, rules over all and deserves our worship and adoration.[1] Earth, with all the cosmos, reveals the Creator's attributes and is sustained and governed by His power and lovingkindness (Psalm 19:1–6). The whole of creation bears the divine imprint, calling all people to recognize God's glory revealed therein (Romans 1:18–21). The created order reflects Yahweh's nature, will, and purpose. Its beauty and order display the glory of God. Earth's living and non-living systems, including the climate system, along with the whole of the universe, are not accidental products of chance but the planned outcome of wise and loving divine design and powerful sustaining.

The Goodness of Creation

The Biblical worldview celebrates the physical world because it is created by God. Intermittently throughout the Bible, at key moments, the goodness of creation is clearly affirmed. It is an essential part of protology (Biblical revelation about the beginning of the world): What God creates is declared "good" six times in Genesis 1, and one final, seventh time, everything He made is declared "very good" (Genesis 1:31). It is an essential part of the final state when "the twenty-four elders . . . say, 'Worthy are you, our Lord and God, to receive glory and honor and power, for you created all things, and by your will they existed and were created'" (Revelation

[1]The focus of this document does not permit detailed discussion of the nature and attributes of God. Let it suffice to say here that God is a spirit (John 4:24; Luke 24:39; Acts 17:29), infinite (1 Kings 8:27; Psalm 139:7–10; 145:3; 147:5; Jeremiah 23:24), eternal (Deuteronomy 33:27; Psalm 90:2; 102:12, 24–27; Revelation 1:8), and unchangeable (Malachi 3:6; Hebrews 1:12; 6:17–18; 13:8; James 1:17) in His being (Exodus 3:14; Psalm 115:2–3; 1 Timothy 1:17), wisdom (Psalm 104:24; Romans 11:33–34; Hebrews 4:13; 1 John 3:20), power (Genesis 17:1; Psalm 62:11; Jeremiah 32:17; Matthew 19:26), holiness (Isaiah 6:3; Habakkuk 1:13; 1 Peter 1:15–16; 1 John 3:3, 5; Revelation 15:4), justice (Genesis 18:25; Exodus 34:6–7; Deuteronomy 32:4; Psalm 96:13; Romans 3:5, 26),

goodness (Psalm 103:5; 107:8; Matthew 19:17; Romans 2:4), and truth (Exodus 34:6; Deuteronomy 32:4; Psalm 86:15; 117:2; Hebrews 6:18).

4:10–11). And it is an essential part of present eschatology (Biblical teaching about the end of the world) for the Church in this world, as Paul in 1 Timothy 4:4 declares, against some form of proto-Gnosticism, "For everything created by God is good."

Creation is good, not evil; holy, not profane. God's holiness (separateness, being set apart) manifests itself in that, though as infinite He is present everywhere, still He specially occupies a distinct "place," Heaven, separate from the creation (Matthew 6:9). Creation reflects the holiness of God by God-ordained separations within it. God's work of sanctification/separation of matter into functioning parts makes the creation "good." The Creator/creature distinction is a fundamental expression of ontological holiness, the distinctness of God from all other beings, which determines entirely the way God creates: He makes all things not of Himself but of nothing. In Greek *cosmos* means an ordered, structured universe; *chaos,* on the other hand, means total disorder.[1] From the original unformed matter, God's work of creation makes a cosmos by establishing distinctions, by separating things out, and by giving each thing its holy place and function.

Divine Order in Creation

Creatures also, like God, have distinct, holy places and callings. Thus, as He creates, God in effect sanctifies, separating light from darkness, waters above from waters below (Genesis 1:3, 6). He forms the great lights to separate day from night (Genesis 1:14, 18). He brings forth each type of vegetation and every living creature according to its kind (Genesis 1:21), naming and clearly distinguishing everything (Genesis 1:5, 8, 10). At the climax of creation, God makes the human species in his image, differentiating between male and female (Genesis 1:26–27). This understanding of holiness lies at the root of biblical morality. Maintaining divinely ordered distinctions is the *sine qua non* of a holy cosmos. The unholy appears as soon as Adam and Eve attempt to cross the line between the created and the divine.

But Earth is not divine, and neither is man. While man should not worship the Earth, neither should he abuse it. Unlike worldviews that celebrate autonomy—*abasileutos* (literally "without any king")—the Bible ennobles obedience/submission because it recognizes and rejoices in the divinely ordained holiness and goodness of the distinctive structures of creation and the hierarchies within it. Everyone gets to participate in the holy design and purposeful goodness of God's extravagant work, as, in various ways, we joyfully submit—to magistrates, to church leaders, to employers, to husbands, to parents, to Christ, and to God—because the created cosmos is holy and good.

The events of redemption reflect the goodness of creation. God raises the physical body of Jesus from the tomb not only because Jesus was sinless but also because His body is a part of the good creation. The body, and, by extension, the physical universe, is not to be sloughed off at death by a soul undergoing endless rounds of reincarnation, but has its place in the final accounting (2 Corinthians 5:10). Hence there is a resurrection of all the dead, the just and the unjust. Because the physical creation is good, it will one day be transformed (Romans 8:21), just as will our physical bodies (Romans 8:23).

[1] Our use of the term *chaos* here should be distinguished from its use in the chapter on science. There, *chaos* denotes the inherent unpredictability of nonlinear fluid dynamic systems (like climate) to finite man, but not that they are ultimately chaotic, i.e., outside God's sovereign control.

The world is uniquely fitted for man's existence. This is true for Earth's ability to support not only life in general but also human life in particular. The same God who designed man with his ability to reason and invent also designed the heavens to accommodate man in the exercise of his God-assigned role to fill, subdue, and rule the Earth (Genesis 1:28). Earth's climate system, like the rest of earthly creation, is good (Genesis 1:31), the Hebrew *tob* meaning appropriate to intended function, beautiful, orderly, and fitting.

The Robustness of Creation

A crucial element of the environmentalist worldview is that Earth and its habitats and inhabitants are extremely fragile and likely to suffer severe, even irreversible damage from human action. That view contradicts Genesis 1:31. It is difficult to imagine how God could have called "very good" the habitat of humanity's vocation in a millennia-long drama if the whole thing were prone to collapse like a house of cards with the least disturbance—like a change in carbon dioxide from 0.027 to 0.039 *percent* of the atmosphere (the change generally believed to have occurred from pre-industrial times to the present).

Some object to this reasoning, pointing out that after all some things in this world *are* fragile—a fly's wing, for instance. But there are two mistakes in this argument. First, it confuses the part with the whole. That some inhabitants of the Earth are fragile doesn't entail that the whole Earth is, and that the wings of individual flies are fragile doesn't entail that therefore the genus *Drosophila*, or even the species *Drosophila melanogaster*, is fragile. Though many individual flies lose their wings and all flies die, the genus and even the species endure. Second, it neglects that, seen in proportion, what deprives a fly of its wing is not, in proportion to the fly and its wing, a tiny disturbance. The fly's wings serve quite well for their normal purposes and in the absence of *proportionally* overwhelming impingement.

To speak of the whole biosphere, or even of extensive subsystems, such as the climate system (comprising the entire atmosphere, oceans, and land masses of the planet, with all their biota), as extremely fragile is both to neglect the force of Genesis 1:31 and to ignore the testimony of geologic history, which includes the recovery of vast stretches of the Northern Hemisphere from long coverage by ice sheets several miles thick—which certainly wiped out more ecosystems more thoroughly than human action has come close to doing—not to mention the recovery, according to Genesis, of the whole Earth from a Flood that destroyed all airbreathing life but the few representatives rescued in Noah's ark.

Fear of Dangerous Manmade Global Warming

This has important implications for fear of manmade global warming. The fear is that human emissions of carbon dioxide and other so-called "greenhouse gases" will cause sufficient warming to threaten the survival of modern human civilization. Although the direct warming effect of the "greenhouse gases" is thought to be too little to have such dire effects, the assumption is that it could initiate positive feedback loops, causing a "runaway greenhouse effect." But clearly this scenario rests on the assumption of the fragility of the whole of the geo/biosystem—an assumption contrary to the Biblical worldview. That an increase in atmospheric carbon dioxide from one molecule in every 3,704 to one in every 2,597—from 270 to 385 parts per million—should cause dangerous warming is fundamentally inconsistent with the Biblical worldview of Earth as the "very good" product of the infinitely wise Creator.

The Biblical worldview instead suggests that the wise Designer of Earth's climate system, like any skillful engineer, would have equipped it with balancing positive and negative feedback mechanisms that would make the whole robust, self-regulating, and self-correcting. The United Nations' Intergovernmental Panel on Climate Change (IPCC) and other climate alarmists, however, all depend for their projections of dangerous warming on computer climate models that have a strong bias toward *positive* feedbacks. In addition to the Biblical worldview, two empirical considerations render that assumption highly doubtful.

First, it conflicts with what we know about climate feedbacks. With no greenhouse effect, Earth's surface temperature would average about 0° F; with it, but with no climate feedbacks, it would be about 140° F; and with both the greenhouse effect and feedbacks, it is about 59° F. Net climate feedbacks, in other words, are strongly *negative*, eliminating about 58% of greenhouse warming. But greenhouse gases are greenhouse gases, whatever their origin. It is highly unlikely, therefore, that the climate models are correct in assuming strong net *positive* feedback. The commonly calculated temperature increase from doubled CO_2 without feedbacks is 2.16° F (Weitzman, 2009, p. 4), and subtracting 58% yields 0.9° F as the likely post-feedback warming from doubled CO_2. That is only one sixth the midrange estimate of the IPCC and is not dangerous.

Second, one particular assumption about feedbacks is that clouds are a net positive feedback, i.e., that they respond to surface warming in a way that increases it. But, as the science chapter of this paper points out, actual observation of cloud response to surface temperature shows they are a net negative feedback—they reduce both warming and cooling, keeping temperature within a narrow range. The clouds' response is somewhat like that of the iris of the eye. The brighter the light to which the eye is exposed, the more the iris grows, shrinking the pupil to protect the retina from discomfort and damage. The dimmer the light, the more the iris shrinks, enlarging the pupil to increase vision, as Massachusetts Institute of Technology climatologist Richard Lindzen has argued (Lindzen, Chou, and Hou, 2001).

Although these and similar findings (discussed in the science chapter) have stunning implications for the ongoing debate about global warming, their more important effect should be to prompt Christians to praise God for the way in which Earth, like the human body, is "fearfully and wonderfully made" (Psalm 139:14). In some senses Earth, like the eye, may be fragile, but overall it is, by God's wise design, more resilient than many fearful environmentalists can imagine.

Consequently, fear of dangerous manmade global warming is questionable not only scientifically but also theologically. God did not create the world and walk away from it, but actively sustains it so that His purposes will be achieved. God is sovereign, and it seems unlikely that man can thwart His purposes. Consequently there is no need to adopt anti-global warming policies, especially if, as the economics chapter argues, they will consign our poorest neighbors to additional decades or generations of grinding poverty.

THE IMAGE OF GOD IN MAN, AND THE DOMINION MANDATE

Men and women were created in the image of God. Humanity is the pinnacle of God's created order, unique in all of creation. God gave people a privileged place among creatures and commanded them to exercise stewardship over the Earth. Human life is sacred and is to be treasured and preserved, not disdained and discouraged. People are moral agents for whom freedom is an essential condition of responsible action. Sound environmental stewardship must attend to both the demands of human well-being and the divine call for human beings to exercise caring dominion over the Earth. Biblical stewardship affirms that human well-being and the integrity of creation are not only compatible but also dynamically interdependent realities.

The goodness of creation and the image of God in man imply two things of particular relevance to environmental stewardship.

Man as Maker and Master

First, human beings are different from all other creatures on Earth. *Like* all other creatures, they're not God, they're creatures. But *unlike* all other creatures, they are God's image. *Like* all other living things, they are to reproduce after their kind. But *unlike* all others, they are to fill not just "the waters in the seas" (fish, Genesis 1:22), not just the air (birds, verse 20), but the whole Earth (verse 28). And *like* all other living things, they are to obey their Creator (implicit in His commanding them), but *unlike* all others, people are to have rule over other living creatures, and over the Earth itself.

And what is it for them to bear the image of God? It is partly what we have just noticed: to rule over other creatures. Elsewhere we learn that it is for them to have rational and moral capacity (Ephesians 4:24; Colossians 3:10). But we must not neglect what the immediate context reveals about the image of God in man. It is what it reveals about God Himself in Genesis 1:1– 25: that He is a Maker—indeed, a prolific, even extravagant Maker. People, too, are to be makers—not makers of things *ex nihilo*, out of nothing, which is the province of God alone, but *ex quispiam*, out of something. That is, people, made in God's image, are to make new things out of what God puts before them—and, as God made all things of nothing, so people more fully express this creative aspect of His image as they make more and more out of less and less.

Earth as Arena for Human Stewardship

Second, Earth and the various living creatures in it—in its seas, in its air, on its ground— Earth and all in it, while "very good" (Genesis 1:31), were not yet as God intended them to be. They needed filling, subduing, and ruling. Was this because there was something evil about them? No. We have already seen that the Biblical doctrine of creation rules out notions of the inherent evil of the material world, including (as Gnostics, Hindus, and Buddhists believe) that matter and spirit are antithetical, and (as the Platonic and neo-Platonic doctrine implies) that there is a hierarchical "great chain of Being" from God (who has most being) to nothing (which has none). No, it was not that there was something evil about the Earth and its non-human living creatures. Rather, it was that they were designed as the setting, the circumstance, the surroundings—the *environment*, if you will (that word coming from the French *envirroner*, "to surround")—in which Adam and Eve and their descendants are to live out their mandate as God's image bearers. As God created it, Earth and all its constituents were very good. They were perfect—not terminally perfect, but circumstantially perfect, perfectly suited as the arena of man's exercise of the *imago Dei* in multiplying, filling, subduing, and ruling according to the knowledge and righteousness that most essentially constitute the *imago*.

Nonbiblical religions and worldviews teach contrary views of God and creation.

- Hinduism, Buddhism, and other forms of pantheism deify nature, implying that it is a proper object of worship and depriving humanity of its unique position as bearing God's image and uniquely called to exercise dominion.
- Animism, polytheism, and spiritism invest creation with independent, unpredictable spirits, undermining confidence in scientific experiment, exploration, and technology, and in the exercise of human dominion.

- New Age Gnosticism turns the story of creation and fall in Genesis on its head. In the Gnostic version, the Serpent is not just clever but good. God, the wise and good Creator, has become not just a fool but the personification of the Devil. Thus the creation of matter becomes the root of all evil, so the Gnostics mistreated ("liberated") their bodies either by rigorous asceticism or anything-goes libertinism.
- Secular materialism and humanism yield the view that Earth and the rest of the universe are products of blind chance, and are therefore fragile. At the same time, they reject the transcendent basis of moral obligation, leading to ethical relativism that undermines stewardship.

These observations imply some important distinctions between a Biblical ethic of creation stewardship, on the one hand, and secular and pagan religious environmentalisms, on the other. In the Biblical view, people and nature can flourish together. No other philosophy, religion, or worldview provides a sufficient basis for stewardship of creation. All others deify nature, degrade people, or disregard the needs of the poor.

CONTRASTING ENVIRONMENTALIST AND BIBLICAL VIEWS OF MAN AND EARTH

The common environmentalist vision of human beings as chiefly consumers and polluters, using up Earth’s resources and degrading it through their waste, also contradicts the Biblical worldview (*Cornwall Declaration on Environmental Stewardship*). Paul Ehrlich expressed the environmentalist view in the formula I=PAT: Environmental impact (always seen as harmful) is a function of population, affluence, and technology, so that an increase in any of those factors inevitably brings more harm to the Earth.

People: Consumers and Polluters, or Producers and Stewards?

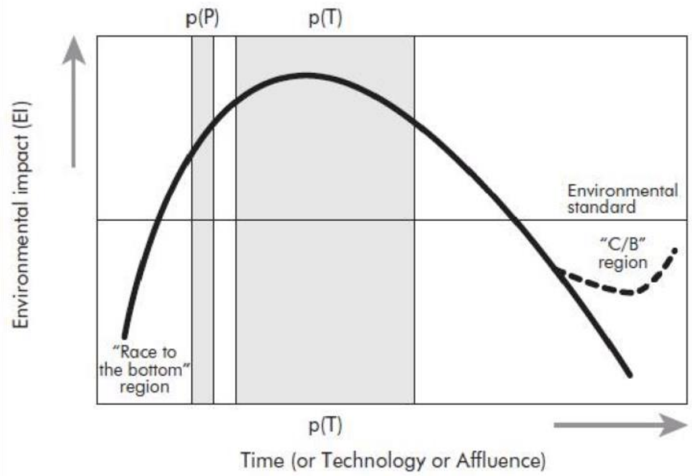
This vision of man as essentially consumer and polluter contradicts the Biblical view that people, the image of God, are commanded to be producers and stewards. We can transform raw materials into resources through ingenuity and hard work, making more resources than we consume, so that each generation can pass on to the next more material blessings than it received, and—through godly subduing and ruling of the Earth—can actually improve the environment. The well-documented phenomenon of declining inflation-adjusted and wage-indexed prices of all extractive resources (mineral, plant, and animal) running right alongside increasing population, affluence, and technology (Simon and Kahn, 1984; Simon, 1995) contradicts the environmentalist view and confirms this Biblical view (Beisner, 1990).

The increasing realization of this human potential has enabled people in societies blessed with an advanced economy, especially when they also have transparent, accountable governments, not only to reduce pollution while producing more of the goods and services responsible for the great improvements in the human condition, but also to alleviate the negative effects of much past pollution (Beisner, Duke, Livesay, et al., 2008). A clean environment is a costly good; consequently, growing affluence, technological innovation, and the application of human and material capital are integral to environmental improvement. The tendency among some to oppose economic progress in the name of environmental stewardship is, therefore, often sadly self-defeating.

The Environmental Transition

This is an important distinction between the Biblical vision and aspirations and the common environmentalist vision and aspirations. Environmentalism tends to hold as the ideal a natural world little shaped by human action—a world in which people, animals, plants, land, waters, and atmosphere all coexist harmoniously but in which human influence is no greater than that of other species. While the Biblical vision aspires to harmony, it recognizes that true environmental harmony will be perfected only in the eschaton of the New Heavens and New Earth (Isaiah 11:1–10; 65:17–25) and will prevail before then only to the extent that humanity fulfills its mandate to fill, subdue, and rule the Earth. This was humanity's mandate before the fall (Genesis 1:28), and it remains humanity's mandate after the fall, when, far from revoking it, God went so far as to assure Noah and his descendants that beasts, birds, and creeping things would still be subject to them (Genesis 9:1–17). How fully humanity will implement this mandate before the eschaton we cannot know, but that we should strive toward it is certain.

Figure 1 **A stylized depiction of the Environmental Transition Hypothesis, a generalization of the Environmental Kuznets Curve**



It shows the evolution of environmental quality – the negative of environmental impact (EI) – as a society evolves from a low to a high level of economic development. The figure assumes that affluence and technology advance with time, which is broadly consistent with historical experience since the start of the Industrial Revolution. NOTE: p(P) = "period of perception," the period during which the notion that environmental degradation can compromise human well-being gains acceptance; p(T) = "period of transition," the period over which that perception leads to actions which eventually reduce environmental degradation; "Race to the Bottom Region" (where society strives to increase economic development despite increasing EI); NIMBY Region = "not in my backyard region" (EI enters this region if benefits far exceed costs to beneficiaries); C/B Region = cost/benefit region (where benefits and costs have to be more carefully balanced). Source: Goklany (2007a)

This Biblical vision anticipates, through the wise application of knowledge and skill to the raw materials of this world and the just ordering of society, the development of environmentally friendly prosperity—the achievement of high levels of economic development and the reduction of poverty right along with reductions in resource scarcity, pollution, and other environmental hazards. That this vision can be realized, not perfectly but to a growing extent, is demonstrated by what environmental economists call the *environmental transition*, illustrated in Figure 1. Historical data show that as societies move from subsistence agriculture to low-tech industry, pollution emissions rise—yet the benefits to health and longevity outweigh the risks posed by the pollution, as demonstrated by rising life expectancy and standard of living during that period. Soon, however, the added wealth and higher technological levels brought on by economic development enable the society to afford to reduce pollution emissions even while attaining still higher standards of living.

Nature Knows Best?

Another false assumption is that "nature knows best," or that Earth untouched by human hands is the ideal. Such romanticism leads some to deify nature or oppose human dominion over creation. A more Biblical position, informed by revelation and confirmed by reason and experience, views human dominion, or stewardship, as a vital means to unlock the potential in creation for all Earth's inhabitants.

Population Growth: Blessing or Curse?

The Biblical view also opposes fears of population growth—now often linked with fears of global warming (Institute on Religion and Democracy and Acton Institute, n.d.; Murtaugh and Schlax, 2009). John Guillebaud, co-chairman of the Optimum Population Trust and former professor of family planning at University College, London, has said, "The greatest thing anyone in Britain could do to help the future of the planet would be to have one less child" (Templeton, 2007). Paul Watson, founder and president of Sea Shepherd Conservation Society, a co-founder of Greenpeace, and a former board member of the Sierra Club, calls human population "a virus . . . killing our host planet Earth" (Jacoby, 2007). Chris Rapley, director of the Science Museum in London, says, "if we believe that the size of the human [carbon] 'footprint' is a serious problem . . . then a rational view would be that, along with a raft of measures to reduce the footprint per person, the issue of population management must be addressed" (Clover, 2007). And billionaire environmentalist Ted Turner says, "We're too many people; that's why we have global warming" (Westen, 2008). Sadly, such comments come not only from non-Christians. Even Richard Cizik, then vice president for governmental affairs of the National Association of Evangelicals, has said, "I'd like to take on the population issue, but in my community global warming is the third rail issue. I've touched the third rail . . . but still have a job. And I'll still have a job after my talk here today. But population is a much more dangerous issue to touch. . . . We need to confront population control and we can—we're not Roman Catholics after all—but it's too hot to handle now" (Institute on Religion and Democracy and Acton Institute, n.d.).

The Bible, however, sees human population differently. The command to multiply and fill the Earth came in the context of a blessing, not a curse (Genesis 1:28; 9:1, 7). Part of God's promise of blessing to Abraham was that his seed would multiply to be like the stars in number (Genesis 12:2; 15:5; 17:1–6), a promise renewed to Isaac (Genesis 26:4, 24) and to Israel as a whole (Deuteronomy 10:22; 28:62–63; Leviticus 26:22). The Scriptures see a large national population as a good thing (Proverbs 14:28). Children are not a curse but a gift and reward from the Lord (Psalm 127:3–5; 128:1, 3). They help fulfill the mandate to fill and rule the Earth. By exercising the *imago Dei*, they can—given freedom, the rule of law, and property rights under accountable government—make more resources than they consume and improve the natural world. Consequently, fears of overpopulation are unjustified (Beisner, 1990; Cromartie, 1995; Simon, 1977; Simon, 1990; Simon, 1996; Goklany, 2007a).

God's original intention, then, was for man to multiply and fill the Earth (Genesis 1:28). That intention was renewed in the covenant with Noah (Genesis 9:1, 7) and again with Abraham (Genesis 17:2) and Isaac (Genesis 26:4, 24), then with the nation of Israel (Deuteronomy 7:13). Then it was renewed with all believers (Hosea 1:10; Romans 9:26). And in the New Testament, the Apostle Paul tells us that God "made from one [man] every nation of mankind to live on *all* the face of the earth, having determined their appointed times and the boundaries of their habitation" (Acts 17:26, emphasis added).

Biblical Stewardship

The Biblical sense of stewardship implies both the responsibility to produce and the right to consume what we produce. Man is not an alien or a disease on Earth but a proper part of the worldwide ecology. Because man, made in the Triune God's image, is a social creature, he is to establish just and righteous families, communities, and civilizations through multiplication. Humanity alone, of all the created order, is capable of developing resources and can thus enrich creation, so it can properly be said that the human person is the most valuable resource on Earth (Simon, 1996). Human life, therefore, must be cherished and allowed to flourish. The alternative—denying the possibility of beneficial human management of the Earth—removes all rationale for environmental stewardship.

Human *dominion over* the Earth is *stewardship under* God. God gave humanity dominion over all the Earth, which it was to fill, subdue, and rule (Genesis 1:28).

Some Christian environmentalists have argued that Genesis 2:15—which they suggest should be translated to say that God placed Adam in the Garden of Eden to "serve and keep" it (Wilkinson, ed., 1991, pp. 286–287; Gelderloos, 1992, p. 13)—governs the interpretation of 1:28. Assuming this, they resist the idea that 1:28 mandates a powerful subduing and ruling of the Earth by mankind. But the language in the two stipulations differs radically. In 1:28 God used *kabash* and *radah*, words meaning, respectively, to subdue or bring into bondage, and to have dominion or rule. The words denote strong and forceful action (Young, 1994, p. 26; Beisner, 1997, pp. 15–16). In 2:15 God used *abad* and *shamar*, words meaning, respectively, to work, till, serve, or sometimes by extension to worship, and to keep, watch, preserve, or sometimes by extension to obey. Further, if, as these writers understand it, the object of these verbs is the Garden (or by extension the Earth), then translating the Hebrew *abad* in this instance as "serve" is mistaken. Although it may bear that sense when followed by a personal object, it does not when followed by an impersonal object (Brown, Driver, and Briggs, 1978, pp. 712– 713). It is unlikely, then, that *abad* and *shamar* in 2:15 were intended to define *kabash* and *radah* in 1:28.[2]

Another possible piece of evidence against the idea that 2:15 defines 1:28 arises from the possibility that the holiness principle discussed above is reflected in the separation between the Garden of Eden and the rest of the Earth. Genesis 2:8–10 specifies the geographic location of the Garden—"eastward, in Eden"—and adds that a river went "out of Eden to water the garden," from whence it divided into four rivers to water the surrounding land. The Garden is "the garden of God" (Ezekiel 28:13; 31:8–9), distinct from the rest of the Earth. On this view, Genesis 1:28 and 2:10–15 together suggest that, in the mandate to subdue and rule the Earth, mankind was intended to spread out from the Garden to fill the Earth and so make it more and more like the Garden.

