

Solar Photovoltaic Energy for Mitigation of Climate Change: A Catalytic Application of Catholic Social Thought*

Joshua M. Pearce,^a Anna L. Santini,^b and Jennifer M. DeSilva^c

^a *Queen's University*

^b *Pennsylvania State University Pax Christi*

^c *Eastern Connecticut State University*

Abstract

This paper explores an application of Catholic theology to mitigate the current destruction of God's creation underway due to global climate destabilization. Specifically it describes the possibility of the U.S. Catholic Church adopting a systematic plan to catalyze the world energy market to shift to solar photovoltaic energy, a non-polluting renewable energy source. The science behind the ecological crisis and climate change in the context of the Catholic basis for environmental stewardship is summarized to provide a moral foundation for the plan. Then, the viability and ramifications of integrating solar photovoltaic systems in all U.S. Catholic Churches is analyzed from technical, economic, and ethical perspectives.

Keywords

Catholic, energy, environment, solar, stewardship

1. Introduction

Global environmental decline is so pronounced that the late Pope John Paul II described it as an "ecological crisis" (1990). The most serious aspect of this crisis is the destabilization of the earth's climate, which is a direct result of human energy use via the combustion of fossil fuels and the resultant emission of greenhouse gases (The Intergovernmental Panel on

*) The authors would like to thank Rev. Jason A. Glover, Dr. Jennifer K. Bow, and the anonymous reviewers for helpful suggestions with regards to this work.

Climate Change 1995). Modern industrial society, however, is made possible by this energy use. In order to maintain our standard of living and to uplift the standard of living¹ of those in the developing world, while not contributing to global warming and pollution, a large-scale energy alternative to fossil fuels must be developed. The scientific community has recognized that problems of such magnitude, which demand solutions with such a broad perspective, have a spiritual/religious as well as a scientific dimension.² Global climate change challenges fundamental Catholic concepts regarding our stewardship of creation, our membership in the one human family and our responsibility to our descendants to protect our natural and human environments (U.S. Catholic Bishops 2001). In summary, Pope Benedict XVI warned in his address to the Pontifical Academy of the Sciences of the “continuing threats to the environment which are affecting whole peoples, and the urgent need to discover safe, alternative energy sources available to all” (2006).

Solar photovoltaic (or PV) technology, which produces usable energy by directly converting sunlight into electricity, can be the energy source to solve this global problem (Pearce 2002). Although PV energy conversion is a technically-feasible method of providing for the world’s energy needs and mitigating human interference with the climate, the economic costs will be prohibitive until a large-enough demand is mobilized to drive down

¹) It should be noted that the standard of living or more specifically the human development index, which is a measure of wellbeing, has been shown to be proportional to electricity use (Pasternak 2000). Although the amount of energy and electricity used in the U.S. may be excessive, inefficient and wasteful, it is beyond the scope of this paper to argue if the high standard of living as it is practiced within the U.S. is either beneficial for the society as a whole or morally acceptable to the Roman Catholic Church. It can, however, be assumed based on historical precedent that America as a whole and most Americans will continue to increase their energy use (Department of Energy 2008) unless acted on by outside forces. For example, market forces generated by the influence of war, weather, and speculation are a well known to influence consumers energy use, as recently observed with the fluctuations of gasoline prices driving up public transport use (Karush 2008). When the supply of liquid transport fuels cannot meet the demand and the maximum extraction rate per year is reached (e.g. “peak oil”), fossil fuel prices will assist in reducing energy use. Thus environmental, political and economic factors can also influence energy use and thus standard of living.

²) This sentiment was expressed pointedly in an *Open letter to the Religious Community by 32 Internationally Imminent Scientists*, Jan. 1990. Copies available from the National Religious Partnership for the Environment. Also see *Developing Ecological Consciousness* by Chris Uhl (2003) for a detailed look at a scientist’s view of the awakening and caring necessary to follow a path to a sustainable world.

costs with economies of scale (Pearce 2005; 2006). Both industry and government are moving slowly in this direction, but with PV electrical production still making up less than 1% of the total world energy market, a catalyst is needed. The U.S. Catholic Community could be this necessary medium of change.