While the concepts of "subdue/rule" and "cultivate/guard" (or "serve/guard" or "worship/obey") imply different relationships between humanity and the Earth, whether wilderness or garden, the divinely mandated intervention of humanity in the "natural" order is

[2] The interpretation of 2:15 is complicated by the fact that the grammatical object of the Hebrew verbs is a pronominal suffix, not a specific noun. To what does it refer? Historically, most translators and interpreters have identified the object as the Garden of Eden (e.g., Keil and Delitzsch, 1976, and the provision of "it" as the object in most translations). More recently, some interpreters have asserted that *abad* and *shamar* in 2:15 should be translated "worship and obey" without any expressed object, though God would be implied (Sailhamer, 1990, in loc.; Liederbach and Reid, 2009, pp. 121–122). Whichever sense is preferred, however, "worship" or "serve" and "obey" cannot be the senses if the implied object of the verbs is taken to be the Garden (or Earth), for we are to worship God alone (Exodus 20:3–4), and neither the Garden nor the Earth gives commands to obey.

unmistakable. Humanity is not a foreign agent in creation, "pristine nature" is not to be idolized as God's ultimate intent for the world, and humanity is not subject to and servant of the planet but the planet is subject to humanity, which is subject to and servant of God. Mankind has a God-given vocation of enhancing the beauty, harmony, and productiveness of creation.

The responsibilities and attendant, though limited, rights of humanity entailed by the divine mandate of dominion provide the core content of the Christian concept of stewardship. Humanity has the right and responsibility to intervene in nature, but must do so in ways that are consonant with the will of God. The principle of stewardship is necessary, but not sufficient as a guide to ecological ethics. It raises the issue of how human actions impact nature, but it will not in itself allow us to adjudicate between competing goods. Human responsibility to steward creation must be considered in light of theological principles such as the inalienable dignity of humanity as the *imago Dei*, and more mundane concepts such as cost-benefit analysis. Stewardship does not include the right to carelessly pollute the earth.

Flaws in Stewardship

Our ability to act as good stewards is limited and marred by several important factors—our limitations as finite beings, human sinfulness, the curse, and our exile from the divinely given garden-model of Eden. Both the inherent limitations of finite minds and the fallenness of human reason and desires (Jeremiah 17:9; Romans 1:18, 28) mean that human intervention in natural systems can and often will have a negative impact—e.g., pollution or resource depletion. The curse (Genesis 3:17-19) means that nature rebels against the intervention of man, even when that intervention is benign or beneficial. Further, our exile from the Edenic garden (Gen 3:22-24) deprives us of a concrete model upon which to plan and against which to judge the suitability of our impact upon nature. The fall, the curse, and our exile from Eden entail that we shall never achieve perfect stewardship of the Earth.

But these problems neither eliminate our responsibility nor preclude the possibility of improvements as God equips individuals and groups with insights that lead to more productive and less destructive ways of interacting with creation. Ultimately, addressing environmental problems, especially those caused by human beings, requires not just the multiplication, redirection, limitation, or expanded use of technologies, but a renovation of the human heart that can only be accomplished by the work of the Spirit through the Gospel of salvation from sin and its consequences.

Until such time as the children of God come into their full freedom in Christ, risk of environmental damage will be ever present (Romans 8:19–24). Nevertheless, the mandates of Genesis 1:28 (to multiply and to fill, subdue, and rule the Earth) and 2:15 (to cultivate and guard the Garden) are not only commands but also stipulations—God's speaking them ensuring their fulfillment just as surely as His saying "Let there be light" ensured that light would be. This means that God's intention that mankind multiply and fill, subdue, and rule the Earth, and that he cultivate and keep the Garden, is not conditioned on mankind's remaining morally perfect. We *shall* multiply, we *shall* fill, we *shall* subdue, we *shall* rule, we *shall* cultivate, and we *shall* guard—none of that is uncertain. *How* we shall do these things—*that* is what is in question: whether we shall do them wisely and righteously, or foolishly and wickedly. Our fall into sin unquestionably influences *how* we do these things, but it cannot prevent our doing them or relieve us of the duty imposed by these mandates.

Biblical Law: Criteria for Stewardship Ethics

God's Law—summarized in the Decalogue and the two Great Commandments (to love God and neighbor), which are written on the human heart, thus revealing His own righteous character to the human person—represents God's design for *shalom*, or peace, and is the supreme rule of all conduct, for which personal or social prejudices must not be substituted. We therefore aspire to a world in which

- human beings care wisely and humbly for all creatures, first and foremost for their fellow human beings, recognizing their proper place in the created order.
- objective moral principles—not personal prejudices—guide moral action.
- right reason (including sound theology and the careful use of scientific and economic analysis) guides the stewardship of human and ecological relationships. Abusing the creation is sin—an offense against the Creator. But abuse of creation must be defined by Biblical law, not by shifting, subjective personal or societal preferences.
- liberty as a condition of moral action is preferred over government-initiated management of the environment as a means to common goals.
- the relationships between stewardship and private property are fully appreciated, allowing people's natural incentive to care for their own property to reduce the need for collective ownership and control of resources and enterprises, and in which collective action, when deemed necessary, takes place at the most local level possible.
- right reason (including sound theology and the careful use of scientific methods) guides the stewardship of human and ecological relationships.
- widespread economic freedom—which is integral to private, market economies—makes sound ecological stewardship possible for ever greater numbers.
- advancements in agriculture, industry, and commerce not only minimize pollution and transform most waste products into efficiently used resources, but also improve the material conditions of life for people everywhere (Cornwall Declaration on Environmental Stewardship).

The fact that God has given humanity dominion over the Earth implies that man has property rights. The Earth is the Lord's (Psalm 24:1), yet He has given it to humanity (Psalm 115:16). The property rights implied by the Eighth Commandment ("You shall not steal.") are therefore subordinate to and limited by man's accountability to God. Man is to serve God by the use of his property.

The God-given purposes of man's filling, subduing, ruling, cultivating, and guarding include the provision of resources for the fruitfulness and multiplication of humanity; the provision of a place of meaningful vocation for humanity to reflect the character of God; and the magnification of God's glory in the created order.

Divine Promises and Global Warming

God's plans are reflected in His promises, which human sin cannot nullify. Among those promises are two that are particularly relevant to fears of dangerous manmade global warming: (1) that the natural cycles necessary for human and ecosystem thriving (summer and winter, planting and harvest, cold and heat, day and night) will continue as long as Heaven and Earth endure

(Genesis 8:22), and (2) that flood waters will never again cover the Earth (Genesis 9:11– 12, 15–16; Psalm 104:9; Jeremiah 5:22).

The first passage suggests that God ensures, by His all-powerful providence, that major disruption of natural cycles on which people and other living things depend will not occur. The poetic device in which one or a few things represent all in a class or all their subsets (called merism) appears here. By naming several pairs of opposite extremes on different cycles, the Hebrew writer conveys that not just these four cycles but all others necessary for life to flourish will continue. The seasons, the annual and daily alternation of cold and heat, and with them the functioning of the water cycle (precipitation, flow, evaporation, precipitation) will continue as long as Heaven and Earth endure.

The other passages are difficult to reconcile with fears of catastrophic sea level rise. While there is evidence that sea level was once much higher than it now is, that evidence is best interpreted in light of the flood of Noah's day—a never-to-be-repeated, cataclysmic judgment of God that would have been followed by a sudden ice age (accompanied by much reduced sea level as water was stored in vast ice sheets on land) as the atmosphere lost its high water vapor content and so cooled rapidly, and then a gradual recovery as temperatures rose and water vapor rose to approximately its concentration (accompanied by a gradual sea level rise to present levels as the continental glaciers melted and ocean waters expanded as they warmed). Although these verses do not guarantee that no local floods will occur or even that the sea level will not rise, nonetheless since they were given as assurance against devastating judgment (before the last judgment; 2 Peter 3:1–13) similar to that of the great flood of Noah's day, they would seem to preclude the kind of catastrophic sea level rise envisioned by global warming alarmists.

This does not mean that sea level cannot rise (and likewise fall) gradually and within certain boundaries over long periods as Earth warms and cools through natural cycles. But catastrophic sea level rise depends on its occurring suddenly, too quickly for human adaptation—and that is simply not in the offing. Just as the vast majority of all human settlements and structures within ten or twenty meters in altitude from the sea were created during just the last century, so they can, if necessary, be replaced and added to in the coming century by an increasingly wealthy world. But it is extremely unlikely that it will be necessary. The most credible forecasts of sea level rise suggest no more than about eight inches in this century—a rate no faster than has prevailed for many centuries—and possibly none.[3] Recent data from sea level monitoring stations around the southwest Pacific confirm that sea level rise during the last thirty years, despite widespread claims to the contrary and (what turned out to be unwarranted) widespread fears of the impending submersion of island nations like Tuvalu and Kiribati, has been slight to nonexistent and certainly not significantly greater than its long-term rate (Ollier, 2009). Despite their comparative poverty, human beings have adjusted successfully to sea level rise for centuries. Their increasing prosperity will enable them to do so even more successfully in the future.

[3] The IPCC reduced its estimate of likely twenty-first century sea level rise from about 35 inches in its 2001 report to just 17 inches in its 2007 report, in which it also projected that there would be no significant melting of the Greenland ice sheet for several millennia—and then only if the world remained at least 2° C (3.6° F) warmer than today throughout those millennia (an unlikely scenario granted historical temperature cycles driven by solar and planetary cycles). While the IPCC included no sea level experts among its authors, one of the world's leading experts on sea level, Nils-Axel Mörner, head of the sea level commission of the International Union for Quaternary Research, concluded that twenty-first century sea level rise would be much lower than even the revised IPCC estimates—in the range of zero to eight inches (Mörner, 2004).

The Criteria of Divine Judgment

Some Christian environmentalists claim that God sent Israel and Judah into exile because they defiled the land (e.g., Northcott, 2007). That is true, but not in the sense in which such writers think.

According to the prophetic books leading up to and during the exile, the sins for which God sent His people into exile were not "environmental" sins like overuse of soil or pollution of water and air.[5] Never once do the prophets describe the sins for which God punishes them as unsustainable farming practices, pollution, or similar things.[6] Yes, the people of Israel and Judah defiled the land. But how? They "filled My inheritance with the carcasses of their detestable and abominable idols" (Jeremiah 16:18).

The Root of Irrational Fears of Environmental Catastrophe

There is a profound spiritual lesson in Jeremiah 5:21–25:

> Declare this in the house of Jacob and proclaim it in Judah, saying, "Now hear this, O foolish and senseless people, who have eyes but do not see; who have ears but do not hear. Do you not fear Me?" declares the LORD. "Do you not tremble in My presence? For I have placed the sand as a boundary for the sea, an eternal decree, so it cannot cross over it. Though the waves toss, yet they cannot prevail; though they roar, yet they cannot cross over it. But this people has a stubborn and rebellious heart; they have turned aside and departed. They do not say in their heart, 'Let us now fear the LORD our God, who gives rain in its season, both the autumn rain and the spring rain, who keeps for us the appointed weeks of the harvest.' Your iniquities have turned these away, and your sins have withheld good from you."

The full impact of this text depends on our recognizing the contrast drawn here between the sea, which, though it has neither eyes nor ears, still stays within the boundaries God has set for it, and the "foolish and senseless people," who, though they have eyes and ears, neither see nor hear

[5]Instead, taking Jeremiah as exemplary, they were: idolatry (1:16; 2:5; 3:6; 7:9, 18; 8:19; 10:2; 11:10; 16:18; 17:2), forsaking Yahweh and worshiping pagan gods (which God called spiritual adultery) (1:16; 2:11, 17, 20; 3:1, 2-3, 9, 20; 5:7, 18; 7:30; 9:2, 13; 11:10, 17; 13:10, 25, 27; 14:10; 15:6; 16:11), prophets speaking in the name of false gods (2:7), absence of the fear of God (2:19), rejecting and killing God's prophets (2:30), forgetting God (2:32), murder (2:34; 4:31; 7:9), injustice (5:1; 7:5), falsehood and lies (5:1, 12; 6:13; 7:9; 8:8, 10; 9:3), deception (9:8), oppression (5:25–29, 6:6; 7:6; 9:8; 17:11), fraud (5:27), false priests and prophets "and My people love to have it so" (5:30; 14:15), rejection of God's Word (6:10, 19; 8:9; 9:13; 11:10; 13:10), covetousness (6:13; 8:10), religious formalism and presumption (7:3–4), stealing (7:8–9), sexual adultery (7:9; 9:2), general disobedience to God's law (7:28), child sacrifice (7:31), worship of nature (8:2), covenant breaking (11:3), general wickedness (12:4), complaint against God (12:8), pride (13:8), trusting in man instead of in God (17:5), and Sabbath breaking (17:21).

[6]It is true that Leviticus 26:34–35 and 2 Chronicles 36:21 relate the seventy-year exile to the land's enjoying the (year-long) Sabbaths Israel had failed to give it. However, it is unlikely that this was punishment for poor environmental practice, for the Biblical rationale for the Sabbatical year (as for the weekly Sabbath and the Jubilee year) was not physical (the land, or the people, or the animals need rest—though that is true, it would not entail a seventh-day Sabbath or a seventh-year Sabbatical or a fiftieth-year Jubilee) but spiritual and liturgical. The setting aside of one day or year in seven for rest is not *primarily* to provide for the physical needs of land or people or draft animals but to set aside time for the worship of God, during which His people would learn that their needs are met not primarily by their labors but by His providential care—a lesson that points to the gospel of salvation by grace alone through faith alone in Christ alone apart from the works of the law (Romans 3:28; Ephesians 2:8–9). The Sabbatical and Jubilee year laws having been given expressly to Israel as a theocratic state, not generally to all people (unlike the weekly Sabbath, which as one of the Ten Commandments is universally and perpetually binding),

there remains no obligation to let land lie fallow one year in seven, and much land, depending on the crops, does well without that, while other land can be kept fertile and healthy indefinitely by the application of nutrients.

God and therefore transgress the boundaries He has set for them. And what lies at the root of their blindness and transgression? It is their lack of the fear of God, which is the beginning of wisdom (Psalm 111:10). The real root of irrational fears of natural catastrophes is the absence of the fear of the Lord, manifested in persistent sins like those named so frequently throughout Jeremiah: It is precisely because the people of Judah do not fear God (and so practice all kinds of sin) that they come to fear that the spring and autumn rains will fail.

Fear of environmental catastrophe grows out of lack of the fear of God. That is the real root of the many false or exaggerated environmental scares that have plagued the modern world (chronicled in Simon, 1995; Wildavsky, 1995; Bailey, 1993; Booker and North, 2007). And such fears will continue—with or without scientific basis (Mackay, 1841; Booker and North, 2007)—until people repent and fear the Lord. “Cursed is the man who trusts in man, and makes flesh his strength, whose heart departs from the LORD. . . . Blessed is the man who trusts in the LORD, and whose hope is in the LORD. For he shall be like a tree planted by the waters, which spreads out its roots by the river, and will not fear when heat comes; but its leaf will be green, and will not be anxious in the year of drought, nor will cease from yielding fruit” (Jeremiah 17:5, 7–8).

God’s wisdom, power, and faithfulness justify confidence that Earth’s ecosystems are robust and will by God’s providence accomplish His purposes for them.

Rational and Irrational Fears

By disobeying God’s Law, humankind brought on itself moral and physical corruption as well as divine condemnation in the form of a curse on the Earth. Since the fall into sin people have often ignored their Creator, harmed their neighbors, and defiled the good creation.

While some environmental concerns are well founded and serious, others are without foundation or greatly exaggerated (Lomborg, 2001). Some well founded concerns focus on

- human health problems in the developing world arising from the inadequate sanitation, widespread use of primitive biomass fuels like wood and dung, and primitive agricultural, industrial, and commercial practices that accompany poverty;
- distorted resource consumption patterns driven by perverse economic incentives; and
- improper disposal of nuclear and other hazardous wastes in nations lacking adequate regulatory and legal safeguards.

Some unfounded or undue concerns include fears of dangerous man-made global warming, overpopulation, and rampant species loss. Real problems tend to be proven and well understood; often localized; of concern to people in developing nations especially; of high and firmly established risk to human life and health; or amenable to cost-effective solutions that maintain proven benefit. Unfounded and undue concerns tend to be speculative; global and cataclysmic; of concern mainly to environmentalists in wealthy nations; of very low and largely hypothetical risk; or addressed by solutions that are unjustifiably costly and of dubious benefit.

Unsound Environmental Policy Impacts the Poor

Public policies to combat exaggerated risks can dangerously delay or reverse the economic development necessary to improve not only human life but also human stewardship of the environment. The poor, who are most often citizens of developing nations, are often forced to suffer longer in poverty with its attendant high rates of malnutrition, disease, and mortality; as a consequence, they are often the most injured by such misguided, though well-intended, policies.

A clean, healthful, beautiful environment being a costly good, wealthier people can afford more of it than poorer people. Consequently, economic growth is a necessary means to environmental improvement. A technologically advanced society and ecological well-being can coexist (Simon, 1990; Simon, ed., 1995; Simon, 1996; Bailey, ed., 1995; Goklany, 2007a), and indeed they must coexist if humanity is to fulfill the stipulation of Genesis 1:28 to multiply and to fill, subdue, and rule the Earth—a stipulation not repealed after the fall but repeated in God's covenant with Noah (Genesis 9:1–17) (Beisner, 1990; Beisner, 1997; Beisner, 2008). But environmental protection and improvement depend also on certain institutions (as discussed above), especially: (a) effective, just, limited, responsive governments; (b) enforceable and tradable property rights; and (c) a functioning market with freely changing prices to signal the value of goods and services (including ecosystems) to different individuals and communities.

The Importance of Cost/Benefit Analysis

Coupled with absolute, transcendent ethical principles, cost/benefit and opportunity cost analysis are legitimate and necessary aspects of environmental ethics and policy. Proper cost/benefit analysis takes into account not just a few people's monetary values but all people's values expressed in comparable (that is, monetary) terms. The answer to the question "How much more should we reduce a given pollution in a given locale?" is "Until the cost of removing one more unit equals the benefits from its removal—and no more." And opportunity cost analysis means identifying the action we must forgo in order to pursue the one we choose—and comparing the cost/benefit performance of the one with the other (Goklany, 2001).

Consequently, while laws should protect the environment, they should never do so at the expense of human life and well-being. Even if we assume the reality of dangerous anthropogenic global warming, we must recognize that severe reductions in economic growth and productivity that would result from major reductions in energy use (caused by mandated shifts from fossil fuels to more expensive alternatives) would consign about two-thirds of the human population to added decades or even generations of severe poverty and the attendant high rates of disease and premature mortality. To justify policies to mitigate global warming, two conclusions must be supported by sound economic analysis:

- There is a positive tradeoff between the policies' known costs to human well-being and the mostly speculative benefits of the mitigation as opposed to adaptation.
- The cost/benefit ratio of mitigation must be better than that of adaptation.

Without the first, the mitigation policy is certainly immoral. Without the second, it probably is.

Assessment of Climate Policy

Policies like carbon cap and trade, carbon taxes and tariffs, and conditional foreign aid, which are designed to force reductions in greenhouse gas emissions to mitigate alleged dangerous manmade global warming, fail the tests of Biblical principle (moral law) and prudence (cost/benefit and opportunity cost).

- They fail the test of Biblical principle by substituting human judgments (e.g., of optimum global temperatures, optimum levels of trace chemicals in the atmosphere, moral obligations regarding the emissions of such chemicals) for God-given laws like the Ten

Commandments, and assuming a climate system with properties contrary to the Biblical worldview (fragility, lack of wise design).

- They fail the prudence test because, if implemented, the costs of implementation would far outweigh the benefits of the minute temperature reduction they might achieve, and implementing them would divert resources from far more cost-effective ways of helping the world's poor through both targeted programs addressing specific health and welfare problems and the general promotion of economic development. They would instead slow economic development for the world's poor (Lomborg, ed., 2004; Lomborg, ed., 2006; Lomborg, 2007a; Lomborg, ed., 2007b).

What the World's Poor Need in Environmental and Economic Policy

Abject poverty forces the poor in much of the world to use firewood and dried dung for fuel. Every day, untold thousands of people must spend hours gathering wood or dung to obtain fuel for cooking and heating. The indoor smoke from their kitchens and open fires causes respiratory diseases like tuberculosis that kill millions every year. Spending on problems like those would yield much higher benefits than spending to reduce global warming, and in a world with finite wealth, choices must be made. We cannot do everything. As Bjørn Lomborg put it, while the experts working with the Copenhagen Consensus took at face value alarmist claims of dangerous, anthropogenic global warming, they nevertheless concluded that, "for some of the world's poorest countries, which will be adversely affected by climate change, problems like HIV/AIDS, hunger, and malaria are more pressing and can be solved with more efficacy." Consequently, after carefully comparing the severity of many challenges and the cost/benefit ratios of proposed solutions, they agreed that top priority should go to fighting communicable diseases, relieving malnutrition and hunger, and eliminating trade subsidies and barriers, all of which had benefits far outweighing their costs, while proposals to fight climate change were the worst, with their costs far outweighing their benefits (Lomborg, ed., 2006).

What impoverished people desperately need is abundant, affordable electricity—most easily achieved by using fossil fuels like coal, petroleum, and natural gas. However much these might emit real pollutants (not CO_2, which is essential to all plant growth and not a pollutant, but nitrous oxide, mercury, soot, and others), they are tremendously cleaner and safer than wood and dung.

Environmentalists committed to fighting alleged manmade global warming lobby to prevent the poor from obtaining electricity from fossil fuels, insisting instead that they must either continue as they are or adopt much more costly alternative energy systems like solar, wind, or biofuels. Of course, since these people are so poor, the latter option really is not open to them. So, if they are not to use fossil fuels, they must resign themselves to added decades and generations of abject poverty, malnutrition, disease, and premature death.

Some people, recognizing the developing world's just aspiration for economic development to rise out of misery, suggest that global treaties to reduce greenhouse gas emissions not bind poor nations or be applied less stringently in them. They advise that developed countries restrict their own production of greenhouse gases, regardless what the poorer nations do. But such policies are not only needless if, as the science chapter argues, human influence on global temperature is negligible, but also moral and prudential failures, whether implemented in wealthy countries or poor, since they are very inefficient, as the economics chapter argues. Such policies would steeply raise the cost of living for people in the developed world at the same time that they suppress production and therefore income, harming not only the people in the developed world but also those in the developing world, whose trade-based income would decline. They would also raise the incentive for companies to move from the highly regulated developed countries to unregulated developing countries, where they would be likely not only to continue their emissions but to increase them as they operated in less regulated societies. Further, because developing countries will soon surpass developed countries in CO_2 emissions, excluding them from emissions reductions will make reductions in developed countries essentially ineffective, even assuming that CO_2 is driving climate change.

Remembering the Poor

When the Apostle Paul wrote to the Galatians about his visit to Jerusalem, he said the other apostles there only asked him "to remember the poor—the very thing I also was eager to do" (Galatians 2:10). Care for the poor is a high priority throughout Scripture—especially care to protect them from oppression. Job protests those who "drive away the donkeys of the orphans" and "take the widow's ox for a pledge"; who "push the needy aside from the road" so that "the poor of the land are made to hide themselves altogether"; who "cause the poor to go about naked without clothing, and . . . take away the sheaves from the hungry" (Job 24:3–4, 10). No doubt that is not the *intent* of many who support CO_2 emission reduction policies, but it is the practical effect. In Job's day, donkeys and oxen were standard means of transportation and industry (mainly agriculture), the counterpart to cars and machinery today.

Policies that raise the cost of energy effectively reduce the poor's access to everything that depends on energy: not just transportation and industry, but also clothing and food and almost everything else people need. So the world's poor must remain indigenous, traditional, and poor—or as Leon Louw has put it, must continue living in "human game preserves," so that affluent Westerners can visit them in their quaint villages (Driessen, 2003). As the economics chapter of this document points out, because the poor spend a higher proportion of their income on energy than do others, a policy that drives up the cost of energy is in effect a regressive tax, hurting the poor more than others. Until someone can justify such a regressive tax and its fatal consequences, we can only conclude that it is unethical, and that we are morally obligated not to impede access by the poor to abundant, affordable fossil fuels.

Policymakers face a choice: will they be like those Job condemns, who "cause the poor to go about naked without clothing, and [who] take away the sheaves from the hungry" (Job 24:10)? Or will they join the Apostles and "remember the poor" (Galatians 2:10)?

CONCLUSION

Why is the relationship of poverty and ecology so complex? Surely it would not be so were it not for humanity's fall into sin and the God's curse on the Earth in response (Genesis 3:17–19). But God in His mercy has not abandoned sinful people or the created order to sin and the curse, but has acted throughout history, and particularly in the atoning death and resurrection of Jesus Christ (Romans 8:16–25; Colossians 1:15–20), to restore men and women to fellowship with Him and through their stewardship to enhance the beauty and fertility of the Earth. The environmental transition discussed earlier illustrates how the effects of the curse, including pollution, can decline as people learn to steward God's creation increasingly wisely. Through the preaching of the gospel, Christianity has spread over all of the world. It has brought with it the Biblical worldview and ethics. These are the *sine qua non* of scientific method and technological advance, and they are the soil in which economic development took off during and following the Reformation (Beisner, 1988; Beisner, 1997). These in turn have enabled humanity to greatly reduce the effects of the curse on human health, longevity, and standard of living in the past three centuries.

The passion to reduce environmental pollution is noble. That ideal springs from Biblical presuppositions that are peculiar to Western civilization, with its underlying Biblical worldview, namely, that

- nature deserves care because it is good, not evil;
- people—not gods or spirits or blind chance—are responsible for the care of the Earth;
- people are not just another species in nature but transcend nature;
- fate does not determine the extent of our well-being on Earth, either as a species or as individuals—rather, our well-being increases or diminishes according to the active will of the personal God and the wisdom and righteousness of our actions.