This paper will explore the possibility of the U.S. Catholic Church adopting a systematic plan to catalyze the world energy market to shift to a non-polluting renewable energy source and dramatically reduce the primary cause of the current, ongoing destruction of God's creation. First, the scientific data detailing the ecological crisis, with particular focus on global climate change will be reviewed. Then the social justice aspects of climate change, our responsibility to future generations, and the Catholic basis for environmental stewardship will be presented. Next, a techno-economic analysis will be made for PV systems as a possible solution to the climate/energy problem. The viability of purchasing such PV systems for all U.S. Catholic Churches will be analyzed from technical, economic, and ethical perspectives. Finally, the benefits and consequences of the Church pursuing such a catalytic action will be summarized, and the world energy policy ramifications will be discussed.

2. The Future of Creation: The Ecological Crisis and Climate Change

Human progress and indiscriminate application of advances in science and technology have led to an ecological crisis—an intolerable negative toll on the life support system of the earth (Pope John Paul II 1990). Over the entire earth, but especially in the most impoverished lands in the developing nations, the land, air, and water is being poisoned by biological, chemical, and radioactive toxins. The list of environmental indicators is sobering: soil is eroding, deserts are spreading, fresh water is diminishing, forests are being destroyed, the ozone layer is thinning, and coral reefs are bleaching. Perhaps the most important indicator of global environmental health is the growing instability observed in the global climate, which is contributing to alarming rates of species extinction, melting ice, rising sea levels, and extreme weather.

The primary cause of climate destabilization is the combustion of fossil fuels (coal, oil, and natural gas) and resultant emissions of carbon dioxide

(CO₂) and other gases that enhance the greenhouse effect. As our fossil-fuel-based energy use increases, we are approaching the physical limits of the planet's ability to adapt to its changing atmospheric chemical composition. The Intergovernmental Panel on Climate Change (IPCC), representing 2,500 scientists from more than 80 countries, analyzed over 20,000 relevant articles to report that while the atmospheric CO₂ concentration has increased by more than 30% to the highest level in 160,000 years, the global mean surface temperatures have increased 0.3-0.6°C since the late 19th century (1995). The IPCC (2001) projected that average global surface air temperatures will heat up by 1.4 to 5.8°C by 2100 relative to 1990 temperatures. The IPCC concluded that human energy use (and thus greenhouse gas emissions) significantly affects the global climate. As we burn more fossil fuels, the temperature will continue to rise. Small changes in temperature can have a large impact on nature—the last Ice Age was only -5°C cooler than today. If the rising CO₂ concentration is sustained, it could produce global warming comparable in magnitude, but opposite in sign, to the global cooling of the last Ice Age (Hoffert and Covey 1992).

Globally, burning fossil fuels releases over 6 gigatons of CO₂ into the atmosphere each year; this release is increasing CO₂ concentrations in the atmosphere, which then leads to further temperature increases. Eventually, humanity must stabilize atmospheric CO₂ concentration in order to prevent further warming of the planet. CO₂ concentration stabilizations of 450, 550, and 650 ppm correspond to global warming over the next 100 years of approximately 1.2°C to 2.3°C, 1.5°C to 2.9°C, and 1.7°C to 3.2°C respectively (Cubash et al. 2001). However, to forestall serious ecological problems like coral reef bleaching, thermohaline circulation shutdown, and a disintegration of the West Antarctic Ice Sheet, global temperatures would need to be limited to 1°C, 2°C, and 3°C respectively (O'Niell and Oppenheimer 2002). Each of these seemingly far removed disasters would result in serious difficulties for humanity as well as nature. As it stands today, if we do nothing, CO₂ concentration will pass 550 ppm this century (Hoffert et al. 2002).

Nowhere is the ecological crisis and climate change ramifications more poignant than their combined effect on species extinction rates. Forests and other habitats have been diminishing at a rate that is causing widespread bio-depletion and extinction of species (McDaniel and Borton 2002).

Climate change will continue to seriously compound this problem. Many species have very narrow ecological niches; location, temperature, and other factors must be just right for them to survive (Bazzaz 1998). As global climate change upsets these sensitive ecosystems, the rate of species extinction has spiked sharply in the last few decades (Wilson 1992; Ayres 2000). According to The World Conservation Union, only a small fraction of the planet's species has been catalogued, yet approximately 34,000 of the known species of plants are now approaching extinction. Utilizing projections of species distributions and abundances for future mid-range climate warming scenarios for 2050, Thomas et al. place lower projections of species extinction between 15% and 37% in the regions they studied (2004). The American Museum of Natural History reported that a large majority of scientists surveyed believe that during the next 30 years, one of every five species alive today will become extinct (1998). The consensus among those who study life is that the fastest mass extinction in the planet's history is underway.