Human beings are called to be fruitful, to bring forth good things from the Earth, to join with God in making provision for our temporal well being, and to enhance the beauty and fruitfulness of the rest of the Earth. Our call to fruitfulness, therefore, is not contrary to but mutually complementary with our call to steward God's gifts. This call implies a serious commitment to fostering the intellectual, moral, and religious habits and practices needed for free and prosperous economies, genuine care for the environment, and justice for the poor.

A world in which humanity, animals, plants, and Earth itself flourish harmoniously; in which free people exercise responsible stewardship under God in service to one another; in which fewer and fewer people experience poverty, sickness, and premature death, while more and more experience prosperity, health, and long life; in which ecosystems thrive under wise human care; in which human ingenuity turns raw materials into helpful resources, improving living standards for present and future generations—such a world is the one to which thoughtful Christians should aspire.

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REFERENCES

Bailey, Ronald, 1993. *Eco-Scam: The False Prophets of Ecological Collapse*. New York: St. Martin's Press.

Bailey, Ronald, ed., 2000. *Earth Report 2000: Revisiting the True State of the Planet*. New York: McGraw-Hill.

Bailey, Ronald, ed., 2002. *Global Warming and Other Eco-Myths: How the Environmental Movement Uses False Science to Scare Us to Death*. Roseville, CA: Forum.

Bailey, Ronald, ed., 1995. *The True State of the Planet: Ten of the World's Premier Environmental Researchers in a Major Challenge to the Environmental Movement*. New York: Free Press.

Bast, Joseph L., Peter J. Hill, and Richard C. Rue, 1994. *Eco-Sanity: A Common-Sense Guide to Environmentalism*. Lanham, MD: Madison Books.

Beisner, E. Calvin, 1988. *Prosperity and Poverty: The Compassionate Use of Resources in a World of Scarcity*. Wheaton: Crossway Books. (Reprint edition, 2002. Eugene, OR: Wipf & Stock.)

Beisner, E. Calvin, 1990. *Prospects for Growth: A Biblical View of Population, Resources, and the Future*. Wheaton: Crossway Books.

Beisner, E. Calvin, 1997. *Where Garden Meets Wilderness: Evangelical Entry into the Environmental Debate*. Grand Rapids: Eerdmans/Acton Institute.

Beisner, E. Calvin, 2008. "What Is the Most Important Environmental Task Facing American Christians Today?" *Mount Nebo Papers*, No. 1, Spring 2008.Washington, D.C.: Institute on Religion and Democracy. Available at http://www.theird.org/Document.Doc?id=25.

Beisner, E. Calvin, Barrett Duke, Stephen Livesay, et al., 2008. *Cornwall Stewardship Agenda*. Available at http://www.cornwallalliance.org/agenda/, accessed November 12, 2009.

Booker, Christopher, and Richard North, 2007. *Scared to Death: From BSE to Global Warming: Why Scares Are Costing Us the Earth*. London: Continuum.

Brown, Francis, S. R. Driver, and Charles A. Briggs, edd., 1907, 1953, 1978. *A Hebrew and English Lexicon of the Old Testament*. Oxford: Clarendon Press.

Cornwall Declaration on Environmental Stewardship, 2000. Available at http://www.cornwallalliance.org/cornwall-declaration/, accessed November 12, 2009.

Clover, Charles, 2007. "We need fewer people to halt global warming," *Telegraph*, July 24. Available at http://www.telegraph.co.uk/science/science-news/3301442/We-need-fewerpeople-to-halt-global-warming.html, accessed November 12, 2009.

Cromartie, Michael, ed., 1995. *The 9 Lives of Population Control*. Washington: Ethics and Public Policy Center/Grand Rapids: Eerdmans.

Driessen, Paul, 2003. *Eco-Imperialism: Green Power Black Death*. Bellevue, WA: Free Enterprise Press.

Fumento, Michael, 1993. *Science Under Siege: Balancing Technology and the Environment*. New York: William Morrow.

Gelderloos, Orin, 1992. *Eco-Theology: The Judeo-Christian Tradition and the Politics of Ecological Decision Making*. Glasgow: Wild Goose Publications.

Gesenius, F. W., 1910. *Gesenius' Hebrew Grammar*, 2d ed., ed. E. Kautzsch, rev. A. E. Cowley. Oxford: Clarendon.

Goklany, Indur M., 2001. *The Precautionary Principle: A Critical Appraisal of Environmental Risk Assessment*. Washington, D.C.: Cato Institute.

Goklany, Indur M., 2007a. *The Improving State of the Planet: Why We're Living Longer, Healthier, More Comfortable Lives on a Cleaner Planet*. Washington, D.C.: Cato Institute.

Goklany, Indur M., 2007b. "Integrated strategies to reduce vulnerability and advance adaptation, mitigation, and sustainable development," *Mitigation and Adaptation Strategies for Global Change*, DOI 10.1007/s11027-007-9098-1

Hagen, Eric W., and James J. Worman, 1995. *An Endless Series of Hobgoblins: The Science and Politics of Environmental Health Scares*. Irvington, NY: Foundation for Economic Education.

Hollander, Jack M., 2003. *The Real Environmental Crisis: Why Poverty, Not Affluence, Is the Environment's Number One Enemy*. Berkeley: University of California Press.

Horner, Christopher C., 2007. *The Politically Incorrect Guide to Global Warming and Environmentalism*. Washington, D.C.: Regnery.

Institute on Religion and Democracy and Acton Institute for the Study of Religion and Liberty, n.d. "From Climate Control to Population Control: Troubling Background on the 'Evangelical Climate Initiative.'" Available at http://www.cornwallalliance.org/docs/fromclimate-control-to-population-control.pdf, accessed November 12, 2009.

Jacoby, Jeff, 2007. "A world full of good news," *Boston Globe*, May 13. Available at http://www.boston.com/news/globe/editorial_opinion/oped/articles/2007/05/13/a_world_full_of_good_news/.

Karplus, Walter J., 1992. *The Heavens Are Falling: The Scientific Prediction of Catastrophes in Our Time*. New York: Plenum.

Liederbach, Mark, and Alvin L. Reid, 2009. *The Convergent Church: Missional Worshipers in an Emerging Culture*. Grand Rapids: Kregel.

Lindzen, Richard S., and Yong-Sang Choi, 2009. "On the determination of climate feedbacks from ERBE [Earth Radiation Budget Experiment] data," *Geophysical Research Letters*, forthcoming (revised July 14, 2009). Available at http://www.leif.org/EOS/2009GL039628pip.pdf, accessed August 27, 2009.

Lindzen, Richard S., Ming-Dah Chou, and Arthur H. Hou, 2001. "Does the Earth Have an Adaptive Infrared Iris?" *Bulletin of the American Meteorological Society* 82:3 (March), 417– 32.

Lomborg, Bjørn, 2001. *The Skeptical Environmentalist: Measuring the Real State of the World*, rev. ed. Cambridge, UK: Cambridge University Press.

Lomborg, Bjørn, ed., 2004. *Global Crises, Global Solutions*. Cambridge: Cambridge University Press.

Lomborg, Bjørn, ed., 2006. *How to Spend $50 Billion to Make the World a Better Place*. Cambridge: Cambridge University Press.

Lomborg, Bjørn, 2007a. *Cool It: The Skeptical Environmentalist's Guide to Global Warming*. New York: Alfred A. Knopf.

Lomborg, Bjørn, ed., 2007b. *Solutions For the World's Biggest Problems: Costs and Benefits*. Cambridge: Cambridge University Press.

Mackay, Charles, 1841. *Extraordinary Popular Delusions and the Madness of Crowds*. Hampshire, UK: Harrman House Ltd., reprint edition 2007.

Mörner, Nils-Axel, 2004. "Estimating future sea level changes from past records," *Global and Planetary Change* 40:49–54.

Murtaugh, Paul A., and Michael G. Schlax, 2009. "Reproduction and the carbon legacies of individuals," *Global Environmental Change* 19 (2009):14–20. Available at http://blog.oregonlive.com/environment_impact/2009/07/carbon%20legacy.pdf.

Northcott, Michael S, 2007. *A Moral Climate: The Ethics of Global Warming*. Maryknoll, NY: Orbis Books.

Ollier, Cliff, 2009. "Sea Level in the Southwest Pacific is Stable," *New Concepts in Global Tectonics Newsletter*, no. 50. Available at http://nzclimatescience.net/images/PDFs/paperncgtsealevl.pdf, accessed September 7, 2009

Sailhamer, John H., 1990. "Genesis," in *The Expositor's Bible Commentary*, ed. Walter C. Kaiser and Bruce K. Waltke. Grand Rapids: Regency.

Simon, Julian L., 1977. *The Economics of Population Growth*. Princeton: Princeton University Press.

Simon, Julian L., 1990. *Population Matters: People, Resources, Environment, & Immigration*. New Brunswick, NJ: Transaction Publishers.

Simon, Julian L., 1996. *The Ultimate Resource 2*. Princeton: Princeton University Press, 1996.

Simon, Julian L., ed., 1995. *The State of Humanity*. New York and London: Blackwell.

Simon, Julian L., and Herman Kahn, edd., 1984. *The Resourceful Earth: A Response to 'Global 2000'*. New York: Basil Blackwell.

Spencer, Roy W., 2009. "Global Warming as a Natural Response to Cloud Changes Associated with the Pacific Decadal Oscillation." Available at http://www.drroyspencer.com/researcharticles/global-warming-as-a-natural-response/, accessed August 27, 2009.

Spencer, Roy W., and William D. Braswell, 2008. "Potential Biases in Feedback Diagnosis from Observational Data: A Simple Model Demonstration," *Journal of Climate* 21 (November 1). Available at http://www.drroyspencer.com/Spencer-and-Braswell-08.pdf, accessed August 27, 2009.

Spencer, Roy W., W. D. Braswell, J. R. Christy, and J. Hnilo, 2007. "Cloud and Radiation Budget Changes Associated with Tropical Intraseasonal Oscillations," *Geophysical Research Letters*, 34, L15707, doi:10.1029/2007GL029698. Available at http://www.drroyspencer.com/Spencer_07GRL.pdf, accessed August 27, 2009.

Templeton, Sarah-Kate, 2007. "Children 'bad for planet'," *The Australian.* Available at http://www.news.com.au/story/0,23599,21684156-5009760,00.html, accessed November 12, 2009.

Weitzman, Martin L., 2009. "On Modeling and Interpreting the Economics of Catastrophic Climate Change," *Review of Economics and Statistics* 91 (February): 1–19.

Westen, John-Henry, 2008. "Turner's Depopulation Plan: 'We're Too Many People; That's Why We have Global Warming.'" LifeSiteNews.com, April 3. Available at http://www.lifesitenews.com/ldn/2008/apr/08040306.html.

Wildavsky, Aaron, 1995. *But Is It True? A Citizen's Guide to Environmental Health and Safety Issues*. Cambridge, MA: Harvard University Press.

Wilkinson, Loren, ed., 1991. *Earthkeeping in the Nineties: Stewardship of Creation*, rev. ed. Grand Rapids: Eerdmans.

Young, Richard A., 1994. *Healing the Earth: A Theocentric Perspective on Environmental Problems and Their Solutions*. Nashville: Broadman and Holman.

Chapter Two

The Science of Global Warming

EXECUTIVE SUMMARY

When people ask, "Do you believe in global warming?" chances are they mean, "Do you believe human beings are causing global warming?" It is unfortunate that global warming has become synonymous with *manmade* global warming, because it obfuscates the real question: To what extent are human beings contributing to changes that are always occurring in nature anyway?

Some people claim repeatedly that melting sea ice, an increase in global-average temperatures, stronger storms, more floods, and more droughts are occurring due to humanity's burning of fossil fuels. But how many of these changes are real versus imagined? And of those that are real, how much, if at all, can they be attributed to human activities?

Indeed, there have been some significant climatic changes in recent decades. For instance, the normal summer melt-back of Arctic sea ice has increased in the 30 years during which we have had satellites to monitor this remote region of the Earth. There has also been a slow and irregular warming trend of global-average temperatures over the last 50 to 100 years—the same period of time the carbon dioxide (CO_2) content of the atmosphere has increased.

But correlation does not mean causation, and there has been a tendency in the media to overlook research suggesting that these recent changes are, in fact, related to natural cycles in the climate system rather than to atmospheric CO_2 increases from fossil fuel use. That changes occur does not mean human beings are responsible. There is good evidence that most of the warming of the past 150 years is due to natural causes. The belief that climate change is anthropogenic (human-caused) and will have catastrophic consequences is highly speculative.

Recent progress in climate research suggests that:

1. Observed warming and purported dangerous effects have been overstated.
2. Earth's climate is less sensitive to the addition of CO_2 than the alleged scientific consensus claims it to be, which means that climate model predictions of future warming are exaggerated.
3. Those climate changes that have occurred are consistent with natural cycles driven by internal changes in the climate system itself, external changes in solar activity, or both.

In fact, given that CO_2 in the atmosphere is necessary for life on Earth to exist, it is likely that more CO_2 will be beneficial. This possibility is rarely discussed because many environmental activists share the quasi-religious belief that everything mankind does hurts the environment. Yet, if we objectively analyze the scientific evidence, we find good evidence that more CO_2 could lead to greater abundance and diversity of life on Earth.

INTRODUCTION: GLOBAL WARMING THEORY

Earth's natural greenhouse effect keeps Earth's surface and lower atmosphere warmer than they would be without it. Think of the greenhouse effect as an insulating layer that inhibits the loss of infrared (heat) energy to the cold depths of outer space. Without any greenhouse effect, it has been calculated that the average surface temperature of the Earth would be a frigid 0°F (18^{o}C). Instead, it's about 59°F (15^{o}C). So the greenhouse effect helps keep Earth habitably warm. But this is only half the story. Without convective air currents to carry away the heat that builds up near the surface, average surface temperature would soar to about 140°F (Manabe and Strickler, 1964). Thus, the cooling effect of those convective air currents—the primary mechanism that drives what we call weather—eliminates about 58% of greenhouse warming. In other words, the climate system is a strong net *negative* feedback on surface warming. This natural cooling mechanism is never mentioned in news reports about global warming, which typically dramatize the issue of climate change.

Despite the profound influence that Earth's greenhouse effect has on weather and climate, it is well known (but seldom mentioned) that the direct warming influence of more CO_2 in the atmosphere is weak. This is because CO_2 represents a relatively small proportion of Earth's total greenhouse effect. The greenhouse effect is due mostly to water vapor and, to a lesser extent, clouds (around 95% combined), far less to CO_2 (around 3.5%), and the remainder to methane and several minor gases. Most of these other components go through large natural variations, and so their contribution to the greenhouse effect does as well.

We can be a little more specific regarding the role of CO_2, since, unlike water vapor and clouds, it is well mixed in the global atmosphere and goes through relatively small variations. The direct warming effect of even doubling the global atmospheric concentration of CO_2 (from about 270 to about 540 ppmv [parts per million by volume]) would enhance Earth's greenhouse effect by only about 3%, or 1°C (1.8°F). It can be calculated theoretically that humanity's assumed 40% addition to the CO_2 content of the atmosphere since the Industrial Revolution (raising it from about 270 to about 385 ppmv) has enhanced the greenhouse effect by about 1%.

If the direct warming effect of more CO_2 is so small, why do we often hear predictions of dangerous warming? It is because those who make these predictions assume that other changes in the climate system—mostly from clouds and water vapor—will greatly amplify the weak direct warming from more CO_2. These amplification mechanisms are called positive feedbacks, and, built into computer climate models, they produce what is termed high climate sensitivity. This amplification—which only exists in theory—is exactly opposite to the *cooling* effect of weather processes on Earth's average surface temperature.

In the scientific debate over global warming, the importance of climate sensitivity cannot be overemphasized. It determines whether anthropogenic global warming will be powerful, modest, or simply lost in the background noise of natural climate variability.

Belief in high climate sensitivity is indispensable to the alleged "scientific consensus" of the United Nations' Intergovernmental Panel on Climate Change (IPCC). The IPCC is a loosely organized, highly politicized group of scientists, bureaucrats, and governmental representatives first assembled in 1988 with the explicit mandate to build the scientific case for anthropogenic global warming—a mandate that has heavily shaped its findings (Henderson, 2007; Paltridge, 2009).

Climate Models and Their Uncertainties

Climate models are computer programs made up of equations that mathematically describe how heat is transported by the global atmosphere and oceans in response to the absorption of sunlight. The models actually "grow" virtual weather systems (e.g., low and high pressure areas) and ocean circulation systems that transport heat from Earth's surface to high in the atmosphere, and from the tropics to higher latitudes. Some of the equations provide highly accurate approximations of physical processes, such as wind. But other processes, such as clouds, are only crudely represented in the models.

The IPCC tracks twenty-one computerized climate models developed by a variety of research groups around the world, and all of those climate models now exhibit net positive feedbacks by varying amounts (Forster and Taylor, 2006). Their high climate sensitivity then leads to projections of moderate to near-catastrophic levels of warming and other changes in the global climate system in coming decades in response to the weak warming effect of more carbon dioxide.

The model developers spend most of their time adjusting the models until the models do a reasonably good job of replicating Earth's average climate—by which the modelers usually mean the seasonal cycles in temperature, humidity, clouds, and precipitation at different locations around the globe. The modelers assume that the better a model is at mimicking today's climate, the better it will predict how climate will change in the future when the small warming effect of more atmospheric CO_2 is imposed on the model.

Unfortunately, just because climate modelers have spent their careers and hundreds of millions of dollars building these models does not mean that the models will be useful for such an ambitious undertaking. Predicting the future of the climate system is so complex a task that it might never be achieved. While it may be possible to adjust or fit a model to mimic past climatic conditions, this does not guarantee that the processes causing climate change are accurately portrayed.

Earth's climate is a hugely complex system that involves interactions between the oceans, the atmosphere, the land surface (both natural vegetation and urbanization), the cryosphere (i.e., ice and snow), volcanic activity, the Sun, and more. All of these interactions occur at a myriad of time and space scales ranging from seconds to millennia, and from molecular to global. In the relatively young science of climatology, our understanding has developed to only a cursory overview of how such a system, replete with feedbacks and interactions, actually functions. Moreover, the climate acts with the inherent internal changeability characteristic of the processes of a chaotic nonlinear fluid dynamic system—processes that we may never know or understand and, more importantly, never hope to predict.

Why, then, do climate modelers think today's climate models can be relied on for guidance regarding climate change? They think so because, knowing Earth's natural greenhouse effect is an important part of how weather and climate operate and that CO_2 is a greenhouse gas, they assumed that more CO_2 in the atmosphere must therefore have at least some warming effect on the climate system. All of that is true. But it is the magnitude of the human influence compared to natural variations in the climate system that is the crucial question. Do human beings now control the climate system, or do we modestly contribute to it, or is our influence merely lost in the noise of natural variability? And how do we know the real climate system amplifies small warming (or cooling) influences with net positive feedback? We don't.

A Robust Climate?

Some people believe humanity has no right to be tinkering with Earth's climate system at all. But having no impact whatsoever would be impossible. "Chaos theory" indicates that in a complex system (like weather and climate) exceedingly tiny influences can forever alter the future course of the system. The famous example given of this is the "butterfly effect," which asserts that the flap of a butterfly's wing thousands of miles away can be the determining factor in whether a storm will form.

Chaos theory tells us that everything in the climate system affects everything else. That leads some people to infer that the climate system is fragile and will respond with large changes to small influences. But chaotic systems are not explosive: the changes stay within the boundaries of the system itself. Small changes today can affect the weather next week, but only within the range of customary variations. Saying the climate system is sensitive is not the same thing as saying it is fragile. Our chaotic climate system is affected by everything, but it still oscillates within some range of variability that is quite stable.

In a chaotic system, given enough time, tiny influences will change the future course of the system. This is neither good nor bad—it is just the way things work. Once we realize and accept that people, vegetation, and everything else have some influence on climate, the question then becomes: How much influence do human activities have compared with all the changes nature imposes on itself in the form of natural variability?

This is where the crucial issue of "climate sensitivity" comes in. "Climate sensitivity" stands for the amount of warming anticipated from doubling the amount of CO_2 in the atmosphere, *after climate feedbacks*. If climate sensitivity is high, then the extra CO_2 we continue to pump into the atmosphere can be expected to cause significant, perhaps dangerous warming. However, it is widely recognized that climate sensitivity is still very uncertain (Knutti and Hergerl, 2008). This is why some climate models are tuned to be very sensitive. The model developers claim that we cannot yet rule out the possibility that the climate system is catastrophically sensitive to more carbon dioxide. But if climate sensitivity is low instead of high, then nature, not humanity, still rules the climate system (Singer, 2008).

So, just how sensitive is our climate system? This question has been surprisingly difficult to answer. It has not even been determined whether, given certain kinds of observations of natural climate variability, there is a method by which we can calculate the sensitivity of the climate system. Depending on the various methods used, and the relatively short time span over which data have been collected, estimates ranging from very sensitive to very insensitive have been obtained.

Some observational studies of short-term climate variability have suggested a very insensitive climate system, at least in the tropics (Spencer et al., 2007; Lindzen and Choi, 2009). A few other researchers claim it is very sensitive, most notably NASA's James Hansen, who claims that the Ice Ages were ultimately caused by the relatively weak changes in Sun-Earth geometry called the Milankovitch cycles, which means that weak forcing was greatly amplified by positive feedbacks. Still other researchers have given up hope that climate sensitivity will ever be directly measured from the climate system itself, even suggesting that the quest should be abandoned (Allen and Frame, 2007).

Because of the difficulties in measuring the sensitivity of the climate system from observations, researchers have increasingly relied on the climate models to reveal the "true" climate sensitivity. But if they are to have any relevance to the real world, models must be based on observations of how weather systems and the climate as a whole operate.

Further, if we are going to rely on the models to tell us how sensitive the climate system is, how do we know whether the cause-and-effect relationships responsible for climate sensitivity have been faithfully replicated in the models? Why might all 21 of the IPCC climate models produce positive feedback, when the real feedbacks in nature may be strongly negative? (Remember what we saw above: With no greenhouse effect, global-average surface temperature would be about 0°F; with the greenhouse effect but no feedbacks, about 140°F; with greenhouse effect and feedbacks, it's about 59°F—implying that feedbacks are strongly negative, eliminating 58% of the greenhouse effect.) One possibility is that the high sensitivity of the climate models might be the result of the modelers' having reversed cause and effect when observing cloud behavior.

A simple example will make this issue easier to understand. One potential positive feedback (which would raise climate sensitivity) is a decrease in cloud cover with warming. This is what *all* of the IPCC climate models now assume. If a warming influence is imposed upon the model—say, by increasing CO_2 concentrations—the resulting weak warming causes a slight decrease in cloud cover, which then amplifies the weak warming to levels that can range from moderate to catastrophic.

How do the modelers know nature really operates that way? When researchers have observed warm years, they have typically found that there was less cloud cover during them (Forster and Gregory, 2006). So they have seen this relationship as supporting the model's positive cloud feedback.

But what if the decrease in clouds actually caused the warming to begin with, rather than the other way around? The effect of such a misinterpretation is to exaggerate climate sensitivity (Spencer and Braswell, 2008). While you would think this basic cause-and-effect issue would have been thoroughly researched by now, the scientific community is largely unaware of it. The possibility that the strong warming predicted by climate models might be the result of a reversal of cause and effect warrants more research before we can have any level of faith in the models' projections of future warming and climate change.

In summary, while climate models have come a long way, and many of them do a reasonably good job of mimicking average aspects of today's climate system, their ability to predict anthropogenic global warming and any changes associated with it has been overstated. There are so many adjustable variables in climate models that the modeler must, at some point, decide that the amount of global warming produced by the model looks "about right." Then, when modelers get together to compare results, there is peer pressure not to be an outlier—that is, the model producing the most warming or the least warming. This then causes the different models to converge to average—the result of "group think" (Paltridge, 2009, chapter 6).

Furthermore, scientists are people, and it is human nature to think we know more than we really do about our area of expertise. That tendency, combined with natural idealism—who *wouldn't* want to be part of an international effort to "save the planet"?—suggests that there is ample opportunity for scientists' biases to influence the results of scientific research. Climate models are indeed fairly spectacular inventions—but that does not mean they are up to the task of predicting the future state of the climate system.

Natural Cycles in the Climate System

A particularly disturbing aspect of climate research today is the widespread disregard for the notion that climate can change naturally. As mentioned above, if the climate system is quite sensitive, then it can be argued that we need look no further than mankind's greenhouse gas emissions as the cause of recent global warming. This is widely held by some climate scientists and helps explain why there is so little research funded to study natural climate variability.

The popular view today—exemplified in the now-discredited "Hockey Stick" graph of global temperatures over the last millennium that appeared in *An Inconvenient Truth* and was prominently featured in the UN IPCC's Third Assessment Report (2001)—is that Earth's climate system remained in a perpetual state of harmonious balance until human beings upset that balance by massive burning of fossil fuels, emitting vast amounts of CO_2 into the atmosphere. But that view is false.

As discussed above, chaotic natural variations are an expected feature of the climate system. Multiple reconstructions of past climate (paleoclimate) using various indirect measurements have confirmed this chaotic variability on all time scales. All climate researchers would agree that chaos occurs in weather. But there is no reason to expect that it does not also exist in the form of climate change, the only differences being ones of time scale and magnitude (Tsonis *et al.*, 2007). So, while there are theories of how *external* influences such as solar activity might be a significant controlling factor over centuries or millennia (Perry, 2007; Svensmark and Calder, 2007), the climate system itself is also perfectly capable of causing its own changes through *internal* chaotic variations.

For instance, because the ocean's ability to store and release heat is so enormous, chaotic variations in the ocean circulation could result in natural climate cycles that might be misinterpreted as the result of human activities. One such ocean circulation, the Pacific Decadal Oscillation (PDO), was in its warming phase during the warming since the late 1970s. Yet there has been virtually no research done on the possibility that a PDO-related change in cloud cover might be the source of most of our recent warming.

Yet the changes in atmospheric circulation patterns that define the PDO could, through a small adjustment of cloud cover, affect how much sunlight is allowed to enter the oceans. While this possibility has been alluded to recently in the scientific literature (Douglass, 2009), for the most part it remains an unexplored issue that has the potential for completely changing our perception of humanity's influence on the climate system.

Part of the problem with the scientific study of natural cycles in the climate system is that the mechanisms involved might be beyond our ability to understand and, therefore, theoretically model (Essex and McKitrick, 2007). Chaotic behavior is, by definition, too complex to accurately predict. And there is little motivation on the part of scientists to study the predictability of something that is inherently unpredictable.

This bias against recognizing naturally produced climate change even creeps into the decisions of what kinds of research to conduct, which inevitably leads to biased research results. The climate research that has been funded by the U.S. government over the last twenty years has focused primarily on the threat of anthropogenic global warming, not on natural warming or cooling, or the lack of a threat of anthropogenic warming. If scientists are promised a career of financial support to find evidence of manmade climate change, they will do their best to find it. And computer climate modeling is currently the most popular form of research to accomplish that task. But because many important processes in nature are poorly understood, climate modelers can get just about any answer they want by simply adjusting those processes within what they might consider realistic ranges. The temptation to use the "likely results" criterion (which modelers use routinely to judge their models) as a cover for politically expedient results and the desire never to be an outlier are powerful human impulses to which scientists are not immune. Thus, there is a built-in disincentive to study possible natural causes of climate change that might lead researchers to findings that fall outside of the current orthodoxy of climate science.

Global Temperatures

What has actually been happening with global temperature?

There is little doubt that global average temperature is higher today than it was 50, 100, or 150 years ago. But as can a reconstruction of global temperatures over the last 2,000 years shows (Figure 1), periods of substantial warming and cooling are normal, and since Earth's temperatures were still rising out of a cool period (the Little Ice Age) 150 years ago, it should be no surprise that recent temperatures are warmer than those during that cool period—and their being so is no sign of anything unusual.

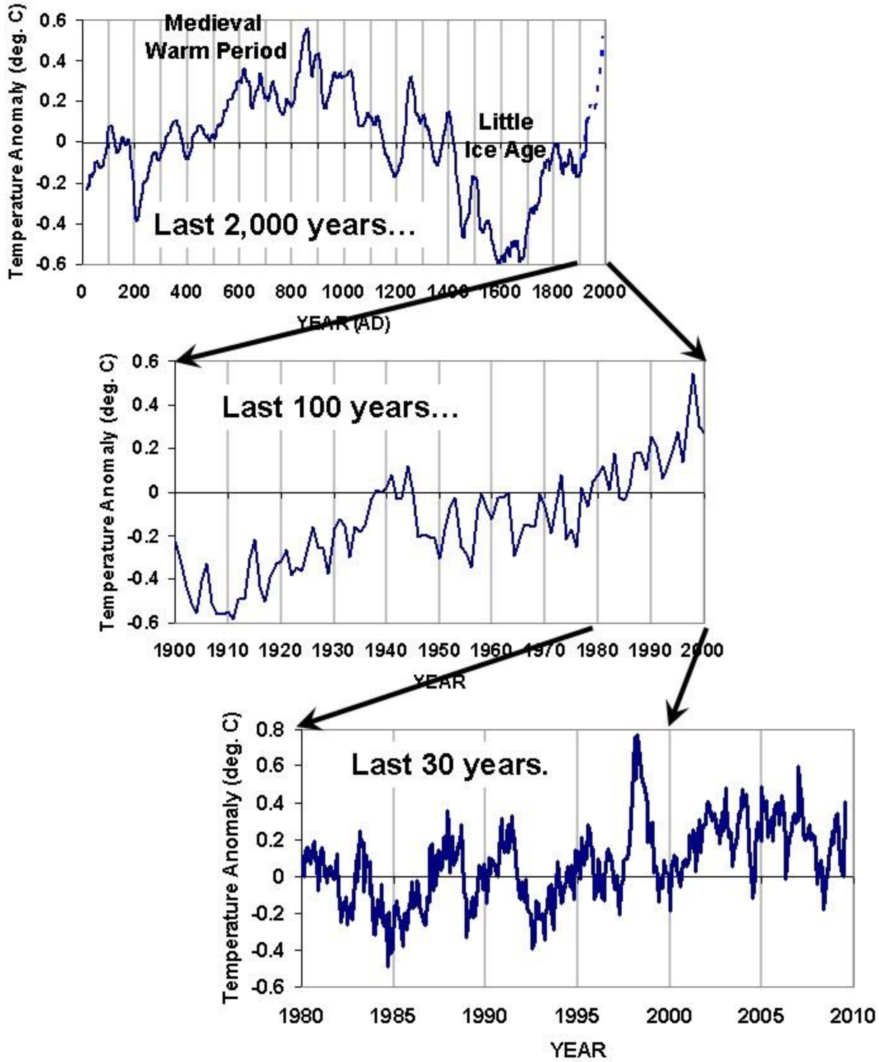

Figure 1: As demonstrated by temperature proxies (top panel, Loehle, 2008), thermometer measurements (middle panel, Brohan et al., 2006), and satellite measurements (lower panel, Christy et al., 2003), periods of global warming and global cooling are not the exception, but the rule. The proxy data in the top panel, which are running 30-year averages, are extended up to the present (dashed line) with the methodology of Brohan et al., 2006, updates of which are available at http://www.cru.uea.ac.uk/cru/data/temperature/hadcrut3gl.txt. The data in the bottom panel are extended up through mid-2009 based upon routine updates of that dataset available at http://vortex.nsstc.uah.edu/data/msu/t2lt/tltglhmam_5.2.

As seen in Figure 1, an extended period of warmth called the Medieval Warm Period (MWP) occurred around a thousand years ago. The MWP was beneficial for humanity as it aided the growing of crops and resulted in fewer environmental stresses on societies. That such warm periods are favorable to human beings is evidenced by the MWP's alternate name: the Medieval Climate Optimum. Then, several hundred years later, the Little Ice Age caused crop failures as summer temperatures were frequently too cold for some kinds of agriculture. These natural climate changes are part of recorded history.

It should be noted that the proxy data that went into the 2,000 year reconstruction of past temperatures seen in Figure 1 comes from more sources distributed over a greater part of the globe than were used in the Hockey Stick reconstruction that the IPCC relied upon for a number of years.

More recently, since 1900 (middle panel in Figure 1), there was substantial warming until 1940. This warming could not have been caused by human activities since it occurred before human beings consumed substantial amounts of fossil fuel. After 1940, slight cooling was observed until the late 1970s.

Finally, as seen in the third panel of Figure 1, warming has again been measured during the period since we launched had Earth-orbiting satellites in 1979. The satellite measurements reveal that large temperature changes occur on time scales from monthly to every few years. The interannual changes are usually due to El Nino and La Nina events in the tropical Pacific Ocean, the warming and cooling effects of which are felt over much of the Earth.

It should be mentioned that all of these methods for monitoring global average temperature are imperfect. For instance, thermometer measurements of increasing warmth in recent years could be mostly the result of urbanization effects in the vicinity of the thermometers. While the developers of the global thermometer datasets have attempted to adjust for this urbanization effect, there is increasing evidence that apparent warming trends over land might still have a large spurious component (e.g. McKitrick and Michaels, 2007; Christy *et al.*, 2009) because there are widespread problems with improper siting and operation of monitoring stations that further contaminate the data (Watts, 2009).

Clearly evident from Figure 1 is that there are substantial changes in the climate system without any help from human beings. How, then, do we know the warming in the last 50 years was caused mostly by humanity's greenhouse gas emissions, not natural processes? We don't.

There are still no widely accepted explanations for the Medieval Warm Period, or the Little Ice Age, or even the period of warming up until 1940. Although the mechanisms are poorly understood, there is increasing empirical evidence that variations in solar activity might be a major contributor (see Plimer, 2009, pp. 72-75 and references therein). But whether these events are due to changes in ocean circulation, solar irradiance, sunspots, some other as yet unknown factors, or a combination of several factors, unless we know what portion of recent climate change is due to nature, there is no way to know what portion is anthropogenic.

It is simply assumed by those scientists working within the milieu of current climate orthodoxy that most recent warming was caused by humanity's greenhouse gas emissions. While hundreds of scientific papers have been written that do not contradict the theory of anthropogenic global warming, neither do they demonstrate that global warming is largely anthropogenic rather than natural. To do that, scientists would need to understand the causes of past natural climate change, and then somehow demonstrate that these have not caused the changes of the last 50 years or so. Some researchers believe the lack of enhanced warming in the upper troposphere (the so-called “hot spot” predicted by climate models) in recent decades is proof that the models’ predictions are wrong. Some claim that there is no “fingerprint” of manmade warming since (for example) global warming caused by more sunlight being absorbed by the ocean would look substantially the same as manmade global warming via more greenhouse gases (Compo and Sardeshmukh, 2009).

Unfortunately, we do not have sufficiently accurate or geographically complete observations to determine what caused the past century’s climate change events. This is never mentioned in the writings of the IPCC. Instead, the latest IPCC report (IPCC, 2007) misleadingly claims that recent warming can only be explained when the effects of more CO_2 are included in the model. This leaves the reader with the mistaken impression that the IPCC has thoroughly considered and ruled out, on the basis of firm evidence, other potential natural sources of climate change, such as a small change in global cloud cover.

But the IPCC is arguing from a position of ignorance—not knowledge—regarding the role of natural cycles in climate. It downplays the possible role of warming in nature to help bolster its claim that human beings are now the largest driver of climate change, an effort that also helps to perpetuate government funding of expensive climate modeling efforts.

Of course, there is much more to climate than just global average temperature. In the discourse on climate change, we oversimplify the problem, and the over-used term “global warming” directly implies “global temperature increases.” While global average temperature is a useful metric in the big picture of how Earth naturally cools to outer space, what really matters to people and ecosystems is how other elements of weather they experience might change over time.

Storminess, Heat Waves, Droughts, Floods, and Melting Ice

Public discourse has reached the point where any kind of change in weather is pointed to as evidence of anthropogenic global warming—as if such changes never occurred before.

Storminess

After the record-breaking Atlantic hurricane season of 2005, there was widespread belief that anthropogenic global warming was the cause. Sea surface temperatures were above normal, storms were numerous, and an unusually large fraction of those storms hit the U.S. mainland.

Numerous scientific studies were then published. Most claimed to have found a clear indication of an increase in tropical storm activity. But the most definitive study looked at whether our historical record of tropical storm occurrences has become spuriously inflated in recent years. It found that our increasing reliance on more sophisticated satellite and aircraft instruments has led to the identification of small, short-lived tropical storms that would have gone unnoticed many years ago. After it was adjusted for this influence, the historical record of tropical storms revealed no long-term increase in tropical storm activity in the last century (Landsea *et al*., 2009).

It should also be remembered that, even if warming were to cause an increase in tropical storm activity, that says nothing about what caused the warming in the first place: nature, as it is known to have done repeatedly throughout geologic history, or human activity, as it is theorized to have done for the first time ever in the last 50 years.

There has been no convincing evidence of an increase in any other kinds of storminess accompanying global warming. While there has been a substantial increase in the number of *reports* of tornadoes in the United States in the last 50 years, this is believed to be due to our greatly improved ability to observe smaller tornadoes with Doppler radars, more people living in remote areas, and more numerous video cameras. Consistent with this explanation, the number of moderate to strong tornadoes has not increased during the same period, probably because the evidence left by a large and damaging tornado is pretty hard to miss. As a result, the IPCC (2007, Synthesis Report, p. 33) has stated that "There is insufficient evidence to determine whether trends exist in small scale phenomena such as tornadoes, hail, lighting, and dust storms."

There has been a dramatic increase not in storm frequency or strength but in storm *damage* in recent years. Is this proof of unusual, particularly of anthropogenic, global warming? No. It is well known to be the result of a rapid increase in the number and value of manmade structures in areas that experience severe weather, especially in coastal areas that suffer hurricane strikes (Pielke *et al*., 2008).

Heat Waves

One of the oft-cited evils of future global warming is higher human mortality rates due to increasing heat and humidity in summer. People exposed to the elements will indeed be more at risk to increasing apparent temperatures (i.e., the combined effect of temperature and humidity, which relates to how hot it *feels* or how difficult it is for your body to maintain the appropriate temperature)—most notably, infants, the elderly, and those working outside. However, to whatever extent global warming does occur, the risk from excessive cold will diminish—and the death rate from cold snaps is higher than that from heat spells, meaning total deaths from heat and cold combined should decline (Lomborg, 2001, pp. 13-21). Further, despite the rising temperatures between the mid-1960s and mid-1990s, mortality rates in the United States due to heat stress and heat waves have actually fallen, indicating—unsurprisingly, granted growing affluence—that our population is less exposed to the effects of extreme weather conditions. Risk from heat has decreased because of improved medical care, air conditioning, and adaptations through building design, inclusion of more shaded outdoor areas, and access to potable water, as well as more proactive responses to warn the public of heat-related threats.

Decreasing mortality rates from weather in developed nations like the United States underscore the need to bring clean water and affordable, abundant energy to the developing and underdeveloped nations of the world—particularly those in Africa. Regardless of the cause of increasing temperatures, energy, clean water, and other amenities of economic advance are necessary ingredients for survival and an enhanced quality of life and to stave off the adverse effects of a number of environmental (and other) ills.

Droughts and Floods

There is no doubt that floods and droughts are being reported more frequently by the news media. But are their frequencies and intensities increasing? There is some evidence that they are—but this is being caused by two important issues independent of climate change.

First, consider floods. A "flood" is often defined as streamflow—water in streams and rivers—that exceeds a certain threshold. Over the past century, reports of floods have increased in both frequency and intensity. As human populations have increased, our landscape has changed, with urban areas exhibiting a considerable growth of concrete, asphalt, and other impervious surfaces. Rain falling on these surfaces runs over the surface (e.g., urban street flooding) and reaches streams and rivers more readily than when trees, grasses, and shrubs pervade the land surface. Thus, with urbanization come increased peak streamflows and, hence, more floods—and when they occur, more intense floods.

In addition, more people now live in areas that are at risk for flooding—flood plains and wetlands—than ever before. This exacerbates flood events by increasing their impact on human beings—even if there is no change in the frequency or intensity of these events in those locations. Therefore, due simply to urbanization and the increased habitation of risk-prone areas, “floods” are now more frequent and more intense—even if there is no increase in precipitation.

At the other extreme, a “drought” can be defined in several ways, but it is often defined as streamflow that falls below a certain threshold. “Drought” frequencies and intensities thus defined have increased as well, due again to urbanization—high concentrations of people using a limited resource—and habitation of arid and semi-arid climates (e.g., the desert southwest of the United States). As fresh water is a limited resource, changes in population have increased the frequency and intensity of “droughts” as well—again, even if there is no decrease in precipitation.

How do we know these increases in floods and droughts cannot be attributed to climate change? First, while precipitation has experienced much variability over the last century, there has been no significant increase globally or by hemisphere (New et al, 2001, see Figure 2). Some regions have experienced changes, especially those on the periphery of deserts—the Sahel region of Africa, for example. But these changes could be mostly natural, possibly enhanced by longterm land use practices by human beings.

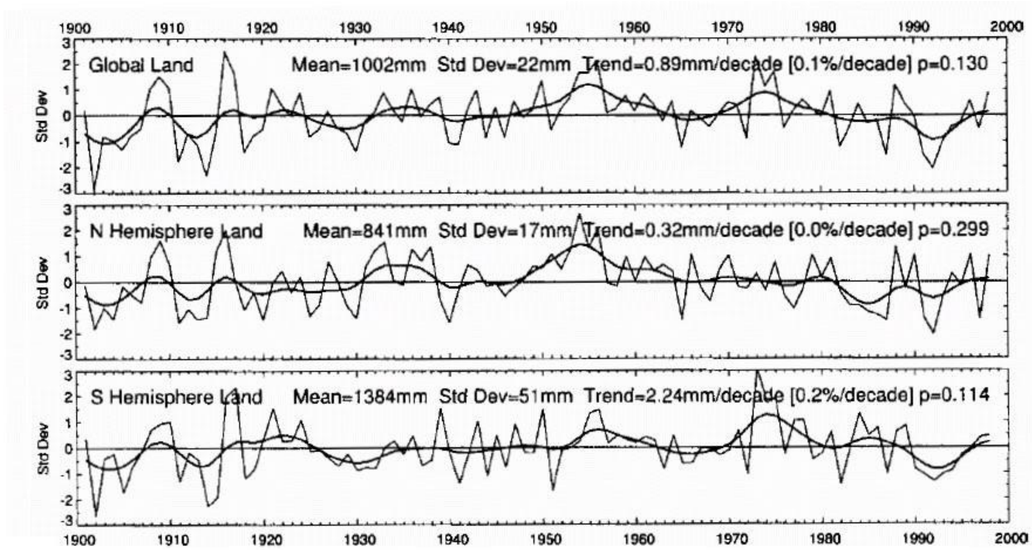

Figure 2: Trends in terrestrial precipitation estimates over the last century. Note that trends are not statistically significant for global land areas or for either hemisphere (New et al. 2001).

Scientists also keep track of the hydrologic cycle through a balance between precipitation and the water demand by plants and evaporation. This statistic, called the Palmer Drought Severity Index, plotted for the United States in Figure 3, also has shown much variability over the years. For instance, the Dust Bowl of the 1930s as well as the droughts of the 1950s are well represented in Figure 3. But there is no significant long-term trend in the proportion of the area of the conterminous United States in either moderate-to-extreme drought or moderate-to-extreme wetness. Moreover, a study of streamflow on non-urbanized and non-channelized streams and rivers for the conterminous United States has shown a slight decrease in drought conditions and no change in flood frequencies or intensities.

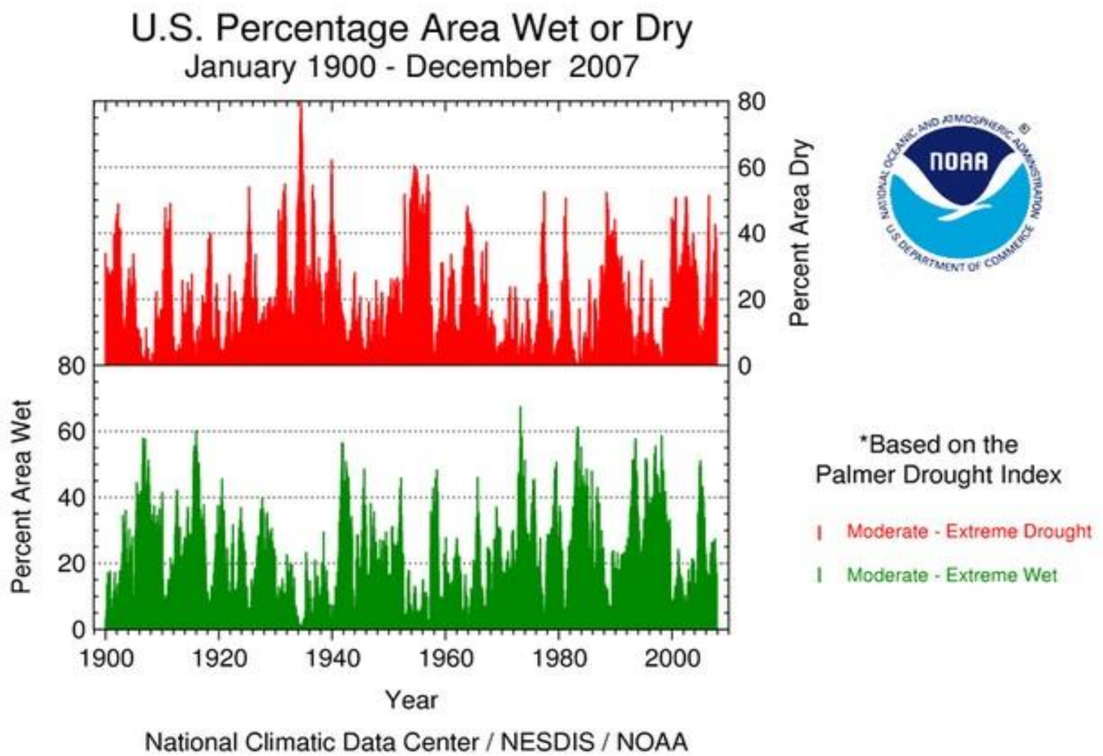

Figure 3: Percentage of the conterminous United States in either moderate or extreme drought (red) or moderate or extreme wetness (green) as represented by the Palmer Drought Index.

Melting Arctic Sea Ice

Finally, enhanced melting of ice has indeed been observed in the Arctic Ocean during the summer melt season. Since we began satellite monitoring of Arctic sea ice in 1979, there has been a significant decline in the area covered by ice, primarily in the summer and fall. This is consistent with the warming that the far northern latitudes have experienced in recent decades. But has this been the result of humanity's greenhouse gas emissions?

There were reports of disappearing Arctic sea ice back in the 1920s and 1930s, likely the result of an extended period of warming (Brooks, 1938). For instance, the November 2, 1922 issue of *The Washington Post* contained an article titled "Arctic Ocean Getting Warm; Seals Vanish and Icebergs Melt." The article stated that "great masses of ice have now been replaced by moraines of earth and stones," and that "at many points well-known glaciers have entirely disappeared."

But without satellites back then to measure the whole Arctic region, there is no way to know just how extensive the melting was. Thermometer measurements suggest that it was nearly as warm in the 1930s in the Arctic as it has been more recently. This obviously raises the question of whether these events might be the result of natural cycles in the climate system.

One possibility is that the Pacific Decadal Oscillation (PDO) could have caused these events (Douglass, 2009). The PDO is an index of weather patterns over the northeast Pacific Ocean, and it switches between its positive, warming phase and negative, cooling phase every thirty years or so. This is illustrated in Figure 4.

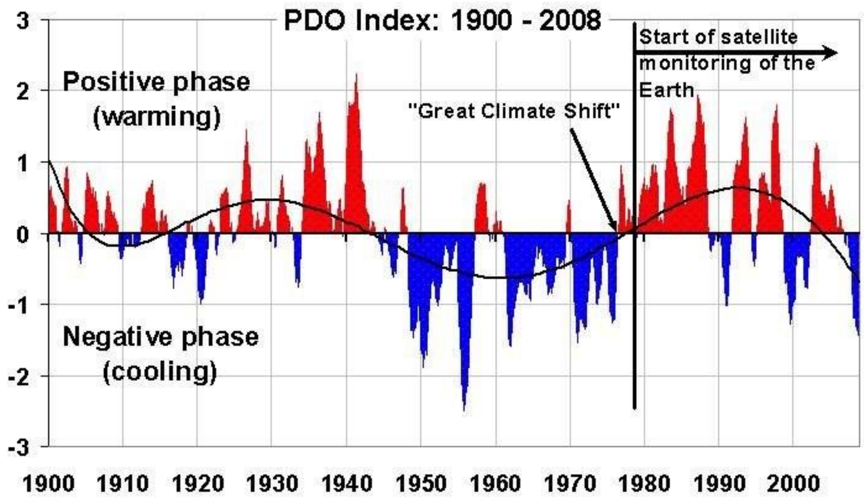

Figure 4: The Pacific Decadal Oscillation, an index of weather patterns over the North Pacific Ocean, has coincided with periods of warming and cooling over the last century (JISAO, 2008).

Our most recent period of warming, since the late 1970s, coincides with one of these shifts in the PDO index. After the "Great Climate Shift" of 1977, Alaska warmed immediately and has stayed warm. Sea ice in the Arctic began to melt more and more each summer. But after Arctic sea ice extent reached a minimum in 2007, Arctic sea ice began recovering in 2008 and 2009 (IARC, 2009). Only time will tell if the sea ice recovery is part of a long-term change, possibly caused by a shift of the PDO into its negative, cooling phase.

Despite this evidence that some substantial portion of recent changes in the climate system might be natural, there has been virtually no government-funded research into the possibility that warming over the last 50 years might be mostly due to natural cycles like the PDO. El Ninos, which are known to cause global warmth, have also been more frequent since 1980. The cumulative effect of more frequent El Ninos might also explain a substantial portion of recent warming (Stockwell and Cox, 2009). Yet virtually all climate research money now goes into the study of the alleged impact of humanity on the climate system.

Is More Carbon Dioxide Necessarily Bad?

Finally, it should be noted that there is no known optimum temperature. Either warming or cooling will lead to both benefits and additional stresses, depending upon the kinds of flora and fauna involved. Warmer is probably better for most life on Earth, as it extends the geographic range of most forms of life toward the high latitudes—an observation contrary to theoretical models on the basis of which some scientists predict rising rates of species extinction associated with global warming (Idso and Idso, 2009).

From an objective scientific point of view, it is reasonable to consider the possibility that more CO_2 will benefit life on Earth. Atmospheric CO_2 is necessary for photosynthesis, and therefore for life on Earth to exist. Numerous studies (hundreds documented by the Center for the Study of Carbon Dioxide and Global Change, www.CO2Science.org), have demonstrated the benefits of elevated CO_2 concentrations on most kinds of vegetation and crops. Many large greenhouses pump in extra CO_2, raising the concentration from today's atmospheric concentration of 385 ppmv to about 1,000 ppmv, to enhance plant growth.

An emerging area of concern is that more atmospheric CO_2 may be causing "ocean acidification." The term "acidification" is misleading, since the oceans are sufficiently alkaline (pH > 7.0) that burning all the fossil fuels in the world will not make them acidic. In fact, a wide range of oceanic pH values exists naturally around the world, just as a wide range of temperatures exists, and nature not only adapts to this wide range—nature produces it!

Partly because of this naturally wide range of pH values, the claim that more atmospheric CO_2 has caused the average pH of the oceans to decrease from 8.18 to 8.10 over the last few centuries has necessarily been based on theoretical computations. The effect is so small that (like warming purported to have occurred due to human emissions of CO_2) it must be calculated based upon theory, not observation.