3. The One Human Family, Social Justice, and Climate Change

Although there will be worldwide damage to humanity as a result of continued global climate change, the very poor will suffer disproportionately. Ignoring global warming is ignoring the Christian call to care for "the least of these" (Mt. 25:40, 45).³ Responsible use of natural resources is necessary in order to obey Jesus' teachings to "love your neighbor as yourself" (Mk. 12:30-31) and "Do unto others what you would have them do to you" (Lk. 6:31). Poor individuals and entire developing countries are often without the resources to face the potential impacts of global climate change. In 1991, the U.S. Catholic Bishops stated:

But in most countries today, including our own, it is the poor and the powerless who most directly bear the burden of current environmental carelessness. Their land and neighborhoods are more likely to be polluted or to host toxic waste dumps, their water to be undrinkable, their children to be harmed... Caught in a spiral of poverty and environmental degradation, poor people suffer acutely from the loss of soil fertility, pollution of rivers and urban

³ Biblical quotes taken from: The New American Bible, St. Paul Editions, 1970 Boston, MA.

stretches and the destruction of forest resources. Overcrowding and unequal land distribution often force them to overwork the soil, clear the forests, or migrate to marginal land. Their efforts to eek out a bare existence adds in its own way to environmental degradation and most infrequently to disaster for themselves and others who are equally poor.

The Bishops from the Dominican Episcopal Conference explain further that often those in developing countries are forced to exacerbate environmental conditions because of poverty (1987). As an example they use the destruction of their soil. Since the majority of people living in undeveloped nations lack adequate workable land, agricultural skills, financial means, and basic necessities; they are forced to make intensive use of marginal lands. The poor's inability to proceed with caution or restriction has lead to widespread devastation of vegetation and the soil itself. This makes the poor exceptionally vulnerable to a changing climate that could be devastating even in the countries with the most advanced agricultural systems. The agricultural output in poorer countries will also be hurt by global warming more than anywhere else, putting 80 to 90 million more people at risk of hunger and malnutrition later in the 21st century (Bishops from the Dominican Episcopal Conference 1997).

As global climate destabilization proceeds, the frequency of 'extreme weather events' will continue to increase (e.g. severe flooding, droughts, forest fires, mudslides, tornados, etc.), which will worsen conditions for those in poverty. Rising temperatures will ensure that 'permanent' snow and ice will continue to melt and glaciers will continue to retreat (Comiso and Parkinson 2004). All of this melted ice and thermal expansion of ocean water will lead to global sea level rise, loss of coastal land and beach erosion (Day 2004). To understand how this will affect the developing world, consider that more than 25% of the population of Africa resides within 100 km of a sea coast (Singh et al. 1999), rendering a significant number of people vulnerable to such rising sea levels. Models on the effects of a 38-cm mean global sea-level rise, estimate that the average annual number of people in Africa impacted by flooding could increase from 1 million in 1990 to 70 million in 2080 (Nicholls et al. 1999). Rising global temperatures also increase the risk of some infectious vector-borne diseases (e.g. malaria, dengue fever, yellow fever, and encephalitis), particularly those diseases that only appear in warm areas (e.g. the majority of the developing world) (Koelle et al. 2005; McMichael et al. 2003).

Temperature increases combined with accelerated flooding and drought, could be devastating to domestic farming and lead to problems in the global food supply. Tropical areas, which are already on the edge of the temperature range, would see decreased production abruptly. Although farming productivity has increased in the past thirty years in the U.S., there have been noticeable dips in productivity related to weather, crop diseases, and pests that show the trend is becoming more erratic (Bennett 2003). One-third of U.S. agricultural output and 80% of the world's crops depend on pollinators like insects, bees, birds, and bats, whose populations are in danger due to global warming (Abramovitz 1997). Again, the developed countries enjoy economic security that can be used to dampen the effects of a drought on their soil (so if the U.S. cannot grow enough food, it possesses the available capital to simply import it). Other nations are not as fortunate and regularly suffer epidemics from starvation and hunger-related diseases due to shortages in food supplies caused by drought.

Global climate destabilization is detrimental for humanity now, but even more so for the unborn of future generations. Pope John Paul II (1990: II6) calls us to careful examination: "We cannot interfere in one area of the ecosystem without paying due attention both to the consequences of such interference in other areas and to the well-being of future generations." The Pope's message is one of utmost respect for life, and most importantly, the dignity of the human person. The decline of nature equals the decline of man. Pope John Paul II concludes (1990: II7), "Delicate ecological balances are upset by the uncontrolled destruction of animal and plant life or by a reckless exploitation of natural resources. It should be pointed out that all of this even if carried out in the name of progress and well-being, is ultimately to mankind's disadvantage."