It should be remembered that, just as is the case with vegetation on land, photosynthesis is also necessary for the growth of phytoplankton in the ocean, at the start of a marine food chain. Recent research suggests that rather than hurting marine life, more CO_2 might actually be enhancing biological productivity in the ocean (Iglesias-Rodriguez, et al., 2008). Thus, the worries over ocean acidification hurting biological activity in the ocean might be premature. And a review of research on the effect of changes in ocean pH indicates that fears of serious harm to coral reefs and their supported ecosystems are probably misplaced. History has shown that corals adapt well to changing pH and water temperature (Idso, 2009).

CONCLUSIONS

As we have seen, the popular assertion that the scientific evidence for global warming being mostly the result of human activities is not nearly as compelling as one might be led to believe based upon media reports. Climate change science is still very young, and in many respects still finding its feet. The supposed scientific consensus on the subject refers to the collective faith of an alleged majority of climate researchers that global average warming (which even "skeptics" acknowledge has occurred) is mostly due to human activities—a faith not justified by the evidence. That alleged majority tends to rely for its view of climate over the last millennium on the work of a small group of closely associated researchers on the history of climate—work that has been found to be badly flawed by improper data handling, faulty statistical methodology, and inadequate peer review (McIntyre and McKitrick, 2005a; McIntyre and McKitrick, 2005b; McIntyre, 2009; Wegman, Scott, and Said, 2006). We still do not know the causes of events such as the Medieval Warm Period, the Little Ice Age, or even the warming that occurred from the 1800s up until 1940—and all of these were before humanity put substantial extra CO_2 in the atmosphere. Until we know how much of observed climate variability is natural, we cannot determine how much of recent warming has been due to human activity.

Meanwhile, the very reality of the consensus remains debatable, as evidenced by surveys of relevant scientific literature (Schulte, 2008) and climate scientists (Bray and von Storch, 2007) and the willingness of over 31,000 American scientists to sign a statement claiming, "There is no convincing scientific evidence that human release of carbon dioxide, methane, or other greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate. Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the Earth" (OISM, 2008).

Consensus is a political term, not a scientific one. The use of the term by the IPCC is an admission that scientific uncertainty exists. As has been demonstrated repeatedly throughout the history of modern science, a scientific theory that is widely believed to be true can be overturned when more is learned. Our scientific understanding is always incomplete, and this is especially true for complex physical processes like those involved in the operation of the Earth's climate system.

Given the state of the science, it is premature to call for major reductions in greenhouse gas emissions in efforts to prevent climate change which might well be mostly natural and outside of our control. Climatology is a young science, and the undisputed data do not support calls for urgent and expensive action.

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REFERENCES

Allen, M. R., and D. J. Frame, 2007. "Call off the quest," *Science*, **318**, 582-583. Available at http://www.sciencemag.org/cgi/content/short/318/5850/582, accessed November 9, 2009.

Bray, D., and H. von Storch, 2007. *The Perspectives of Climate Scientists on Global Climate Change*. GKSS. Available at http://dvsun3.gkss.de/BERICHTE/GKSS_Berichte_2007/GKSS_2007_11.pdf, accessed November 9, 2009.

Brohan, P., J.J. Kennedy, I. Harris, S.F.B. Tett and P.D. Jones, 2006. "Uncertainty estimates in regional and global observed temperature changes: A new dataset from 1850," *Journal of Geophysical Research* **111**, D12106, doi:10.1029/2005JD006548

Brooks, C.E.P., 1938. "The warming Arctic." *Meteorological Magazine*, **73**, 29-31.

Christy, J. R., R. W. Spencer, W. B. Norris, W. D. Braswell, and D. E. Parker, 2003. "Error estimates of version 5.0 of MSU/AMSU bulk atmospheric temperatures," *Journal of Atmospheric and Oceanic Technology*, **20**, 613– 629.

Christy, J.R., W.B. Norris, and R.T. McNider, 2009. "Surface temperature variations in East Africa and possible causes," *Journal of Climate*, **22**, 3342–3356

Compo, G.P., and P. D. Sardeshmukh, 2009. "Oceanic influences on recent continental warming." *Climate Dynamics*, 333-342, available at http://www.springerlink.com/content/au9x40l201105273/fulltext.pdf, accessed November 9, 2009.

Douglass, D. H., and R. S. Knox, 2009. "Ocean heat content and the Earth's radiation imbalance," *Physics Letters* A, vol. 373, issue 36, pp. 3296-3300.

Essex, Christopher, and Ross McKitrick, 2007. *Taken By Storm: The Troubled Science, Policy, and Politics of Global Warming*, rev. ed. Toronto: Key Porter Books.

Forster, P. M., and J. M. Gregory, 2006. "The climate sensitivity and its components diagnosed from Earth Radiation Budget data," *Journal of Climate*, **19**, 39-52.

Forster, P.M., and K.E. Taylor, 2006. "Climate forcings and climate sensitivities diagnosed from coupled climate model integrations," *Journal of Climate*, **19**, 6181-6194.

Henderson, D., 2007. "Governments and Climate Change Issues: A Flawed Consensus," in *The Global Warming Debate: Science, Economics, and Policy*. Proceedings of a Conference Sponsored by the American Institute for Economic Research, Great Barrington, Massachusetts, November 2-3, 2007 (AIER *Economic Education Bulletin* xlviii:5, May 2008), pp. 61-81).

IARC (International Arctic Research Center), 2009. "Data of Sea Ice Extent," available at http://www.ijis.iarc.uaf.edu/en/home/seaice_extent.htm, accessed November 9, 2009.

Idso, C.D., 2009. *CO2, Global Warming, and Coral Reefs: Prospects for the Future.* Center for the Study of Carbon Dioxide and Global Change, Science and Public Policy Institute, available at http://www.co2science.org/education/reports/corals/coralreefs.pdf, accessed November 9, 2009.

Idso, C.D., and Sherwood B. Idso, 2009. *CO2, Global Warming, and Species Extinctions: Prospects for the Future*. Pueblo West, CO: Vales Lake Publishing.

Iglesias-Rodriguez, M.D., et al., 2008. "Plankton calcification in a high-CO2 world," *Science*, **320,** 336-340.

Intergovernmental Panel on Climate Change, 2007. *Climate Change 2007: The Physical Science Basis*, report, 996 pp., Cambridge University Press, New York City.

JISAO (Joint Institute for the Study of the Atmosphere and Ocean), 2008. "Updated standardized values for the PDO index," available at http://jisao.washington.edu/pdo/PDO.latest.

Knutti, R., and G. C. Hegerl, 2008. "The equilibrium sensitivity of the Earth's temperature to radiation changes," *Nature Geoscience*, **1**, 735-743.

Landsea, C.W., G. A. Vecchi, L. Bengtsson, and T. R. Knutson, 2009. "Impact of duration thresholds on Atlantic tropical cyclone counts," *Journal of Climate*, July 31.

Lindzen, R. S., and Y.-S. Choi, 2009. "On the determination of climate feedbacks from ERBE data," *Geophysical Research Letters*, **36**, L16705, doi:10.1029/2009GL039628.

Loehle, C., 2007. "A 2,000 year global temperature reconstruction on non-treering proxy data," *Energy and Environment*, **18**, 1049-1058.

Lomborg, B., 2007. *Cool It: The Skeptical Environmentalist's Guide to Global Warming*. New York: Alfred A. Knopf.

Manabe, S., and R.F. Strickler, 1964. "Thermal equilibrium of the atmosphere with a convective adjustment," *Journal of the Atmospheric Sciences*, **21**, 361–365.

McIntyre, Steve, 2009. "Yamal: A 'Divergence' Problem," ClimateAudit.org; available at http://www.climateaudit.org/?p=7168, accessed November 9, 2009.

McIntyre, Steve, and R. McKitrick, 2005a: "The M&M Critique of the MBH98 Northern Hemisphere Climate Index: Update and Implications," *Energy and Environment* 16(1): 69-100; available at http://www.uoguelph.ca/~rmckitri/research/M&M.EE2005.pdf, accessed November 9, 2009.

McIntyre, Steve, and R. McKitrick, 2005b: "Hockey Sticks, Principal Components and Spurious Significance," *Geophysical Research Letters* 32(3) L03710 10.1029/2004GL021750 12 February.

McKitrick, R., 2007. "Response to Henderson Article," in *The Global Warming Debate: Science, Economics, and Policy, Proceedings of a Conference Sponsored by the American Institute for Economic Research*, Great Barrington, Massachusetts, November 2-3, 2007 (AIER *Economic Education Bulletin* xlviii:5, May 2008), pp. 61-81). Available at http://ross.mckitrick.googlepages.com/McKitrick.final.pdf, accessed November 9, 2009.

McKitrick, R. R., and P. J. Michaels, 2007. "Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data," *Journal of Geophysical Research*, **112**, D24S09, doi:10.1029/2007JD008465. Available at http://www.uoguelph.ca/~rmckitri/research/jgr07/M&M.JGRDec07.pdf, accessed November 9, 2009.

New, M., M. Todd, M. Hulme, and P. Jones, 2001. "Precipitation measurements and trends in the Twentieth Century," *International Journal of Climatology*, **21**, 1899-1922.

OISM (Oregon Institute of Science and Medicine), 2008. *Global Warming Petition Project*, available at http://petitionproject.org/, accessed November 9, 2009.

Paltridge, G.W., 2009. *The Climate Caper*. Ballan, Australia: Connor Court.

Perry, C.A., 2007. "Evidence for a physical linkage between galactic cosmic rays and regional climate time series," *Journal of Advanced Space Research*, doi:10.1016/j.asr.2007.02.079.
Pielke, R.A., Jr., J. Gratz, C.W. Landsea, D. Collins, M. A. Saunders, and R. Musulin, 2008. "Normalized hurricane damage in the United States: 1900-2005," *Natural Hazards Review*, 29-42.

Plimer, I., 2009. *Heaven and Earth: Global Warming the Missing Science*, Quartet Books.

Schulte, Klaus-Martin, 2008. "Scientific Consensus on Climate Change?" *Energy & Environment*, vol. 19, no. 2. Available at http://scienceandpublicpolicy.org/images/stories/papers/reprint/schulte_two_colmun_fomat.pdf, accessed November 9, 2009.

Singer, S.F., editor, 2008. *Climate Change Reconsidered: The Report of the Nongovernmental International Panel on Climate Change*. Heartland Institute, Chicago. Available at http://www.heartland.org/policybot/results/22835/Nature_Not_Human_Activity_Rules_the_Climate_pdf.html, accessed November 9, 2009.

Spencer, R.W., W. D. Braswell, J. R. Christy, and J. Hnilo, 2007. "Cloud and radiation budget changes associated with tropical intraseasonal oscillations," *Geophysical Research Letters,* **34**, L15707, doi:10.1029/2007GL029698.

Spencer, R.W., and W.D. Braswell, 2008. "Potential biases in cloud feedback diagnosis: A simple model demonstration," *Journal of Climate,* **21**, 5624-5628.

Svensmark, Henrik, and Nigel Calder, 2007. *The Chilling Stars: A New Theory of Climate Change*. Cambridge: Icon.

Tsonis, A. A., K. Swanson, and S. Kravtsov, 2007. "A new dynamical mechanism for major climate shifts," *Geophysical Research Letters*, **34**, L13705, doi:10.1029/2007GL030288.

Watts, A., 2009. *Is the U.S. Surface Temperature Record Reliable?* Chicago: Heartland Institute; available at http://wattsupwiththat.files.wordpress.com/2009/05/surfacestationsreport_spring09.pdf, accessed November 9, 2009.

Wegman, E. J., D. W. Scott, and Y. H. Said, 2006. *Ad Hoc Committee Report on the "Hockey Stick" Global Climate Reconstruction*. Report to the U.S. House of Representatives Committee on Energy and Commerce and Subcommittee on Oversight and Investigations. Available at http://www.climateaudit.org/pdf/others/07142006_Wegman_Report.pdf, accessed October 30, 2009.

Chapter Three

The Economics of Global Warming Policy

EXECUTIVE SUMMARY

Many economists who have published articles on the subject consider the science of climate change a settled matter—that human beings are responsible for greenhouse gas emissions that cause dangerous global warming. We are aware of no economic models that take into account the possibility that human influence on climate is negligible. If this argument is correct—and we believe it is (see the science chapter)—then the justification for governments' pursuing greenhouse gas reductions in the name of climate control collapse.

While we believe that human influence on climate is negligible, our task is to assess the economic prudence of policy options offered on the contrary assumption.

Although some sector-level economic studies in agriculture and forestry indicate that warming might enhance well-being, most models find that human well-being improves because of economic growth with or without warming but improves less with significant warming. Even so, economists conclude that an optimal climate policy, assuming there should be one, would avoid locking into a particular technology. Nonetheless, most energy legislation does just that. Economists also recommend against stopping climate change entirely, favoring a policy ramp whereby carbon taxes or emission reduction targets slowly increase as and if average global temperatures rise. But the optimal policy recommendations are based on projected future temperatures from climate models rather than observed temperatures, on the basis of which less warming might be expected.

On the assumption that politicians will seek to force reductions in carbon dioxide (CO_2) emissions, economists generally favor taxes over cap and trade as the means. Carbon taxes are (1) transparent so that citizens can recognize them, (2) flexible so they can be adjusted as needed (e.g., tied to average global temperatures), and (3) widely applicable (including across countries). Their revenues can be used to reduce other taxes, thereby possibly providing a double dividend (reduced CO_2 emissions and economic growth due to removal of other taxes). In contrast, cap and trade leaves room for unjustified credits because of government and business corruption and dubious activities such as forest conservation and tree planting; it gives large emitters huge windfalls in the form of free permits early in the regime unless all emission permits are auctioned by the government; and it yields no double dividend. Both large industrial emitters and financial institutions, unsurprisingly, lobby hard for cap and trade—the former benefiting from the windfall at the start, the latter from transaction fees in a commodity market that could be worth $3 trillion annually. Their support for climate policies must not be mistaken, however, for conviction either that dangerous manmade warming is real or that the policies are the best way to respond. It is rent seeking: lobbying for legislation to profit from potentially massive, policycreated windfalls.

Finally, many supporters of mandated emission reductions assume that price-competitive renewable energy sources will soon displace fossil fuels. However, large technical obstacles need to be overcome before renewable energy will become price competitive on global or national scales—a process that might take 50 to 100 years or more.

In light of these considerations and those of the other two chapters of this document, we recommend against mandated reductions on CO_2 emissions—whether through cap and trade (the worst kind of emissions reduction policy) or a carbon tax (the least bad emissions reduction policy, but still not good)—and for the promotion of economic development and targeted problem solving (e.g., disease reduction and nutrition enhancement) as a means to fortify people the world over—especially the poor—against material threats to their well-being, whether from climate change or anything else.

INTRODUCTION

Christianity has always emphasized rational faith over emotional acceptance of the gospel (e.g., 1 John 4:1; 2 Peter 1:16-18)—or of any other teaching.[4] This Christian emphasis on rational examination and proof carried over into science, leading many famous scientists, including Michael Polanyi (1891-1976) and Eugene Wigner (1902-1995), to conclude that sustained scientific development could occur only in a Christian culture (Schaefer 2003). Likewise, Biblical teaching on private property (Exodus 20:15; Matthew 20;15), free and voluntary trade (Matthew 20:1-15), the legitimacy of profit through investment (Matthew 25:1430), etc., underlies economics (Beisner, 1988). Christian worldview, theology, and ethics were the ground from which modern economics arose in the Reformation and post-Reformation eras (Rosenberg and Birdzell, 1987; Chafuen, 2003; Novak, 2000). But with the rise of postmodernism, emotional response often replaces rational assessment. While Christians certainly must have compassion, we must reassert rationality to determine how best to express it. Nowhere is this more clear than in the economic policy debate surrounding global warming.

Like all interesting and important policy questions, global warming involves choosing among competing values. Does climate change demand drastic and immediate action? If so, at what cost? How willing are we to give up inexpensive fossil fuel energy and accept the consequences? However well intended, it is naïve and irresponsible to ignore the unavoidable tradeoffs.

Along with the tradeoffs come opportunity costs. The best measure of cost is the opportunities forgone, i.e., the value of alternatives sacrificed. Money spent to combat climate change cannot be spent to eradicate malaria (which kills two million people per year, mostly children under 5), to improve female literacy (perhaps the key investment for social progress), to fight hunger, malnutrition, and communicable diseases, or to build roads, electric power plants and grids, and water and sewage treatment plants.

The world is discovering that combating climate change will be extremely difficult and expensive. It is especially vexing because:

- The atmosphere is a commons with unrestricted access. The benefits of burning fossil fuels accrue to individuals, but the alleged costs of CO_2 emissions[5] are borne by all. This makes climate change the mother of all collective action problems. It requires the cooperation of others who often have different interests and incentives.
- The costs and benefits of climate change and of its mitigation will be unequally distributed. This means different countries will bargain strategically to advance their perceived interests.

[4] See also Stott (1972) and Chesterton (2001) for discussions about a rational approach to Christian belief and faith; and MacArthur (1994) and Johnson and Taylor (2009) about proving one's faith.

[5] CO_2 is considered the most important greenhouse gas (GHG), and other GHGs are generally measured in terms of their CO_2 equivalence, denoted $CO_{2\text{-}e}$. For convenience, we will simply use CO_2 to refer to carbon dioxide plus other greenhouse gases measured in terms of their CO_2 equivalence.

- Carbon dioxide is a persistent atmospheric resident. If over night we eliminated every source of manmade CO_2, it is commonly accepted that the warming effect of past human emissions would continue for 100 years or more.
- If current trends continue, developing countries will quite soon become the largest emitters. (China has already become number one.) Their leaders understand that increasing energy consumption is a prerequisite for continued economic development— and, because of cost and availability, the fuels of choice will likely be carbon based.
- Reducing emissions fast enough and far enough to avoid allegedly dangerous human interference with the climate system requires an unprecedented transformation of energy systems. For example, to cut global emissions in half by 2050 requires that, on average, the world economy will then have the same carbon intensity as Switzerland had in 2004—an immense and unprecedented challenge to national and international institutions.

In light of these facts and the discussion below, we believe policies requiring drastic reductions in carbon dioxide emissions are unwise and harmful; that of all variations on such policies, cap and trade is the worst and a straightforward carbon tax the least bad; and that the best response to both warming and cooling of global climate is policies that promote economic development for the poor, ensure abundant and affordable energy (a *sine qua non* for development), and reduce specific risks especially for the poor (such as disease and malnutrition). It's clear: Whether anthropogenic or natural, whether dangerous or benign, climate change is inevitable. Our challenge is to deal with it responsibly. This chapter offers suggestions on how we might begin.

THE ECONOMIC DEBATE

Some scientists, like Sir John Houghton, a former co-chair of the Scientific Assessment Working Group of the United Nations' Intergovernmental Panel on Climate Change (IPCC), and influential public figures, like former Vice President Al Gore, assert that dangerous anthropogenic global warming (DAGW) is the greatest threat to civilization. Former President Bill Clinton has said, "I worry about climate change. It's the only thing that I believe has the power to fundamentally end the march of civilization as we know it, and make a lot of the other efforts that we're making irrelevant and impossible."[6]

With some exceptions, economists take the view that because meteorological, atmospheric and oceanic sciences are outside their realm of expertise, they should accept such warnings without qualification. While their humility is admirable, it is not economists' only justified response. As economist and Czech President Vaclav Klaus points out (Klaus 2008), though economists are not climate scientists, they are trained in the use of mathematical models and know what is necessary for models to be useful in predicting the future. They can recognize when models misuse data or statistical methodology and fail the basic test of falsifiability. Economic models that predict DAGW do just that by assuming the results of climate models that are plagued by literally hundreds of "parameters" (variables whose values are unknown and must be supplied by little better than

[6] All quotes here and elsewhere in this chapter that are not otherwise cited can be found at http://www.c3headlines.com/global-warming-quotes-climate-change-quotes.html or http://www.laurentian.ca/Laurentian/Home/Research/Special+Projects/Climate+Change+Case+Study/Quotes/Quotes.htm?Laurentian_Lang=en-CA, both viewed July 20, 2009.

guesswork) and that rely on unverified, sometimes falsified assumptions about how climate works. (For more, see the science chapter.)

Estimating the Costs of Global Warming

Nonetheless, few economists challenge the alarmists' claims. Instead, they assume DAGW and then attempt to analyze its costs and benefits, searching for an optimal economic response. William Nordhaus of Yale University summarizes this approach as follows:

> Global warming is a serious, perhaps even a grave, societal issue [and] there can be little scientific doubt that the world has embarked on a major series of geophysical changes that are unprecedented in the past few thousand years. … A careful look at the issues reveals that there is at present no obvious answer as to how fast nations should move to slow climate change. Neither extreme—either do nothing or stop global warming in its tracks—is a sensible course of action. Any well-designed policy must balance the economic costs of actions today with their corresponding future economic and ecological benefits. (Nordhaus 2008, pp. 1-2)

In a series of books and articles (e.g., Nordhaus 1991, 1994, 2008), Nordhaus concludes that the effort spent on mitigation should attempt to slow DAGW relative to what it would otherwise be but not stop it, and that controls on emissions should ramp up (become more stringent) over time. Consequently, he concludes that an optimal carbon tax should rise from $9.50 per ton of CO_2 in 2005 to about $25 in 2050 and $56 in 2100—or 12¢ per gallon of gasoline in 2005 to nearly 70¢ by 2100 (Nordhaus 2007a, 2008).[7] This optimal path for a carbon tax is predicated on unmitigated damages from climate change that amount to nearly 3% of global output in 2100 and 8% by 2200. Three scenarios of projected damages from different assumed variables that Nordhaus inserted into his model appear in Table 1. It is important to note that these are calibrations, not statistical evidence, so they really amount to nothing more than an assumed relation between temperature increase and economic damages based on projections of possible damages in specific sectors (such as agriculture). Furthermore, each of these sectoral analyses has its own sometimes dubious assumptions regarding the relationship between projected climate change and damages. Also, Nordhaus fails to take adequately into account a fundamental truth of economics: People respond to incentives, so adaptations are likely to reduce or eliminate much of the damage even if the warming occurs as projected.

Table 1: Modeled relation between temperature rise and damages

Temperature rise	Damages as proportion of global output		
	Worst case	Mid case	Best case
0 ºC	0.00%	0.00%	0.00%
1 ºC	0.32%	0.28%	0.10%
2 ºC	1.27%	1.14%	0.58%
2.5 ºC	1.98%	1.77%	1.01%
3 ºC	2.85%	2.55%	1.60%
4 ºC	5.07%	4.54%	3.28%
5 ºC	7.93%	7.10%	5.74%
6 ºC	11.41%	10.22%	9.05%

[7] Values are in real 2005 purchasing power US dollars.

Source: Nordhaus (2007b)

A recent critique by Murphy (2009) of Nordhaus's model finds that Nordhaus probably overstates future greenhouse gas concentrations, climate sensitivity (the temperature increase to be expected from doubled CO_2 concentration after feedbacks), and the expected damages from any given temperature increase. It also argues that Nordhaus's model incorporates an unjustifiable "catastrophic impact" component that unrealistically raises risk projections. Eliminating that component and reducing climate sensitivity from Nordhaus's (and the IPCC's) 3.0° C to a more defensible 2.5° C (a 17% reduction) results in reducing the optimal carbon tax in any given year by 77 percent (e.g., from $41.90 to $9.46 per ton in 2015, and from $137.82 to $30.62 per ton in 2075). Of course, if the studies cited in the science chapter—pointing toward climate sensitivity of about 0.5° C (83% reduction from Nordhaus and the IPCC)—are correct, the justification for a carbon tax effectively disappears.

In contrast to the approaches used by Nordhaus (1994, 2008) and others (e.g. Tol 2002), which rely on integrated assessment models, Goklany (2009) measures the impacts of projected global warming on human risks, mortality, and ecosystems using a bottom-up approach. Surprisingly, he is one of the few who begin with the IPCC's (2000) emission scenarios, which are the principal driver of fears of DAGW (see also Tol 2005a).

Goklany (2009) provides a brief description of four key scenarios in the first eleven rows of Table 2. The scenarios indicate the range of possible greenhouse gas emissions for different economic development trajectories if nothing is done to mitigate climate change, and include assumptions about technological change, land use changes, and the energy mix. The final three rows summarize Goklany's estimates of the associated changes in mortality, changes in populations at risk due to water stress, and losses of coastal wetlands.

The crucial thing to note about Goklany's scenarios is the projected increase in per capita GDP (measured in 2005 US dollar equivalents). *All scenarios foresee substantial increases in wealth*. Even the scenario leading to the lowest increase in income and highest increase in population (scenario A2) would have those living in developing countries producing more than $16,000 per person, equivalent to standards existing in some eastern European countries today. Two scenarios (A1F1 and B1) see those in developing countries with incomes equivalent to those in wealthy countries today, while those in wealthy countries would see a doubling of their real incomes. The negative impacts of climate change are offset by rising incomes, so much so that the overall climate impact is essentially negligible. Among the scenarios, *the greatest human costs occur for the situation where people are poorest—no matter what the climate*.

Goklany (2009) also reports that net biome productivity will increase as a result of climate change and less wildlife habitat will be converted to cropland as a result of global warming, a finding similar to that of Sohngen, Mendelsohn and Sedjo (1999). Finally, compared to mitigation through emissions reductions, Goklany finds that targeted adaptation can yield large benefits. This implies that adaptation, not mitigation, is the optimal policy response.

Nonetheless, the demand continues for mitigation.

Table 2: Selected emission scenarios used to drive projections of global warming and the projected impact on population and ecosystem health

	IPCC Scenarios			
Item	A1F1	A2	B2	B1
Population ($\times 10^9$) in 2085	7.9	14.2	10.2	7.9
Average global per capita GDP in 2085 ($)[a]	78,600	19,400	29,900	54,700
Average per capita GDP in 2100, Industrialized countries ($)[a]	160,300	69,000	81,300	108,800
Average per capita GDP in 2100, Developing countries ($)[a]	99,300	16,400	26,900	60,000
Technological change	Rapid	Slow	Medium	Medium
Energy use	Very high	High	Medium	Low
Energy technologies	Fossil fuel intensive	Regionally diverse	"Dynamics as usual"	High efficiency
Land-use change	Lowmedium	Mediumhigh	Medium	High
Atmospheric CO_2 concentration (ppmv) in 2085	810	709	561	527
Global temperature change (^oC) in 2085	4.0	3.3	2.4	2.1
Sea level rise (cm) in 2085	34	28	25	22
	Goklany (2009) estimates			
Change in total mortality in 2085 compared to baseline[b,c]	–2,064,000	+1,927,000	–1,177,000	–2,266,000
Total population at risk due to water stress compared to baseline[c]	299,000	5,648,000	2,746,000	857,000
Average net global loss in coastal wetlands by 2085 compared to baseline[c]	13%	9%	9%	10%

[a] GDP per capita is given in 2005 US $, converted from 1990 $ using the US Consumer Price Index.

[b] Mortality due to hunger, malaria and flooding; deaths directly due to climate change increase slightly, but are offset in the A1F1, B2 and B1 scenarios by reduced mortality resulting from improved living standards. [c] The baseline assumes incomes are kept at the 1990 level and there is no climate change. Source: Adapted from Goklany (2009).

In addition to the idea of a policy ramp, economists who (like Goklany) accept IPCC projections of DAGW and (unlike Goklany) favor mitigation over adaptation almost unanimously prefer market incentives over mandated technologies as the means to reduce greenhouse gas emissions, particularly a carbon tax that uses proceeds to reduce other taxes (thus making it revenue neutral). A carbon tax would theoretically lead to higher well-being as the economic distortions caused by other taxes would be reduced—the so-called double dividend of a green tax. It could also increase employment (see Bovenberg and Goulder 1996). As Nordhaus's work indicates, the optimal mitigation policy would be to impose a carbon tax set low at the outset and then slowly increased over time. One compelling reason for a tax is to avoid getting locked into an emission-reduction technology that might prove inferior to another option yet to be developed. For example, one would not want to lock into the hydrogen economy—with its network of transmission lines and fueling stations—in case a much better option, such as a competitive electric vehicle capable of going 200 km or more on a single charge, should come along. Doing so might be prohibitively expensive and militate against the development of such an electric vehicle.

Thinking a carbon tax would not guarantee adequate emissions reductions, some economists prefer quantitative controls and emissions trading, arguing that if the price of a permit to emit CO_2 becomes too high the authority can always issue more permits. If carbon trading is the instrument of choice, the majority of economists and environmentalists prefer that the government auction off permits, using the revenues to reduce income taxes and other taxes. But economists are not wedded to the idea of auctions because, other than the revenue benefits to government and the potential for a double dividend, the emissions outcomes are the same whether permits are auctioned, given freely to existing emitters on the basis of past emissions, or allocated in some other fashion. Large industrial emitters prefer a scheme that grandfathers permits instead of either a carbon tax or a scheme that requires them to pay for permits. Environmentalists, however, are against grandfathering because they see it as rewarding polluters for polluting. We return to market incentives below because they have a great deal of impact on efficiency and the poor.

The Debate Heats Up

Two unrelated events changed the foregoing consensus among economists who accept the claims of DAGW. First was the publication of the Stern Review (Stern 2007). Contrary to all previous economic analyses (e.g., Nordhaus 1991, 1994; van Kooten 2004; Tol 2005b), the Stern Review asserts that the benefits of severely restricting CO_2 emissions today exceed the costs, and it offers no ramping up policy, only the conclusion that immediate severe restrictions on CO_2 emissions are warranted.

The reasons, and their weaknesses, soon became apparent: To convert future values into present values, Stern relied on a very low (1.4%) rate of discount (a concept to be explained below) (Mendelsohn 2006). This implied that distant damages (costs) of global warming were much more highly valued today than had been assumed before (Nordhaus 2007a), thereby raising the discounted benefits of acting now. This bias was compounded by another. By cherry picking the most pessimistic estimates of warming's effects on agriculture, health, insurance, and economic development, and ignoring contrary studies, the Stern Review assumed damages from global warming three or more times higher than were previously assumed, and much lower costs of mitigating CO_2 emissions (Tol 2006; Mendelsohn 2006; Nordhaus 2007a; Goklany 2009; Byatt et al. 2006). But it is only when non-market environmental damages are taken to be extremely large that an argument can be made for immediate drastic action to reduce CO_2 output (Weitzman 2007).[8]

[8] Much controversy surrounds attempts to demonstrate high values of such things as forest ecosystems, wildlife species, etc. In addition to the problem of budget constraints in the estimation of values (some people are willing to pay more than their entire income to protect nature, others very little), there is much confusion about average versus marginal values. For example, an old-growth forest might have tremendous worth, but a single hectare might have little non-market value at the margin, much as the hundredth pair of shoes has little value to a single owner.

These first two errors—applying an unrealistically low discount rate and exaggerating future damages from warming (especially ecological damages)—compounded each other. Finally, on the grounds that we cannot rule out the possibility of a future climate disaster caused by anthropogenic emissions, Stern argued that it would be folly not to take action immediately to avert disaster.

The Stern Review did not change the view of economists that society should wait before taking costly action on global warming. Rather, economists widely condemned it as "the greatest application of subjective uncertainty the world has ever seen" (Weitzman 2007, p. 718), an analysis not based on "solid science and economics" (Mendelsohn 2006, p. 46), and one that "can therefore be dismissed as alarmist and incompetent" (Tol 2006, p. 980).

The second event was the global financial crisis that began in 2008, one effect of which was to rivet attention on the costs of climate policy. In some circles, however, the crisis became an excuse to circumvent markets, with economist Jeffery Sachs commenting, "Free-market ideology is an anachronism in an era of climate change."

The Difficulty of Discount Rates

Because costs are incurred and benefits accrue at different points in time, cost-benefit analysis relies on discounting to a common date so that financial inflows and outflows occurring at different times are comparable. Compared to low interest rates, high rates encourage saving and investment that lead to higher future incomes, but they also cause one to focus more on the short run because gains and losses that occur farther in the future are valued less today (as they are discounted more highly).

There is no ready consensus about what discount rate to use when analyzing public policies and projects. On debatable moral grounds, some advocate a zero discount rate in comparing one generation's costs and benefits with another's. Discounting implicitly values future generations' costs and benefits less than the present generation's. The higher the discount rate, the lower is the *current* value of a *future* gain or loss.

The long-run rate of growth in per capita consumption is often used as a starting point for calculating the discount rate. To this is added a rate of time preference of one or two percent (not the 0.1% used by Stern). Thus, if the rate of growth in consumption is 1.3%, then the actual rate of discount might be 2.3% or 3.3%. As noted above, the Stern Review employed a discount rate of 1.4%, with the result that future damages (which were also overstated) appeared 10 to 20 times larger in current terms than under a more realistic discount rate, as did future benefits from mitigation.

There is a more puzzling aspect of discounting when time frames are on the order of many decades or even centuries, as is the case with climate change. As the controversy surrounding the Stern Review indicates, small differences in the discount rate used in cost-benefit analysis can lead to significantly different policy conclusions. However, the world changes greatly over the course of a half century or more. One hundred years ago, the automobile was only slightly more than a curiosity; today the economies of most industrial and developing nations depend on it. Electricity, refrigeration, airplanes, radio, television and computers were largely unknown, but today we cannot envision doing without them. How can we predict the potential damages (or benefits) from climate change in 2050 or 2100, much less 2200, without knowing what technologies and social constructs will have arisen, and what will have fallen into disuse?

Some think discounting costs borne and benefits enjoyed by future generations is morally objectionable, violating the command to "Love your neighbor as yourself." Yet in the parable of the talents (Matthew 25:14-30) Jesus has the ruler (who represents God) condemn the servant who buried his talent in the ground for not at least putting it into a bank, where it would have earned interest. Interest is the discount rate for future money. People discount the future because they quite properly prefer something today (because it's sure and can be used productively immediately) over something tomorrow (because it's unsure and cannot be used productively until the future). They exhibit an implicit rate of time preference. Thus a dollar of future benefits or costs should be valued less than a dollar of benefits or costs today. The moral objection disappears when we distinguish between the intrinsic value of *people* (all of whom bear the image of God) and the subjective value of money, time, labor, and other things. Discounting applies to the latter, not to people *qua* people.

Lomborg's View: We Adapted Before, We Can Adapt Again

By far the best and most rational cost-benefit analysis of future climate change has been conducted by Bjørn Lomborg (2007a). It is the only one of which we are aware that takes into account technical progress in assessing climate change. Lomborg's approach is simple, but sensible and powerful. He indicates that the climate change that has occurred in the past 100 years is about what the IPCC's models predict, both in terms of global temperature rise and sea level rise, for the next hundred. He then compares life a hundred years ago with life today, showing how well people have adapted, and considers it rational to expect the continuation of similar adaptive abilities and technological changes in the future. The result is the expectation that people will be better off in any case—with or without the warming, with or without mitigation—but best off with greater investment on adaptation (including economic development) than on mitigation.

Weitzman's Case: Drastic Response to Low-Probability Catastrophe

A very different approach to that of Stern (2007) is taken by Martin Weitzman, who first criticizes the Stern Review for its highly speculative nature but then sets about to provide an alternative defense for taking drastic action on DAGW, one not based on low discount rates and optimistic estimates of mitigation costs. Weitzman (2009a, 2009b, 2009c) bases his case on what he calls "fat-tailed" probability density functions that, based on his derivations (discussed below), provide a reasonable probability that average global temperatures might rise by more than 10^{o} C or possibly even 20^{o} C. "At a minimum such temperatures would trigger mass species extinctions and biosphere ecosystem disintegration matching or exceeding the immense planetary die-offs associated in Earth's history with a handful of previous geoenvironmental mega-catastrophes" (Weitzman 2009a, p. 5). The cause of the catastrophe, according to Weitzman, is unprecedented anthropogenic greenhouse gas emissions coupled with a critical climate sensitivity parameter that converts changes in atmospheric CO_2 into temperature increases. "It is universally accepted that in the absence of any feedback gain, *s* [warming from doubled CO_2 before feedbacks] = 1.2° C" (Weitzman 2009, p. 4). But it is *climate sensitivity* (warming *after* feedbacks) that is uncertain, so much so that its probability distribution is necessarily characterized by "fat tails" that bring about the high probabilities of large increases in temperature.

How does Weitzman come to the conclusion that there is a high probability of high temperature increase? He bases this on four points (Weitzman 2009b, 2009c):

1. According to Antarctic ice core data reported by Dieter et al. (2008), current atmospheric concentrations of CO_2 are the highest ever recorded in perhaps the past 850,000 years, and the current rate of increase in atmospheric CO_2 is historically unprecedented. This unprecedented increase, Weitzman asserts, can only be attributed to human causes.

2. Weitzman applies what he calls a "meta-analysis based on Bayesian model averaging" to 22 studies reported in IPCC's Fourth Assessment Report (IPCC-AR4) (IPCC 2007, pp. 721-722, 798-799) to determine the scientific consensus about expected future temperatures if emissions of CO_2 continue unabated. On the basis of this analysis, he suggests that there is a 5% probability that the expected temperature will increase by more than 7^o C and a 1% probability that it will exceed 10^o C.

3. Next, he assumes that higher atmospheric concentrations of CO_2 lead to higher temperatures, which will cause permafrost and boggy soils to release methane, thereby amplifying global warming (Sheffer et al. 2006, Matthews and Keith 2007, and *The Economist* 2009). The possibility of such a feedback effect leads Weitzman to increase the value of climate sensitivity so that, based on information from Torn and Harte (2006), the probability that temperatures could rise above 11.5^o C is 5% and that they could rise above 22.6^o C is 1%! However, recognizing the crude and speculative nature of his calculations, Weitzman rounds these levels down to 10^o C and 20^o C.

4. Finally, given the potential for huge increases in temperature, Weitzman argues that economic damage (utility) functions parameterized on the basis of current fluctuations in temperature make no sense. While the damages reported by other economists might make sense for low temperature rise, they will be much, much higher for the larger increases in temperature.

Based on these values, Weitzman concludes there is a real possibility that, regardless of the discount rate, the damages from climate change could be infinite—that human beings cease to exist as a species.

Weitzman makes a creative case for a massive R&D program to find a technological solution to DAGW (an argument in which Weitzman depends on Barrett 2008, 2009). But Weitzman's economic case rests on three faulty premises: (1) human beings are solely responsible for the vast majority of the observed increase in atmospheric CO_2; (2) increased atmospheric CO_2 leads to increased global temperatures via strong net positive feedbacks, resulting in high climate sensitivity (warming anticipated from doubled CO_2 *after feedbacks*); and (3) there is a rational basis for assigning probabilities to the catastrophically high temperature increases. If any of these suppositions is false, or even if one of them is only partially true, his economic conclusions disappear.

The first premise is doubtful, since even slight warming of the oceans, which we know has happened before in the absence of anthropogenic greenhouse gases, could explain recent increases in CO_2 (Spencer 2009a).

The second premise is almost certainly false. Weitzman's bias on the matter is clear: "It is universally accepted that in the absence of any feedback *gain* [emphasis added], *s*=1.2° C." He does not even consider that there could be feedback *loss*. The Earth's surface temperature with no greenhouse effect would be about 18° C; with it, but with no feedbacks, it would be about 60° C; with feedbacks, it is actually about 15° C. In the natural system, then, feedbacks eliminate about 58% of GHG warming—that is, *feedbacks are strongly net negative*. But to get climate sensitivity above 1.2° C one must assume that positive feedbacks are strongly net positive— precisely the opposite of what is found in nature. Research published since the May 2005 cutoff date for consideration in the IPCC 2007 Scientific Assessment Report (Schwartz 2007, Spencer et al. 2007, Spencer and Braswell 2008, Spencer 2008, and Lindzen and Choi 2009) confirms that the feedbacks are net negative, with climate sensitivity probably around 0.5° C instead of the IPCC's midrange of 3.0° C. This virtually eliminates the possibility of 10° to 20° C warming from doubled CO_2.

The third premise is false. The so-called probabilities provided by the 22 studies reported by the IPCC (2007), and on which Weitzman based his calculations, are determined solely from computer models, beginning with models used to develop the emission scenarios and then the global circulation models (GCMs) that provide projections of associated future climate scenarios. These are not probabilities in the classical sense—based on repeated observations, as in the case of a fair coin toss yielding a 50% probability that the coin comes up tails. The future level of warming is not a matter of chance but of physics. It *will* turn out only one way, and it will be the feedbacks that largely determine that. As climatologist Roy Spencer explains, the use of statistical probabilities implies that the climate system's response to any change is a roll of the dice. It is not. Unlike rolling dice, outcomes in the climate system are not random events. There is instead a real climate sensitivity in the real climate system. Worse, Weitzman's ad hoc metaanalysis both confuses peer-reviewed scientific publications with climate-system processes and treats them, too, as random events. But even if 99 papers claim the climate system is very sensitive and only one says it is not, that does not mean there is a 99% chance that the climate system is very sensitive. Often a single research paper overturns what most scientists thought they knew. Even assuming (wrongly) that scientific publications were random events would only imply a 99% chance that the next paper would espouse high sensitivity. Since in climate research those 99 papers typically all make the same assumptions, they are nearly guaranteed to reach the same conclusions. Hence, they are not independent pieces of evidence. They are evidence of group think in the climate-science community (Spencer 2009b).

Properly speaking, probability theory cannot be applied meaningfully to climate projections. Weitzman's exercise is nothing more than a scientific-sounding way to express his level of faith.

Finally, the "fat tails" argument (low probability of infinitely disastrous consequences) fails to acknowledge "fat tails" at the other end. If a temperature increase of 10° C or more is a disaster, what about a fall in average global temperature of 10° C or more? Geologic history tells us that this is possible, and if enhanced atmospheric CO_2 could mitigate a possible new ice age, that would surely be good. It seems convoluted to be concerned about one side of the probability distribution but not the other.

In short, Weitzman's case for massive spending to fight global warming on the basis of "fat tail" probability analysis fails.

FROM THEORY TO POLICY

Despite its profound economic disadvantages (discussed below) when compared with alternative policies to reduce carbon emission, "cap and trade" has dominated the public policy discussion since at least the early 1990s. Cap-and-trade policies differ in their details, but all center on the concept of imposing limits (or "caps") on carbon emissions and allowing entities (whether companies, countries, or even states and other localities) to "trade" unused allocations. Under a national cap-and-trade scheme, for example, a company that emits less CO_2 than it is entitled to could sell its unused allocations to another, more carbon-intensive company, on a carbon trading market. Subsequent to the ratification of Kyoto Protocol (1994), carbon markets have been set up in Europe and elsewhere. President Clinton refused to submit the Kyoto Protocol to the U.S. Senate for treaty ratification; in fact, the Senate voted 98-0 in favor of a resolution condemning the Protocol for not including binding limits on emerging economies. A 2007 attempt to pass a cap-and-trade bill died in the Senate.

Fifteen years after the ratification of the Kyoto Protocol, the U.S. House of Representatives in July 2009 narrowly passed the American Clean Energy and Security Act (also known as Waxman-Markey), which purported to reduce American CO_2 emissions by 17% (from the 2005 level) by 2020 and by 83% by 2050. Although subsequent policy proposals will undoubtedly differ in their details and impacts, our quantitative analysis focuses on the Waxman-Markey bill for sake of illustration. Similar policy proposals are likely to have similarly costly economic impacts, and further political horse-trading seems unlikely to benefit consumers or tax-payers. As one study of the Waxman-Markey bill put it, "the economic impact estimates reported here will likely be lower than the economic cost of cap and trade hobbled further by mandates" (Beach et al. 2009b).

A Case Study: Waxman-Markey

The central feature of the Waxman-Markey bill is a cap-and-trade scheme that would require firms to purchase permits to emit CO_2 (and other GHGs). Covered firms (about 7,400) would receive 4.627 billion allowances in 2012 and as few as 1.035 billion in 2050, with each allowance permitting one metric ton of CO_2 emissions. Interestingly, 29.6% of allowances will be auctioned off in the first two years, 2012-2013, thereby raising $846 billion in federal revenue—a cost that firms will pass on to consumers. The proportion of allowances auctioned off falls to less than 18% in 2020, rises to 18.4% by 2022, and then gradually rises to about 70% by 2031, where it would remain.[9] In the first few decades, therefore, significant allowances would be grandfathered.

Grandfathering allowances ensures the political support of industry, although there is the notion that, by freely giving allowances to large emitters such as power companies, there will be little immediate impact on output prices. This is misleading. Because allowances have a market value (as they are traded), a company will consider its "freely-allocated" allowances to be an asset whose cost must be covered by revenues. Large industrial emitters could take the "free" asset, sell it, and invest the proceeds in reducing CO_2 emissions. The cost of reducing CO_2 emissions will certainly need to be covered. Consequently, whether they are auctioned or given away (grandfathered), allowances' cost will be reflected in final output prices. Thus, all citizens will face higher costs for energy and everything produced by energy.

Economists do not care in principle whether emission permits are auctioned or given away—the goal is to meet the desired outcome at least cost. But the different methods do result in different distributions of income—different sets of winners and losers. From a theoretical perspective, income inequalities can be adjusted by lump sum transfers, although the potential double dividend is lost under tradable permits instead of a carbon tax, and where such transfers do occur they are somewhat suspect. However, large industrial firms strongly favor climate mitigation schemes that give them free emission allowances. The financial gains can be enormous, with taxpayers and consumers footing the bill. Financial institutions such as Morgan Stanley, Goldman Sachs, and JP Morgan-Chase, and well-placed individuals like Al Gore (Solomon 2009), eagerly savor the

[9] This information is based on a report by the Congressional Budget Office and Congressional Joint Committee on Taxation, as reported by Amanda DeBard (CBO: House climate bill to raise $973B, Washington Post Monday, June 8, 2009) and available at: http://washingtontimes.com/news/2009/jun/08/cbo-house-climate-bill-raise-973b/, viewed June 11, 2009 . See also Congressional Budget Office (2009a).

opportunities afforded by carbon trading; after all, carbon is forecast to become the largest commodity traded in the world, with a trading value estimated to reach $3 trillion by 2020.[10] No wonder large financial institutions lobby governments to employ permit trading instead of carbon taxes—this has the makings to be the next crisis with huge amounts of money to be made before the bubble bursts.

Unfortunately, in addition to enabling large companies to gain at everyone's expense, politicians also introduce subsidies, regulations, and provisions that lead to inefficiency—that actually increase the costs of meeting emission targets. Waxman-Markey, for example, comes laden with regulations and provisions that make achieving targets much more expensive than would be the case with a carbon tax or even emissions trading; lock the economy into potentially inefficient investments; and make it much less likely that targets will be met. For example, there are mandated biofuel targets, with subsidies to farmers for ethanol production. Agricultural economists have long opposed ethanol subsidies because they raise food prices (which harm the least well off in society), intensify crop production (increasing chemical use and machinery operations), distort land use by converting grassland into crop production and forestland into agriculture, reduce the performance of automobiles consuming gasoline with ethanol, provide only questionable climate mitigation benefits, and lock society into facilities that will produce ethanol for many years to come (Morriss et al. 2009, pp.79-89; Searchinger et al. 2008; Klein and LeRoy 2007).

The Costs of Reducing CO_2 Emissions

What will be the cost of Waxman-Markey (or something quite similar)? Low-end estimates come from two government agencies. Based on estimates that allowances for greenhouse gas emissions would start around $13 to $15 per ton of CO_2 in 2010 and increase to $26 in 2019, the Congressional Budget Office (CBO) and Environmental Protection Agency (EPA) estimate that each household will have to pay upwards of $140 (EPA 2009) or $175 (CBO 2009b) per year so that firms can purchase emission allowances. These estimated costs of allowances are low if the European Union's Emissions Trading System (ETS) can be used as a guide, since permits have already traded in the ETS for more than $30 (Ellerman and Joskow 2009). Nevertheless, the CBO expects the annual budgetary cost to U.S. taxpayers of Waxman-Markey to rise from $52 billion in 2012 to over $800 billion by 2020 (CBO 2009a). The EPA projects an increase in consumption expenditures of 18% to 19% between 2010 and 2020.

The optimistic cost estimates provided by the CBO and EPA are misleading, however, because they fail to take into account costs to the economy as a whole. These are difficult to calculate, especially because true economic costs are opportunity costs, which are inherently subjective. But several studies provide some rough calculations. The more realistic forecasts come from two private sources.

First, McKibbin, Wilcoxen and Morris (2009) of the Brookings Institution estimate the costs to consumers of a cap-and-trade scheme that seeks to reduce CO_2 emissions by upwards of 49%, not the more costly 83% of the 2050 Waxman-Markey target. They estimate that cap and trade would lead to a loss in personal consumption of $1 to $2 trillion (about $3,225 to $6,450 per person) in present-value terms. The authors suggest that even an additional 8% cut in CO_2

[10] See Matthew Carr, China, Greenpeace Challenge Kyoto Carbon Trading (Update1). June 19. Available at http://www.bloomberg.com/apps/news?pid=20601080&sid=aLM4otYnvXHQ, viewed August 31, 2009.

emissions would increase costs by 45%. U.S. GDP would be lower by 2.5% in 2050 with cap and trade, and there would be 1.7 million fewer jobs in the average year in the first decade compared to the without-cap-and-trade baseline.

Second, Beach et al. (2009a) of the Heritage Foundation estimate an average annual GDP loss of $393 billion, reaching a high of $662 billion in 2035.[11] Over the period 2012-2035, the accumulated GDP loss is estimated to be $9.4 trillion (in 2009 dollars)—on average, about $1,260 per person per year. It also finds that in the average year there will be 1.1 million fewer jobs compared with the baseline assumptions, and that, by 2035, there would be 2.5 million fewer. Electricity rates are projected to rise by 90%, gasoline prices by 74%, and residential natural gas prices by 55%. The average household's direct energy costs are expected to rise by over $1,200 per year, to which undetermined indirect costs must be added (Beach et al. 2009b).

Although the Heritage and Brookings studies are more thorough than the CBO and EPA studies, none of the studies cited above provides a full economic accounting of costs and benefits. No study attempts to determine the true costs to the U.S. economy using a general equilibrium model that would take into account changes in prices and the economic effects of an increased government role in the economy and subsidies for biofuels, wind energy, and so on. Subsidies and regulations could increase costs significantly. However, one would not expect joblessness to continue for long as, in a well-functioning economy where wages can adjust, wages would fall and more people would be employed. Studies also ignore environmental costs and benefits—costs would increase if lands are converted from forest to cropland, for example, while there might be benefits from reduced consumption of certain automotive fuels. Again, calculating all of these costs and benefits is no easy task.

If we tax CO_2 emissions, whether directly or via cap and trade, we raise the price of energy and so the prices of all things made and transported by energy—which is essentially everything. This is particularly devastating to the poor, for whom energy constitutes a higher proportion of spending than for others. Forcing the poor in the developing world to forgo the use of carbonbased fuels—coal, oil, and natural gas, the cheapest fuels (except nuclear) per kilowatt-hour of energy delivered—means delaying by decades or generations the time when they can afford electricity for their homes and industries, and thus delays for similar periods the time

- when they can refrigerate their food to protect it from spoilage and themselves from undernutrition and the diseases that spoiled food can cause;
- when they can heat their homes with clean electricity rather than by open fires of wood and dried dung, the smoke from which causes respiratory diseases that reduce the amount of work they can do and so reduce their incomes, and kill two to four million every year;
- when they can air condition their homes and so close windows and doors, keeping out insects that spread malaria, dengue fever, and other diseases that kill millions and disable hundreds of millions every year.

And as Bjørn Lomborg put it in *Cool It: The Skeptical Environmentalist's Guide to Global Warming*:

> In the third world, access to fossil fuels is crucial. About 1.6 billion people don't have access to electricity, which seriously impedes development. Two and a half billion people use biomass such as wood, waste, and dung to cook and keep warm. For many Indian

[11] As a reference point, U.S. GDP was $14.4 trillion in 2008.