4. Protecting the Natural and Human Environment—Our Stewardship of God's Creation

It has been argued that the Judeo-Christian worldview is a primary factor in the historical shift from subsistence to complete human domination of nature and its resultant destruction (White 1967). This negative view of the Christian environmental ethic is often centered on a misinterpretation of God's words in Genesis 1:28: "God blessed them, saying: 'Be fertile and

multiply; fill the earth and subdue it. Have dominion over the fish of the sea, the birds of the air, and all the living things that move on the earth.’” Literal interpretation of this passage implies an anthropocentric attitude that raises humans above the rest of creation and justifies ecological exploitation for our own self-interest. Historically this anthropocentric attitude has prompted the organization of many areas of human culture.

However, when Biblical scholars looked at Genesis 1:28 in context, as in the story of Noah, the full meaning of dominion becomes clear—it is to see to the survival of other living creatures (Clifford 1998). The story of Noah and the flood illustrates the recognition of the biblical authors that human offenses potentially imperil the rest of creation, similar to what scientists are observing in our own time. The meaning of the word “dominion” does not signify domination over the earth, as anthropocentrism advocates, but rather, a duty of care. God entrusted creation to humanity to protect and treasure (Clifford 1996). Similarly, the command to “subdue” the earth in context of sixth century B.C.E. suggests claiming a holy gift (Clifford 1996: 24). The covenant with Noah was a covenant with *all of creation*, indicating that although humans are unique and special in God’s view, we share a relationship with the rest of creation and must exercise a stewardship of care and responsibility for it.

In Genesis 1:26-27, on the same day on which God created the animals, humankind was made, and the 6th day’s creation was proclaimed to be “very good” (Gen 1:31). Thus, humans and the rest of creation are connected at a fundamental level. Our mandate to care for the environment is most clearly stated directly after God created humans, “The Lord God then took man and settled him in the garden of Eden, to cultivate and care for it” (Gen 2:15). This clearly rules out the toleration of a human-centered exploitation of nonhuman nature. Anne Clifford summarizes, “The Genesis creation texts, read in the context of the time of their formation and in light of other texts on creation in both testaments, present a picture that differs greatly from the domination—exploitation scenario. For humans to live in harmony with all creatures requires us to show the kind of loving care for all of creation revealed to us in the scriptures, especially in the life and teachings of Jesus Christ, the Son of God incarnate in creation” (1996: 41).

There has been a groundswell of revived interest in the relationship between religion and environmental stewardship. The stewardship of

nature has long been in the Catholic tradition. Many of the saints spoke passionately for a deep respect for nature and the use of nature as a method of knowing God including: St. Irenaeus of Lyons (c. 130-200), St. Athanasius (c. 296-373), St. Basil the Great (c. 329-379), St. Gregory of Nyssa (c. 329-395), St. John Chrysostom (c. 327-407), St. Patrick (c. 386-461), St. Columbanus (c. 543-615), St. John Damascene (c. 675-749), St. Francis of Assisi (c. 1181-1226), St. Bonaventure (c. 1221-1274), and St. Thomas Aquinas (c. 1225-1274) (Barnett 2002).

Many of the saints found God by contemplating nature. St. Ignatius of Loyola (1491-1556) liked to see God in nature, "...look how God dwells in creatures, in the elements, giving them being, in the plants vegetating, in the animals feeling in them, in men giving them to understand: and so in me, giving me being, animating me, giving me sensation and making me to understand...". St. Augustine (354-430) supported such thinking in the *City of God* "Some people, in order to discover God, read books. But there is a great book: the very appearance of created things. Look above you! Look below you! Note it. Read it. God, whom you want to discover, never wrote that book with ink. Instead he set before your eyes the things that he had made. Can you ask for a louder voice than that?" The revelations of the saints concerning knowledge of God through nature have a firm Biblical foundation. Job 12:7-10 "But now ask the beasts to teach you and the birds of the air to tell you; or the reptiles of the earth to instruct you, and the fish of the sea to inform you. Which of all these does not know that the hand of God has done this? In his hand is the soul of every living thing, and the breath of all mankind." Also in Psalms a similar sentiment is repeated: "The heavens declare the glory of God, and the firmament proclaims his handiwork" (Psalm 19:1-2) and all of Psalm 104—Praise to God the creator (e.g. "How manifold are your works, O Lord! In wisdom you have wrought them all—the earth is full of your creatures..." (Psalm 104:24)). These ideas that all creatures praise God and humans are to join in the praise has often been misunderstood and neglected in the modern societies (Bauckham 2002). In the New Testament, these ideas are not as clear although Jesus often uses parables and analogies called upon from the natural world: Mathew 12:33-37, 13:24-30, 18:10-14; Mark 4:26-29, 30-32; Luke 15:1-7; and John 15:1-7.