> women, searching for wood costs three hours each day, as they sometimes walk more than six miles per day. It also causes excess deforestation. About 1.3 million people— mostly women and children—die each year due to heavy indoor-air pollution. A switch from biomass to fossil fuels would dramatically improve 2.5 billion lives; the cost of $1.5 billion annually would be greatly superseded by benefits of about $90 billion. For both the developed and the developing world, a world without fossil fuels in the short or medium term is a lot like a world gone medieval. (Lomborg, 2007a).

Inexpensive fossil fuels contributed enormously to the economic development of the wealthy countries of the world. To demand that poor countries forgo their use is to deprive them of that benefit. It is the demand of wealthy, powerful elites at the expense of the vulnerable poor. It is in effect a regressive tax, since the poor spend a higher proportion of their income on energy than do others. The morality of such is questionable.

Job Creation and Citizens' Willingness to Pay to Mitigate Global Warming

Employment is a controversial element of any government program as politicians are wont to promote job creation as the most essential component of any legislation. As (at this writing) U.S. unemployment tops 10% (with much higher unemployment in several parts of the country), socalled green (or environmentally friendly) jobs have been touted by proponents of action to reduce reliance on fossil fuels. However, an in-depth study by Morriss et al. (2009) that carefully explores what is meant by green jobs indicates that special interest groups have overstated the number of jobs various clean-energy (and other positive environmental) initiatives have created, and questions whether environmental expenditures (such as subsidies to ethanol producers, wind, and solar energy) increase jobs overall. In this regard, a recent study by Álvarez et al. (2009) found that, for every green job created by government investment in Spain's renewable energy sector, 2.2 jobs were lost elsewhere in the economy. Similarly, the claim that electricity from renewable energy creates more jobs per kWh than traditional power generation simply implies "that renewable energy is more costly in labor terms than alternatives—hardly a virtue to anyone asked to pay for the energy produced" (Morriss et al. 2009, p. 44). We could, of course, create millions more jobs by paying people to produce electricity by riding stationary bicycles attached to generators, but the electricity produced would not be worth the time and caloric energy consumed. Creating jobs is not an end to be pursued; it is a means to an end—one that should be minimized, not maximized.

It is also helpful to consider the benefits of spending money on emissions reduction, and whether citizens are prepared to pay for climate mitigation efforts. The benefits of climate change mitigation brought about by U.S. action are minuscule. They amount to a reduction of perhaps 0.20° C in the projected temperature increase in 2100 if Waxman-Markey is fully implemented, and only slightly more if all wealthy nations follow suit—and this assumes climate sensitivity at the midrange estimate of the IPCC, though more recent studies point to an increase of only one-sixth that amount (Schwartz 2007; Spencer et al. 2007; Spencer and Braswell 2008; Spencer 2008; Lindzen and Choi 2009), which would entail an insignificant temperature reduction of 0.03° C instead. The problem is that developing countries, particularly China and India, are not about to restrain their development simply because wealthy countries are concerned about an environmental problem that ranks at the bottom of their list of priorities (see Lomborg 2004, 2007b).[12] With AIDS

[12] From U.S. Senate hearings on July 7, 2009, it is clear that Waxman-Markey will have no effect on climate unless both China and India reduce their CO_2 emissions. See

killing more than two million people annually in Africa, and worldwide more than four million children dying of respiratory infections, diarrhea, and malaria each year, global warming is mainly a concern of the rich (e.g., Lomborg 2004).

Next consider citizen willingness to pay and a poll conducted on behalf of *The Economist* (Economist, 2009). Forty-one percent of those polled called climate change a "very serious" problem with 28% calling it "somewhat serious." For comparison, 57% of respondents thought it was a "very serious" problem that many Americans do not have health insurance, while a further 27% rated this "somewhat serious." When asked to choose between passing health care legislation or legislation to address global warming, 61% chose health care reform ahead of global warming, with only 16% considering global warming more important; the remaining 23% were "not sure." Finally, Americans tended to favor legislation to reduce CO_2 emissions only as long as it did not cost much. When costs reached even the low Congressional Budget Office (2009b) estimate of $175 per household per year, the majority (53%) was opposed, while only 30% favored the bill (see Figure 1). Needless to say, costs of mitigating climate change are very likely going to be vastly greater than this.

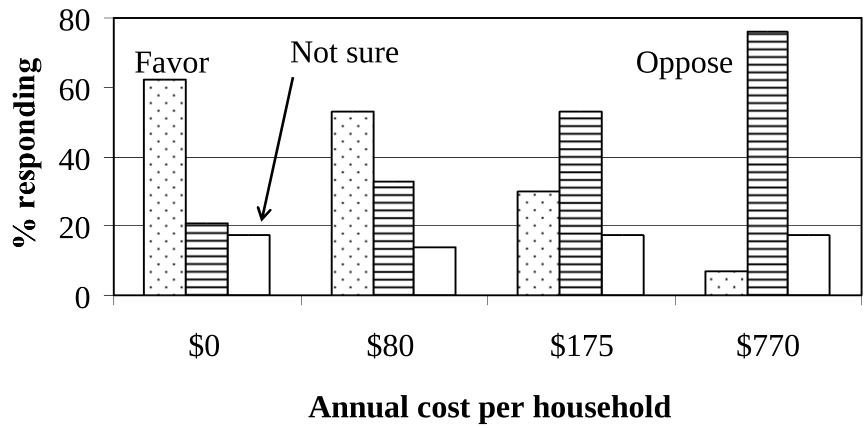

Figure 1: Respondents' willingness to pay to mitigate climate change

Carbon Taxes vs. Emissions Trading

From an economist's perspective, it is disconcerting, though from a politician's perspective it is unsurprising, that governments have eschewed a carbon tax in favor of emissions trading. A carbon tax is a straightforward instrument that can be adjusted to the actual severity of observed climate change damages, with revenues used to improve economic performance elsewhere in the economy (resulting in a double dividend) and to fund R&D for addressing climate and other challenges. In this regard, McKitrick (2007) proposes a tax based on actual temperatures in the tropical troposphere, which is where an early and strong signal of anthropogenic warming not affected by solar activity is predicted to occur (CCSP 2006, ch. 5). The tax would be based on temperature data from satellites. According to McKitrick, if the tax were set at twenty times the three-year moving average of mean tropical troposphere temperature anomalies, it would amount in 2005 to about $4.70 per ton of CO_2. If IPCC projections of global warming are correct, the tax

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http://epw.senate.gov/public/index.cfm?FuseAction=Minority.PressReleases&ContentRecord_id=564ed42f-802a23ad-4570-3399477b1393, viewed July 9, 2009.

would rise aggressively to some $200 per ton by the end of this century. If global warming is truly a dire threat, the rising tax would bring about the desired changes in anthropogenic emissions or the R&D needed to remove CO_2 from the atmosphere, or both. McKitrick's tax plan is unambiguous, not dependent on controversies surrounding temperature increases projected from climate models and economic analyses mired in similar assumptions, and could be adopted globally with relative ease and transparency.

In contrast, emissions trading is fraught with political maneuvering, corruption, questionable offset credits, high monitoring costs because of the variety of offsets already appearing in carbon markets, lack of revenue recycling (no double dividend), and difficulties in bringing all countries into the scheme. Political maneuvering is readily evident in current and pending policy proposals: Waxman-Markey would delay much of the economic pain until 2020 (well after most politicians who vote for it will be serving),[13] and large emitters would be granted an enormous windfall in the form of free credits. Yet, the emission credits have value that constitutes an expense to be charged to consumers, much like a tax. In essence, therefore, large industrial emitters (instead of government), would indirectly tax energy consumers, while large financial firms reap huge benefits as intermediaries in carbon trading. Again, it is little wonder that large firms not only favor cap-and-trade schemes, but actually lobby for them. No wonder, then, that large industrial emitters and oil companies have switched from opposing to supporting cap and trade. Large companies stand to make a handsome profit from an emissions trading scheme that would be difficult to end even if the data were to indicate that a more prudent approach would be wiser.

DEVELOPMENT, ENERGY GROWTH, AND CLIMATE CHANGE

While good governance (low corruption, effective rule of law, etc.) is crucial to economic growth, economic development cannot occur without expanding energy use (Smil 2003). All modern societies depend on massive and uninterrupted flows of energy. In the developing world, increased energy production is an absolute prerequisite for reducing poverty. In this section, we briefly consider the alternatives to fossil fuels and increased emissions of CO_2.

The tremendous strides in human progress since the Industrial Revolution have been made possible by our ability to harness fossil fuel energy. By replacing animal and human muscle power and low-density, high-pollution fuels like wood, peat, and dung, we have liberated billions from crushing poverty and short lives characterized by toil.

Over the next fifty years, the world's developing nations will seek to emulate the West's material success, as acknowledged in the IPCC's emissions scenarios. Their leaders know that improving their citizens' quality of life (including the most basic measures: health and life expectancy) requires more, not less, energy consumption. Fossil fuels are currently the choice to meet this growing demand, because they are easily storable, have high energy densities, provide reliable generation, and are cheap. Coal-fired generating stations operate with high load factors of about 75% or more over a year, and nuclear plants above 90%. In contrast, wind and solar are intermittent and hence cannot deliver power consistently. Annual load factors of wind generation

[13] Interestingly, similar ten-year delays appear elsewhere. The Kyoto Protocol, ratified in 1997, did not take effect until 2008. In the 2008 speech in which he famously challenged the country to achieve carbon-neutral energy generation in one decade, Al Gore noted this political reality indirectly: "Ten years is about the maximum time that we as a nation can hold a steady aim and hit our target."

in Denmark, Germany, and Spain are 20% to 25% (often lower), meaning the wind turbines sit idle for the equivalent of 270 to 290 days per year.

Some people presume that affordable renewable energy sources will soon displace fossil fuels. But absent subsidies, low-carbon energy technologies advance only when they are cheaper than fossil fuels. With the exception of natural gas (the proven reserves of which have risen significantly in the past several years due to new technologies),[14] the popular alternatives to coal, petroleum, and nuclear (e.g., wind and solar) are too expensive and limited by geography.

The U.S. consumes about 100 quadrillion BTUs of thermal energy per year. Electricity generation accounts for about 40% of this. Currently we meet this demand with coal (49%), natural gas (21%), and uranium (20%). Hydropower provides 5%, and all other renewables (mainly biomass) together account for only 2.5%.

In all modern economies, electricity does the vast majority of the heavy lifting. Because of their low cost, ability to generate power without interruption, and the relative speed at which they can be scaled up to meet spikes in demand, fossil and nuclear fuels dominate generation. Displacing them requires that any alternative energy source be storable and reliable. As Richard Feynman said, "For a successful technology, reality must take precedence over public relations, for nature cannot be fooled" (Feynman 1986).

Electricity has met almost all of the growth in U.S. energy demand since the 1980s. This is not surprising, since about 60% of our GDP comes from industries and services that rely primarily on electricity to produce or power their products. (In 1950, the figure was only 20%.) Demand for electricity is projected to continue to grow and will do so especially rapidly if plugin hybrid or electric-only vehicles become more common.

By 2030, global energy use is expected to increase by some 150% of that in 2005. This will require the equivalent of one new 1,000 megawatt (MW) power generating plant coming on line every day for the next twenty years just to satisfy growth in electricity demand (Duderstadt et al. 2009, p. 9). The majority of growth in energy use will come in developing countries, especially China and India, which together account for about one-third of the world's population. Developing countries can be expected to continue to strongly resist attempts by wealthy countries to significantly reign in developing countries' economic growth for the purpose of mitigating climate change, although they will welcome wealthy-country subsidies (including technology transfers) for clean and renewable energy. Energy policies that reduce rates of economic growth in developing countries will simply perpetuate the misery of millions of people who live in poverty. While clean and renewable energy sources can contribute to the energy needs of developing nations, economic growth will depend primarily on traditional sources of energy, such as coal, oil, and increasingly natural gas, because they are relatively cheap and ubiquitous.

Alternative Fuels and Renewable Energy Sources

So what role will renewable energy sources play? Are solar and wind viable alternatives? Both have the potential to generate vast amounts of carbon-free, clean energy, but currently they contribute less than 0.1% of total U.S. energy consumption. What is their future?

Renewable sources of energy include large-scale hydro, small-scale run-of-river hydro (a modern version of the water wheel), wind, tidal, solar, wave, municipal solid wastes, biomass for

[14] Natural gas reserves are now sufficient to provide energy for 60 years or more, but CO_2 is often released during extraction.

the generation of electricity and space heating, and biofuels (ethanol and biodiesel) for transportation.[15] Some of these sources are severely constrained.

Biomass and Biofuels

While there has been a great deal of emphasis on the use of terrestrial carbon sinks for reducing atmospheric concentrations of CO_2, and even offsetting fossil fuel emissions, the costs of sequestering carbon in agricultural and forest ecosystems are generally quite a bit higher than emission-reduction options (Manley et al. 2005; van Kooten et al. 2004, 2009). There are some fundamental problems with the use of terrestrial sinks that make them a very dubious means of mitigating climate change; these include their ephemeral nature, high monitoring and transaction costs in establishing CO_2 baselines and flux, and potential for corruption (van Kooten 2009a, 2009b).[16]

Current policies to mitigate climate change have focused on the potential of using biomass to generate electricity or as a liquid fuel instead of gasoline. Increasing electrical power production from waste biomass is constrained by high transportation costs, competition by other potential uses for biomass, and in some cases toxic wastes (Stennes et al. 2009; Niquidet et al. 2009). Ethanol is made from corn, biodiesel from other grains, and cellulosic ethanol from crop residues, switchgrass, willow, or hybrid poplar.

One problem with biofuels is that they are not neutral with respect to GHG emissions; CO_2 is released whenever biofuels are burned, and often more CO_2 is released to generate the same amount of energy compared with fossil fuels. The biomass needs to be harvested, transported and processed, which contributes to CO_2 emissions. Only the growth of plants and trees removes CO_2 from the atmosphere, and such growth takes time—a lot in some regions—and inputs of chemical fertilizers (whose production, transport, and application also release GHGs). While ethanol can be burned in place of gasoline, its energy content is only about two-thirds that of gasoline. Further, compared to fossil fuels, the growth and processing of energy crops requires enormous amounts of land and water, some of the latter coming from non-renewable aquifers (Bryce 2008, pp. 183, 191). Finally, increased demand for energy crops (especially for production of biofuels) reduces cultivated area devoted to food production and so raises food prices (Searchinger et al. 2008), and may convert natural habitat to cropland, which can jeopardize biodiversity (Grunwald, 2008; von Braun, Joachim, 2008).

From a policy perspective, therefore, biological methods are not an efficient means of addressing climate change, although research into various biological organisms that make this process more efficient is ongoing. In essence, the only real options are to conserve energy or turn

[15] Unless otherwise indicated, much of the material for this section comes from graduate student research, seminars and discussions at the University of Victoria's Institute for Integrated Energy Systems (http://www.iesvic.uvic.ca/).

[16] Carbon capture and storage is ignored here because it is extremely expensive, is still a long way from being technically feasible on a large scale, and has one crucial safety problem. There is always a risk that captured CO_2 is released, which could potentially lead to large loss of life, as when an underwater landslide in 1986 naturally "burped" a large mass of CO_2 from Lake Nyos in Cameroon, forming a low-lying cloud that suffocated over 1,700 people, thousands of livestock, and all other air breathing animals it covered before it dispersed (Stager 1987). Unless carbon storage occurs in remote regions, which increases its costs, people would need to be compensated for the risk of living in close proximity to a storage facility. Research pertaining to the transportation and storage of nuclear wastes (by comparison minute by volume and much less transient) indicates that this could be an enormous cost (see Riddell and Shaw 2003).

to alternative renewable or nuclear fuels. Landfill gas generated from solid waste is a potential source of electricity, but even if it is employed on a large scale, its contribution to the globe's electricity needs would be extremely small. The same holds for the incineration of municipal wastes.

Hydro, Tidal, and Wave

Large-scale hydro remains one of the best options for generating electricity, but its main drawbacks relate to inadequate runoff for power generation (especially in regions where water availability is inadequate, intermittent, or unreliable) and negative environmental externalities (changes in the aquatic ecosystem, impediments to fish migration, land inundation by reservoirs, etc.). Environmentalists oppose large-scale hydro development, particularly in developing countries, because of the ecological damage it causes, while even small-scale, run-of-river projects have been opposed in wealthy countries on environmental grounds, and their overall generating capacity will inevitably remain limited in scope.

Tidal and wave energy are also promising. Tidal energy is considered particularly desirable because of its regularity and predictability. While some tidal barrage systems are in place and experiments are underway with tidal turbines (which function much like wind turbines), huge technological and cost obstacles still need to be overcome. This is even more the case for wave energy conversion systems, which simultaneously suffer from unpredictability and intermittency. For both wave and tidal systems, costs of transmission lines can be prohibitive.

Solar

There are two types of solar energy: Solar photovoltaic (PV) converts the sun's energy directly into electricity, and solar heaters warm water (swimming pools, water tanks, etc.). Solar heaters convert up to 60% of the sun's energy into heat, while PV cells convert only 12% to 15% of the energy into electricity, although PV laboratory prototypes are reaching 30% efficiency.

One problem with solar electricity is its prohibitive capital costs, which amount to some $13,000 to $15,000 per kilowatt (kW) of installed capacity (van Kooten and Timilsina 2009).[17]This would amount to roughly $14 billion for each 1,000 megawatt generating plant, or, assuming that one plant of such capacity is added to world production each day, about $5 trillion ($\$5\times10^{12}$)—about one-twelfth of gross world product—per year. In addition, solar power is intermittent (e.g., output is greatly reduced on cloudy days), unavailable at night, and, in high latitudes, less available in winter when demand is high than in summer (due to shorter days). For remote locations that receive plenty of sunshine and are not connected to an electrical grid, avoiding the costs of constructing transmission lines to bring in outside power might make solar PV and solar heaters a viable option, but likely only on a small scale.

Wind

Given the drawbacks of many other renewable sources of energy, wind appears to be the renewable alternative of choice when it comes to generating electricity. As a result, global wind generating capacity has expanded rapidly from only 10 megawatts (MW) of installed capacity in 1980 to more than 100,000 MW by the end of 2008.

However, the euphoria about wind energy needs to be accompanied by a realistic view of its potential contribution to a future energy economy. First, it is unlikely that, even under the most

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[17] Kilo is abbreviated with k and equals 10^3; Mega (M, 10^6); Giga (G, 10^9); Tera (T, 10^{12}).

optimistic estimates, wind will account for more than 5% of total global electricity production (van Kooten and Timilsina 2009). Second, wind energy requires storage, is unreliable, costly to install, a noise nuisance, harmful to wildlife, visually unattractive, and, above all, destabilizing to electrical grids. Wind turbines only produce about one-fifth of their rated output because of vagaries in wind, while attempts to reduce intermittency by scattering wind farms across a large geographic area and integrating wind power into a "super grid" have not overcome the grid instability that occurs when wind provides about 30% of the electricity fed into a grid.[18,19] Even adding a more stable renewable source, such as tidal power, does little to address the problem of intermittency (Monahan et al. 2008).

Nuclear

It is clear to us that the greenhouse gas emission reduction targets proposed by the developing countries and by the U.S. Congress cannot be achieved without nuclear energy, which is why many other scientists favor it (see Scott 2007). It is also why the prominent environmentalist responsible for the Gaia Hypothesis, James Lovelock, initially came out in support of nuclear energy, though he subsequently backed away from it (and any renewable solution to global warming), arguing instead that the human population needs to be drastically curtailed (Lovelock 2009). Greenpeace co-founder Patrick Moore remains an enthusiastic supporter of nuclear power.

There are now 439 nuclear reactors in operation worldwide, meeting the power needs of more than a billion people. Thirty-four are under construction in 14 countries (none in the U.S.). In 2007, France got 77% of its power from nuclear; Lithuania 64%; Belgium 54%; Sweden 46%; Switzerland 40%; Japan 35%; Germany 26%; the U.S. 20%; the United Kingdom 19%; and Spain 17%. However, any attempt to increase reliance on nuclear energy and other non-carbon sources of energy, or to increase conservation of energy, will require huge investments in R&D. Yet, in the United States, for example, energy output is $1.27 trillion annually, but R&D spending is only $3.8 billion, of which the U.S. government supplies $1.4 billion. Government spending on energy R&D is only one-fifth of what it was in the 1970s and 1980s, and well below the $20 to $30 billion annually recommended by the Brookings Institution (Duderstadt et al. 2009).

Many people fear that nuclear energy is unsafe. The fears are generally rooted in misunderstanding and misinformation. A nuclear explosion at a power plant is physically impossible—the fuel never approaches the necessary purity, and the extremely complex firing mechanism necessary to trigger a nuclear explosion is absent. Radiation exposure is well below minimum danger levels. Spent fuel can be reprocessed for reuse, and nuclear waste, tiny in volume compared with waste from coal and other energy sources, can be stored safely or used in many industrial and medical applications. Bernard L. Cohen, one of the world's leading experts on nuclear energy, estimates that, even after accounting for all the challenges of waste disposal, the number of deaths per 1,000 MW plant year over the next 500 years from nuclear wastes is about -0.06. That's right, it's a negative number, because of the health-enhancing effect of lowlevel

[18] Most of these results are based on various modeling exercises (see, e.g., van Kooten 2009c; Prescott and van Kooten 2009; Maddaloni et al. 2008; Lund 2005).

[19] Unless wind power is readily storable behind large hydro dams, wind requires fast-responding, open-cycle (as opposed to base load closed-cycle) gas plants as backup. However, since any wind energy will first displace electricity produced by fast-responding gas (as gas is most expensive), it cannibalizes existing peak load gas capacity and makes investments in such plants less attractive.

radiation exposure.[20] In other words, nuclear waste saves lives. By comparison, wastes from the same capacity coal plant would lead to about 25.6 deaths, and from solar (from coal and, in some uses, cadmium sulfide, used not as fuels but as materials in solar apparatus) 1.6. Even if, from different calculations that Cohen also reports, we assume that for Americans the risk of lost life expectancy from living near a nuclear power plant is about 1/10 of a day, that compares admirably with the risk from eating half a pound of charbroiled steak per week (about 1/3 day), riding a bicycle (six days), drinking water (about 25 days), motor vehicle accidents (about 200 days), being 20% overweight (about 1,000 days), smoking (about 2,300 days), or being an alcoholic (about 4,000 days) (Cohen 1995).

"While one can easily count scores of workers who have been killed in refinery, petrochemical plant, and coal mining operations over the decades," write Alan Herbst and George Hopley, "not a single U.S. nuclear worker has been killed in the workplace or in incidents related to workplace conditions. This is truly an enviable record, a record that the rest of the energy community would like to own" (Herbst and Hopley 2007; on nuclear safety see also Tucker 2008; Cravens 2008).

Cost Comparisons

It is difficult to compare costs of producing electricity from renewable sources with those from traditional sources, but it can be done. Using data from a survey conducted by the International Energy Agency (IEA 2005), it is possible to provide some comparison of costs on a per megawatt hour (MWh) basis. Estimates are provided in Table 3. They indicate that electricity generated from renewable energy sources, including wind, is significantly more expensive than that from traditional sources.

[20] Although radiation treatments to fight cancer are well known, the health-enhancing effect of low-level radiation (such as reduced incidence of cancers in people exposed to low levels of radon gas) is less well known, but it is well established (Tucker, 2008).

Table 3: Index of lifetime generation costs by generating type[21]

Generating Type[22]	Midpoint	Low	High
Waste incineration	1.00	-0.41	5.37
Nuclear	2.70	2.14	7.05
Coal (high quality)	2.80	2.66	7.10
CHP (using coal)	3.43	2.57	4.82
Coal (lignite)	3.45	3.02	6.62
CHP (using other fuel)	3.51	3.02	10.22
Coal (integrated coal gas)	3.93	2.80	6.07
Biomass	4.28	3.83	10.32
Large-scale hydro	4.66	4.66	8.72
Gas (CCGT)	4.80	3.92	6.43
Gas (open)	4.80	4.80	5.03
CHP (using CCGT)	4.84	2.91	8.31
Wind onshore	5.98	3.19	14.81
Wind offshore	6.90	5.19	12.68
Run of river/small hydro	9.51	4.08	24.85
Solar PV	16.88	12.39	192.75
Solar thermal	17.00	17.00	27.67

Waste incineration is the lowest cost means of generating electricity, but only if there is a payment to dispose of municipal and industrial waste (which explains the negative value in the third column, indicating a benefit). Further, because of their relatively small supply, the contribution of wastes to total electricity generation will be small, which is also true of combined heat and power (CHP). Coal and nuclear are the lowest cost realistic alternatives. Gas is more expensive because of high fuel costs, but gas plants are cheap to build and are needed for fast response to shifts in load. At low, mid, and high costs, solar PV and solar thermal run six to 27 times the cost of nuclear and coal and multiples of all other options (except small-scale run-ofriver hydro compared with solar thermal in the high-cost scenario). Wind runs about 1.5 to 2.5 times the cost of nuclear. These cost differences do not account for the problems of intermittency, additional

[21] The costs include capital costs, operating and maintenance costs, and fuel costs over the lifetime of a power generating plant, discounted to the present and "levelized" over the expected output of the generating source over its lifetime. Values are in 2008 US dollars. The midpoint value is based on a 5% discount rate, as is the low value (except in the case of high quality coal); the high value is derived using a 10% discount rate.

[22] Open-cycle gas turbines lose exhaust heat but are therefore able to respond quickly to changes in demand; closed-cycle gas turbines (CCGT) recycle exhaust heat, but this makes such plants suitable for base-load power and more difficult to ramp up and down. Combined heat and power (CHP) occurs when exhaust heat from space heating is used to generate power; such power is usually available at night and in colder climates.

Source: Adapted from van Kooten and Timilsina (2009).

transmission infrastructure, and the need for backup generation with the capacity to scale quickly to meet spikes in demand.