In addition to the scriptural basis for ecological interest, there has been a renewed emphasis on the Catholic magisterium as a way to guide the

Catholic faithful towards right action. The magisterium embodies the teaching authority of the Catholic Church, both the elucidation of doctrine and issues of lifestyle. At the Second Vatican Council Pope Paul VI emphasized the role of the pope and bishops in providing guidance to the worldwide congregation (1964: 20, 25). As the articulators of the magisterium they draw on a scriptural foundation informed by modern concerns and guided by the Holy Spirit, which are accepted by Catholics as part of faith (*fides divina*). This responsibility allows the pope and bishops to influence the social understanding and contribution of Catholics to society. As noted earlier, in recent decades using their institutional influence Catholic clergy have increasingly called attention to the issue of environmental conservation.

The concept of Catholic stewardship is guided by the principal teachings of the magisterium. As such stewardship is an active response to the ancient traditions and modern concerns that constitute the magisterium. Generally stewardship involves a commitment to a lifestyle consciously lived to encourage justice, equality and loving kindness. The steward accepts that all things are part of the divine plan. Thus the steward acts as a curator of Christian values and creation. Peter 4:10 emphasizes the individual's potential contribution as a disciple and steward, "As each one has received a gift, use it to serve one another as good stewards of God's varied grace". The model of Catholic stewardship, working in tandem with the magisterium's teachings on the environment, could galvanize American congregations to great effect. Rather than justifying either exploitation or leadership through anthropocentrism, the steward accepts the responsibility to conserve God's gifts, acting in God's stead, according to God's directions as revealed in Scripture and by the magisterium. According to Sophi Jakowska (1986), as early as 1891 Pope Leo XIII's encyclical *Rerum Novarum*, started to pull these concepts together into the modern "environmental trend" with a claim that the goods of the earth are to be shared by all. Fifty years later, Pope Pius XI wrote *Quadragesimo Anno* (1931), which maintained the theme of sharing of natural resources and even expanded the concept to suggest limits on private property should be made to ensure equitable use. These early documents were concerned with both the material and spiritual well-being of humanity, which was threatened by the social and economic consequences of the industrial revolution (Blake 1996).

The documents of the Second Vatican Council reaffirmed these claims. John XXIII maintained that sharing natural resources was essential for attaining peace and justice in *Pacem in Terris* (Pope John XXIII 1963). In *Gaudium et Spes* (1965), Pope Paul VI restated the human responsibility to care for the earth (no. 67), the necessity of just and equitable sharing of the earth's resources so that human persons can live in dignity and develop physically and spiritually (no. 69). The environmental impact of industrial nations and consumer culture was challenged in *Octogesima Adveniens* (Pope Paul VI 1971: 21); "by an ill-considered exploitation of nature he risks destroying it and becoming in his turn the victim of this degradation." John Paul II continued the themes of responsible use of environmental resources for all people and the criticism of a consumer culture (e.g. *Redemptor Hominis* (1979), *Laborem Exercens* (1981) and more recently the 1991 World Day of Peace Message. After inspiration from Pope John Paul II's Day of Peace Message, over forty statements on ecology or the environment have been issued by bishop's conferences or individual dioceses around the world (Christiansen and Grazer 1996).

It has literally taken billions of years for nature to attain the ecological richness that existed prior to the appearance of humans on this planet. So, as reviewed in section II, when in our own time, we allow pollution, resource exhaustion, and the annual species extinction to fray the delicate tissue of life, we are surely aborting the hidden potential for a larger and wider-than-human future creativity that still lurks in the folds of the earth's complex ecosystem (Haught 1996). Even if the existence of these species does not affect our lives and interests in the present or foreseeable future in an observable way, our faith demands that other natural beings have a meaning and value to their Creator that may be beyond our human powers of discernment. Pope John Paul II in his first encyclical states, "Man often seems to see no other meaning in his natural environment that what serves for immediate use and consumption. Yet, from *Redemptor hominis*, it was the Creator's will that man should communicate with nature as an intelligent and noble 'master' and 'guardian' and not as a heedless 'exploiter' and 'destroyer'" (1979: 15). Catholics do not need to pander to the weak environmentalist argument of possible "lost medical miracles" in the species extinction in the Amazon. The fact that we are effectively allowing so many unique creatures to go extinct on our watch raises sobering questions for a faith tradition which celebrates life and the Creator (McDonagh 2003).