The argument made by proponents of renewable energy generation is that the costs in Table 3 do not reflect externality costs, in particular the costs associated with CO_2 emissions in the case of fossil fuel plants (as other pollutants, such as sulphur dioxide, are now dealt with in the construction of new plants) and the risks to health and safety associated with nuclear power plants. What happens when we account for externalities? Assuming that coal emits 0.9 to 1.0 ton of CO_2 per MWh of electricity (van Kooten 2009c)—an emission level that is dropping as more efficient plants come on line—it would take a carbon tax well above what the EPA envisions (as discussed above) before even wind energy, let alone solar, is competitive with coal, and especially so if the externality costs of wind are taken into account. But there remains another problem: With the exception of biomass and large-scale hydro, only nuclear and closed-cycle gas turbines (CCGT) plants can replace coal because, without storage, intermittent sources of power cannot serve base-load needs (van Kooten 2009c).

CONCLUSION

Despite much heated political rhetoric associated with climate change and GHG emission reduction targets (and acknowledging that some marginal reduction in CO_2 might be attainable), the targets being proposed in the post-Kyoto world (e.g. former Vice President Gore's challenge to abandon fossil fuels by 2017) are simply not rooted in reality. Economists deal with reality, and the reality is that:

- Developed countries have been unable to achieve the 6% reductions in CO_2 emissions from 1990 levels, targeted by the Kyoto Protocol, targets much easier than the 17% to 20% reductions by 2020 and 83% reductions by 2050 in current and pending legislation and treaties.
- Unless energy production is drastically curtailed or there is a huge immediate investment in nuclear energy, or both, the tougher targets required (according to proponents) to forestall allegedly dangerous, anthropogenic global warming cannot possibly be met. Meanwhile, subsidies and legislation under consideration will lock several generations into energy systems that are detrimental to their interests and harmful to the least well off.
- If access to affordable energy is curtailed, economic development in places such as Africa and India will be set back; however, if access to affordable energy is curtailed only in wealthy countries, developing countries will benefit (as the prices they face fall and as industry shifts to less regulated countries), but CO_2 emissions will increase all the more, along with increased air and water pollution as companies, fleeing high CO_2 emissions taxes, relocate to countries with less stringent pollution control laws. Without curtailment of CO_2 emissions in developing countries, any efforts to do so in developed countries will, at best, have very little impact (and may well have large, negative impact) on the climate change expected based on IPCC predictions.
- People are not willing to pay the high price needed to reduce greenhouse gas emissions to the degree advocated by believers in dangerous anthropogenic global warming (DAGW), which is why democratically elected politicians have tended to postpone the future pain of global warming policies beyond the point—usually about a decade—when current politicians will pay a political price. This may also serve to explain why politicians

generally favor bureaucratically complex methods (like cap and trade) to relatively transparent, and therefore economically preferable, options like a carbon tax.

Despite the arguments made in the Science and Theology chapters—that DAGW reflects neither settled science nor a sound Biblical worldview—and accepting, for the sake of argument, that anthropogenic global warming is significant and potentially dangerous, we nevertheless conclude, in agreement with Nobel-winning economists (e.g. Lomborg 2004, 2007b) that:

(a) Policies requiring drastic reductions in carbon dioxide emissions are unrealistic and threaten human well-being, especially in developing countries, where, by curtailing use of the most abundant, reliable, and affordable energy sources, they would prolong abject poverty and the miseries of toil, disease, and premature death that accompany it.

(b) The worst sort of emissions reduction policy is cap and trade; the least bad (but still not good) is a carbon tax indexed to a reliable temperature index.

(c) The most scientifically, economically, and ethically defensible policy response to alleged dangerous anthropogenic global warming is to promote economic development, especially for the world's poor, through policies that ensure abundant and affordable energy, on the one hand, and reduce specific risks from which the poor suffer regardless of climate change (e.g., under-nutrition and malnutrition; waterborne, pest-borne, and communicable diseases; depressed income because of tariffs, trade restrictions, and corrupt governments; high rates of accidental injury and death because of poor transport and industry infrastructure), on the other hand.

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REFERENCES

Álvarez, Gabriel Calzada, Raquel Merino Jara, Juan Ramón Rallo Julián, and José Ignacio García Bielsa, 2009. "Study of the Effects on Employment of Public Aid to Renewable Energy Sources. Lessons from the Spanish Renewables Bubble." Borrador Draft. March. Madrid: Universidad Rey Juan Carlos. Available at http://www.juandemariana.org/pdf/090327-employment-public-aid-renewable.pdf, accessed August 11, 2009.

Barret, Scott, 2009. "The Coming Global Climate-Technology Revolution," *Journal of Economic Perspectives* 23(2): 53-75.

Barret, Scott, 2008. "The Incredible Economics of Geoengineering," *Environmental and Resource Economics* 39(1): 45-54.

Beach, William W., David W. Kreutzer, Karen A. Campbell, and Ben Lieberman, 2009a. "The Economic Impact of Waxman–Markey," Heritage Foundation WebMemo No. 2438. May 13. Available at http://www.heritage.org/Research/energyandenvironment/wm2438.cfm, accessed November 9, 2009.

Beach, William W., David W. Kreutzer, Karen A. Campbell, and Ben Lieberman, 2009b. "Son of Waxman-Markey: More Politics Makes for a More Costly Bill." Heritage Foundation WebMemo No. 2450. May 18. Available at http://www.heritage.org/research/energyandenvironment/wm2450.cfm, accessed November 9, 2009.

Beisner, E. Calvin, 2001. *Prosperity and Poverty: The Compassionate Use of Resources in a World of Scarcity*. Eugene, OR: Wipf & Stock.

Brander, James A. and M. Scott Taylor, 1998. "The Simple Economics of Easter Island: A Ricardo-Malthus Model of Renewable Resource Use," *American Economic Review* 88(1): 119-138.

Bryce, Robert, 2008. *Gusher of Lies: The Dangerous Delusions of Energy Independence.* New York: Public Affairs.

Bovenberg, A. Lans and Lawrence H. Goulder, 1996. "Optimal Environmental Taxation in the Presence of other Taxes: General-Equilibrium Analysis," *American Economic Review* 86(4): 985–1000.

Byatt, Ian, Ian Castles, Indur M. Goklany, David Henderson, Nigel Lawson, Ross McKitrick, Julian Morris, Alan Peacock, Colin Robinson, and Robert Skidelsky, 2006. "The Stern Review: A Dual Critique, Part II: Economic Aspects," *World Economics* 7 (4): 199-224. Available at http://www.katewerk.com/temp/sda_WE.pdf, accessed October 20, 2009.

Chesterton, G. K., 2001. *Orthodoxy*. Colorado Springs, CO: Harold Shaw Press.

CCSP, 2006. *Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences.* A Report By the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Thomas R. Karl, Susan J. Hassol, Christopher D. Miller, and William L. Murray, (eds.)]. Washington, DC. Available at http://www.climatescience.gov/Library/sap/sap1-1/finalreport/, accessed November 9, 2009.

Chafuen, Alejandro, 2003. *Faith and Liberty: The Economic Thought of the Late Scholastics*, 2d ed. Lanham, MD: Lexington Books.

Cline, William R., 2007. *Global Warming and Agriculture: Impact Estimates by Country*. Washington, DC: Center for Global Development and Peterson Institute for International Economics. Available at http://www.cgdev.org/content/publications/detail/14090#Chpt, accessed November 9, 2009.

Cohen, Bernard L., 1995. "The Hazards of Nuclear Power," in *The State of Humanity*, edited by Julian L. Simon et al. Cambridge, MA: Blackwell Publishers.

Congressional Budget Office, 2009a. "Cost Estimate: H.R. 2454 American Clean Energy and Security Act of 2009." June 5. Available at http://www.cbo.gov/ftpdocs/102xx/doc10262/hr2454.pdf, accessed November 9, 2009.

Congressional Budget Office, 2009b. "The Estimated Costs to Households from H.R. 2454 American Clean Energy and Security Act of 2009." June 19. Available at http://www.cbo.gov/ftpdocs/103xx/doc10327/06-19-CapAndTradeCosts.pdf, accessed August 6, 2009.

Cravens, Gwyneth, 2008. *Power to Save the World: The Truth About Nuclear Energy*. Reprint edition. New York: Vintage.

Darwin, R., M. Tsigas, J. Lewandrowski, and A. Raneses, 1995. "World Agriculture and Climate Change: Economic Adaptations," AE Report No. 703, US Department of Agriculture, Economic Research Service, Washington DC. June. Available at http://www.ers.usda.gov/publications/aer703/aer703.pdf, accessed November 9, 2009. Diamond, J., 2005. *Collapse*. New York: Viking.

Diamond, J., 1997. *Guns, Germs, and Steel*. New York: W.W. Norton.

Dieter, Lüthi, Martine Le Floch, Bernhard Bereiter, Thomas Blunier, Jean-Marc Barnola, Urs Siegenthaler, Dominique Raynaud, Jean Jouzel, Hubertus Fischer, Kenji Kawamura, and Thomas F. Stocker, 2008. "High-resolution Carbon Dioxide Concentration Record 650,000800,000 Years before Present," *Nature* 453 (15 May): 379-382.

Duderstadt, James, Gary Was, Robert McGrath, Mark Muro, Michael Corradini, Linda Katehi, Rick Shangraw, and Andrea Sarzynski, 2009. "Energy Discovery-Innovation Institutes: A Step toward America's Energy Sustainability." Washington: Brookings. Available at http://www.brookings.edu/~/media/Files/rc/reports/2009/0209_energy_innovation_muro/0209_energy_innovation_muro_full.pdf, accessed November 9, 2009. *Economist*, 2009. "The Economist/YouGov Poll." Available at http://media.economist.com/media/pdf/Toplines20090701.pdf, accessed November 25, 2009.

Ellerman, A. Denny and Paul L. Joskow, 2009. "The European Union's Emissions Trading System in Perspective. Arlington, VA: PEW Center on Global Climate Change." May 10. Available at http://www.pewclimate.org/eu-ets, accessed August 10, 2009.

Fagan, Briam M., 2008. *The Great Warming: Climate Change and the Rise and Fall of Civilizations*. New York: Bloomsbury Press.

Fagan, Brian M., 2000. *The Little Ice Age. How Climate Made History 1300-1850*. New York: Basic Books.

Feynman, Richard, 1986. "Personal Observations on Reliability of Shuttle," vol. 2, appendix F of *Report of the Presidential Commission on the Space Shuttle Challenger Accident*. Available at http://history.nasa.gov/rogersrep/v2appf.htm, accessed October 20, 2009.

Goklany, Indur M., 2009. "Is Climate Change the 'Defining Challenge of Our Age?'" *Energy & Environment* 20(3): 279-302.

Gould, Stephen J., 1999. *Rocks of Ages: Science and Religion in the Fullness of Life*. New York: Ballantine.

Grunwald, Michael, 2008. "The Clean Energy Scam," *Time*. Available at http://www.time.com/time/printout/0,8816,1725975,00.html, accessed November 25, 2009.

IEA, 2005. *Projected Costs of Generating Electricity* (2005 Update). Nuclear Energy Agency, International Energy Agency, OECD, Paris. Available at http://www.iea.org/textbase/nppdf/free/2005/ElecCost.pdf, accessed November 9, 2009.

IPCC, 2007. *Climate Change 2007. The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

IPCC, 2000. *Special Report on Emissions Scenarios*. Cambridge, UK: Cambridge University Press.

Johnson, Phil and Mike Taylor (eds.), 2009. *Truth Endures: Commemorating Forty Years of Unleashing God's Truth One Verse at a Time, 1969-2009*. Panorama City, CA: Grace to You.

Klaus, Vaclav, 2008. *Blue Planet in Green Shackles: What Is Endangered: Climate or Freedom?* Translated from Czech. Washington: Competitive Enterprise Institute.

Klein, Kurt and Danny G. LeRoy, 2007. *The Biofuels Frenzy: What's In It for Canadian Agriculture?* Lethbridge, AB: Alberta Institute of Agrologists. Available at http://www.aic.ca/whatsnew_docs/Klein%20Final%20%234.pdf, accessed May 8, 2008.

Lindzen, Richard S., and Yong-Sang Choi, 2009 (forthcoming). "On the determination of climate feedbacks from ERBE data," *Geophysical Research Letters*. Available at http://www.leif.org/EOS/2009GL039628-pip.pdf, accessed August 13, 2009.

Lomborg, Bjørn (ed), 2004. *Global Crises, Global Solutions*. Report of the Copenhagen Consensus. Cambridge: Cambridge University Press.

Lomborg, Bjørn, 2007a. *Cool It. The Skeptical Environmentalist's Guide to Global Warming*. New York, NY: Alfred A. Knopf.

Lomborg, Bjørn (ed), 2007b. *Solutions for the World's Biggest Problems: Costs and Benefits*. Report of the Second Copenhagen Consensus. Cambridge: Cambridge University Press.

Lovelock, James R., 2009. *The Vanishing Face of Gaia*. New York: Basic Books.

Lund, Henrick, 2005. "Large-Scale Integration of Wind Power into Different Energy Systems," *Energy* 30(13): 2402-2412.

MacArthur, John F., 1994. *Reckless Faith: When the Church Loses its Will to Discern*. Wheaton, IL: Crossway Books.

Maddaloni, Jesse D., Andrew M. Rowe, and G. Cornelis van Kooten, 2008. "Wind Integration into Various Generation Mixtures," *Renewable Energy* 34(3): 807-814. doi:10.1016/j.renene.2008.04.019.

Manley, James, G. Cornelis van Kooten, Klaus Moeltner, and Dale W. Johnson, 2005. "Creating Carbon Offsets in Agriculture through Zero Tillage: A Meta-Analysis of Costs and Carbon Benefits," *Climatic Change* 68 (January): 41-65.

Mann, Charles C., 2005. *1491 New Revelations of the Americas Before Columbus*. New York: Random House.

Matthews, H. Damon and David W. Keith, 2007. "Carbon-Cycle Feedbacks Increase the Likelihood of a Warmer Future," *Geophysical Research Letters* 34: L09702. doi:10.1029/2006GL028685.

McKibbin, Warwick, Pete Wilcoxen and Adele Morris, 2009. "Consequences of Cap and Trade," Brookings June 8, 2009. Available at http://www.brookings.edu/~/media/Files/events/2009/0608_climate_change_economy/20090608_climate_change_economy.pdf, accessed July 24, 2009.

McKitrick, Ross, 2007. "Why Not Tie Carbon Taxes to Actual Levels of Warming? Both Skeptics and Alarmists Should Expect Their Wishes to be Answered," *Financial Post*, June 12. Available at http://www.uoguelph.ca/~rmckitri/research/T3Tax.NPJune12.pdf, accessed November 9, 2009.

Mendelsohn, Robert O., 2006. "A Critique of the Stern Report," *Regulation* 29(4): 42-46.

Mendelsohn, Robert, Wendy Morrison, Michael E. Schlesinger, and Natalia G. Andronova, 2000. "Country-Specific Market Impacts of Climate Change," *Climatic Change* 45: 553–69.

Mendelsohn, Robert, William D. Nordhaus and D. Shaw, 1994. "The Impact of Global Warming on Agriculture: A Ricardian Approach," *American Economic Review* 84: 753–71.

Monahan, Katherine, Susan Boronowski, and G. Cornelis van Kooten, 2008. "The Economics of Tidal Stream Power." Selected paper presented at the Canadian Economics Association Annual meeting in Vancouver (May) and at the XIIth Congress of the European Association of Agricultural Economists in Ghent, Belgium (September).

Morriss, Andrew P., William T. Bogart, Andrew Dorchak, and Roger E. Meiners, 2000. "Green Jobs Myth." University of Illinois Law and Economics Research Paper Series No. LE09-001. Available at http://ssrn.com/abstract=1358423, accessed August 11, 2009.

Murphy, Robert P., 2009. "Rolling the DICE: William Nordhaus's Dubious Case for a Carbon Tax." *Independent Review*, vol. 14, no. 2 (Fall 2009), 197—217. Available at http://www.independent.org/pdf/tir/tir_14_02_03_murphy.pdf, accessed October 19, 2009.

Niquidet, K., B. Stennes, and G.C. van Kooten, 2009. "Bio-energy from Mountain Pine Beetle Timber and Forest Residuals: The Economics Story." CFS Working Paper. Victoria, BC: Canadian Forest Service. Under review at *Biomass & Bioenergy*.

Nordhaus, William, 2009. "An Analysis of the Dismal Theorem. Cowles Foundation Discussion Paper 1686. Yale University, New Haven, CT." January 16. Available at http://cowles.econ.yale.edu/P/cd/d16b/d1686.pdf, accessed August 20, 2009.

Nordhaus, William, 2008. *A Question of Balance. Weighing the Options on Global Warming Policies*. New Haven, NJ and London, UK: Yale University Press.

Nordhaus, William D., 2007a. "A Review of the *Stern Review on the Economics of Climate Change*," *Journal of Economic Literature* 45: 686-702.

Nordhaus, William, 2007b. Accompanying Notes and Documentation on Development of DICE2007 Model: Notes on DICE-2007.delta.v8 as of September 21, 2007.

Nordhaus, William D., 1994. *Managing the Global Commons: The Economics of Climate Change*. Cambridge, MA: MIT Press.

Nordhaus, William D., 1991. "To Slow or Not to Slow: The Economics of the Greenhouse Effect," *Economic Journal* 101: 920-937.

Novak, Michael, 2000. *The Spirit of Democratic Capitalism.* Lanham, MD: Madison Books.

Prescott, R. and G.C. van Kooten, 2009. "Economic Costs of Managing of an Electricity Grid with Increasing Wind Power Penetration," *Climate Policy* 9(2): 155-168, available at http://www.ingentaconnect.com/content/earthscan/cpol/2009/00000009/00000002/art00003, accessed November 9, 2009.

Riddel, Mary and W. Douglass Shaw, 2003. "Option Wealth and Bequest Values: The Value of Protecting Future Generations from the Health Risks of Nuclear Waste Storage," *Land Economics* 79(4): 537-548.

Rosenberg, Nathan, and L. E. Birdzell, 1987. *How the West Grew Rich: The Economic Transformation of the Industrialized World.* New York: Basic Books.

Schaefer, Henry F., 2003. *Science and Christianity: Conflict or Coherence?* Watkinsville, GA: The Apollos Trust.

Scheffer, Martin, Victor Brovkin, and Peter M. Cox, 2006. "Positive Feedback between Global Warming and Atmospheric CO_2 Concentration Inferred from Past Climate Change," *Geophysical Research Letters* 33: L10702. doi:10.1029/2005GL025044.

Scott, D.S. 2007. *Smelling Land: The Hydrogen Defense Against Climate Catastrophe.* Canadian Hydrogen Association and Natural Resources, Canada, Ottawa, ON: Queen's Printer.

Searchinger, T., R. Heimlich, R.A. Houghton, F. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T. Yu, 2008. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land-use Change," *Science* 319 (February 29): 1238-1240.

Schwartz, S. E., 2007, "Heat Capacity, Time Constant, and Sensitivity of the Earth's Climate System," *Journal of Geophysical Research*, 112, doi:10.1029/2007JD008746. Available at http://www.ecd.bnl.gov/steve/pubs/HeatCapacity.pdf, accessed November 9, 2009.

Smil, V. 2003. *Energy at the Crossroads: Global Perspectives and Uncertainties.* Cambridge, MA: MIT Press.

Sohngen, Brent, Robert Mendelsohn, and Roger Sedjo, 1999. "Forest Management, Conservation, and Global Timber Markets," *American Journal of Agricultural Economics* 81(1): 1-13.

Solomon, Lawrence, 2009. "Carbon Baron Al Gore," *Financial Post*, August 26, 2009. Available at http://network.nationalpost.com/np/blogs/fpcomment/archive/2009/08/25/lawrence-solomoncarbon-baron-gore.aspx, accessed September 1, 2009.

Spencer, Roy W., 2008. "Global Warming as a Natural Response to Cloud Changes Associated with the Pacific Decadal Oscillation (PDO)." Available at http://www.drroyspencer.com/research-articles/global-warming-as-a-natural-response/, accessed August 13, 2009.

Spencer, Roy W., 2009a. "Global Warming Causing Carbon Dioxide Increases: A Simple Model." Available at http://www.drroyspencer.com/2009/05/global-warming-causingcarbon-dioxide-increases-a-simple-model, accessed September 2, 2009.

Spencer, Roy W., 2009b. "The MIT Global Warming Gamble." Available at http://www.drroyspencer.com/2009/05/the-mit-global-warming-gamble/, accessed October 19, 2009.

Spencer, Roy W., and William D. Braswell, 2008. "Potential Biases in Feedback Diagnosis from Observational Data: A Simple Model Demonstration," *Journal of Climate*, February, 56245628. Available at http://www.drroyspencer.com/Spencer-and-Braswell-08.pdf, accessed November 9, 2009.

Spencer, Roy W., William D. Braswell, John R. Christy, and Justin Hnilo, 2007. "Cloud and radiation budget changes associated with tropical intraseasonal oscillations," *Geophysical Research Letters*, vol. 34, L15707. Available at http://www.drroyspencer.com/Spencer_07GRL.pdf, accessed November 9, 2009.

Stager, Curt, 1987. "Silent Death at Cameroon's Killer Lake," *National Geographic*, 172 (3) (September): 404-420.

Stennes, B., K. Niquidet and G.C. van Kooten, 2009. "Implications of Expanding Bioenergy Production from Wood in British Columbia: An Application of a Regional Wood Fibre Allocation Model." CFS Working Paper. Victoria, BC: Canadian Forest Service. Under review at *Forest Science*.

Stern, Nicholas, 2007. *The Economics of Climate Change: The Stern Review*. Cambridge, UK: Cambridge Univ. Press. Available at http://webarchive.nationalarchives.gov.uk/+/http://www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_ index.cfm, accessed November 9, 2009.

Stott, John, 1972 (2006). *Your Mind Matters*. Leicester, UK: Intervarsity Press.

The Economist, 2009. "Thaw Point: Global Warming and the Permafrost," *The Economist*, August 1, p. 70.

Tol, Richard S.J., 2006. "The Stern Review of the Economics of Climate Change: A Comment," *Energy & Environment* 17(6): 977-981.

Tol, Richard S.J., 2005a. "Adaptation and Mitigation: Trade-offs in Substance and Methods," *Environmental Science & Technology* 8: 572-578.

Tol, Richard S.J., 2005b. "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties," *Energy Policy* 33(16): 2064-2074.

Tol, Richard S. J. 2002. "Estimates of Damage Costs of Climate Change," *Environmental and Resource Economics* 21: 47–73.

Torn, Margaret S. and John Harte, 2006. "Missing Feedbacks, Asymmetric Uncertainties, and the Underestimation of Future Warming," *Geophysical Research Letters* 33: L10703. doi:10.1029/2005GL025540.

Tucker, William, 2008. *Terrestrial Energy: How Nuclear Energy Will Lead the Green Revolution and End America's Energy Odyssey*. Savage, MD: Bartleby Press.

U.S. Environmental Protection Agency, 2009. "EPA Preliminary Analysis of the WaxmanMarkey Discussion Draft. April 20. Office of Atmospheric Programs." Available at http://www.epa.gov/climatechange/economics/pdfs/WM-Analysis.pdf, accessed August 10, 2009.

van Kooten, G. Cornelis, 2009a. "Biological Carbon Sequestration and Carbon Trading ReVisited," *Climatic Change* doi: 10.1007/s10584-009-9572-8. In press.

van Kooten, G. Cornelis, 2009b. "Biological Carbon Sinks: Transaction Costs and Governance," *The Forestry Chronicle* 85(3): 372-376.

van Kooten, G. Cornelis, 2009c. "Wind Power: The Economic Impacts of Intermittency." Under review at *Letters in Spatial and Resource Science*.

van Kooten, G. Cornelis, 2004. *Climate Change Economics*. Cheltenham, UK: Edward Elgar.

van Kooten, G. Cornelis and Govinda R. Timilsina, 2009. "Wind Power Development: Economics and Policies. Policy Research Working Paper 4868." Washington, DC: The World Bank, Development Research Group, Environment and Energy Team.

van Kooten, G. Cornelis, Susanna Laaksonen-Craig, and Yichuan Wang, 2009. "A MetaRegression Analysis of Forest Carbon Offset Costs," *Canadian Journal of Forest Research*, in press.

van Kooten, G. Cornelis, Alison J. Eagle, James Manley, and Tara Smolak, 2004. "How Costly Are Carbon Offsets? A Meta-analysis of Carbon Forest Sinks," *Environmental Science & Policy* 7 (August 4): 239-51.

von Braun, Joachim, 2008. "Rising Food Prices: What Should Be Done?" IFPRI (International Food Policy Research Institute) Policy Brief, April. Available at http://documents.wfp.org/stellent/groups/public/documents/resources/wfp175956.pdf, accessed November 25, 2009.

Weitzman, Martin L., 2009a. "On Modeling and Interpreting the Economics of Catastrophic Climate Change," *Review of Economics and Statistics* 91(February): 1-19.

Weitzman, Martin L., 2009b. "Some Basic Economics of Extreme Climate Change." February 19. 29pp. Available at http://www.economics.harvard.edu/faculty/weitzman/papers_weitzman, accessed July 24, 2009.

Weitzman, Martin L., 2009c."Reactions to the Nordhaus Critique." May 17. 18pp. Available at http://www.economics.harvard.edu/faculty/weitzman/papers_weitzman, accessed July 24, 2009.

Weitzman, Martin L., 2009d. "Additive Damages, Fat-tailed Climate Dynamics, and Uncertain Discounting." April 27. 23pp. Available at http://www.economics.harvard.edu/faculty/weitzman/papers_weitzman, accessed July 24, 2009.

Weitzman, Martin L., 1998. "Why the Far-Distant Future Should be Discounted at its Lowest Possible Rate," *Journal of Environmental Economics and Management* 36(3): 201-208.

Weitzman, Martin L., 2007. Review of the *Stern Review on the Economics of Climate Change*, *Journal of Economic Literature* 45: 703-724.