Allowing nature to perish is not just bad stewardship, but as Wendell Berry argues, “[it] is the most horrid blasphemy. It is flinging God’s gifts into his face, as of no worth beyond that assigned to them by our destruction of them.” (2002: 308). For in God’s eyes each species (and indeed each individual life) has value. “Are not five sparrows sold for two pennies? And not one of them is forgotten in God’s sight” (Luke 12:6). When species *are made* extinct, a unique manifestation of the goodness of God is forever extinguished.

The Bible gives us entitlements to use the gifts of nature but not to ruin or waste them. The Bible forbids usury or great accumulations of property. In the Biblical view we are holy creatures; living among holy creatures in a world that is holy. . . . How then can Christianity solemnly fold its hands while so much of the work of God is being destroyed? (St. Augustine 1467).

Following the Catholic view, nature is not merely a field to exploit at will or a museum piece to be preserved at all costs. The stewardship of the earth is not a simple task to discern or implement, because a true planetary commons demands a complex threefold good: 1) the welfare of the planet as a web of natural systems, 2) justice for the living (an aspiration still far beyond our present political reality), and 3) a just sharing in the earth’s bounty for future generations (Christiansen 1996). Catholics believe that however the universe and humans came into being; God is the Creator of the universe and the human race. In this belief, Catholics find the foundation of their conviction that, as Christians, they have an ethical duty to respect the gifts of creation, to give thanks for them, and so use them in accord with the will of God, as best they can interpret (The Australian Bishops’ Committee for Justice, Development, and Peace 1991).

5. The Catholic Theological Critique of Status-Quo Stewardship

In addition to the more historical, mainstream, and papal calls for greater stewardship of God’s creation, several activist-oriented, environmental and liberation theologians offer a critique of the status-quo, which also supports the efforts of humanity to do much more for the preservation of the environment. As one of the preeminent modern environmental theologians, Thomas Berry prompts us to go beyond reforms called for by the

Brundtland Commission and others that argue for “sustainable development”, as the planet and all human affairs would still be governed by a sense of the Earth as a commodity although our approach would be more cautious (1999). Berry calls us beyond status-quo stewardship to accomplish the *Great Work* of transitioning from human devastation of the planet to begin creating a “mutually enhancing mode of human dwelling on the planet Earth” (1999). To do this he argues we must reverse our abandonment of nature for a humanly constructed “wonderworld” and begin living creatively within the organic functioning of the natural world. As is well documented in section 2, efforts to create this sanitized wonderworld are unfortunately creating a toxic wasteworld that threatens the human mode of being. Other modern theologians agree. For example, the Latin American liberation theologian Leonardo Boff believes that the utilitarian and anthropocentric values of modern society must be replaced by a new covenant with nature, one of integration and harmony (1997). Boff calls on humanity to be “guardian angels of the earth” by seeing ourselves as members of a larger planetary and cosmic community (Boff 1995;1997). This is similar in concept to the “great chain of being”⁴ discussed by Berry (1988) and parallels the call from scientists for humanity to develop an “ecological consciousness” to solve environmental problems (Uhl 2003). Berry points out that although scientific knowledge of the universe is greater now than ever before, it is not necessarily this type of knowledge that leads to an intimate presence in the universe, nor have we yet proven adept at using this knowledge to help all of our own kind and other species (1999).

The current situation that the human community is confronted with requires an unprecedented sudden and radical change in lifestyle under the threat of a comprehensive degradation of the planet and its major life systems (Berry 1999). This is such an enormous challenge that many authors acknowledge that the scope of the ecological problem is so vast that all religions must examine their own cosmologies and participate in

⁴ There is an alternate understanding of the Great Chain of Being, discussed in Giovanni Pico della Mirandola’s *Oration on the Dignity of Man* (1486), which argues that since man is located in the middle of the chain, his attempts to improve himself (mind and body) cause him to rise on the chain thus moving closer to the Divine. In the same way, avoiding improvement will cause one to fall and move closer to the Devil, passing through the realms of animals and inanimate objects. Pico uses the chain to justify the goodness of reading pagan classical texts for self-improvement within a thoroughly Christian worldview.

the solution (Scharper 2002). For example, Paul Knitter, well known for his pluralist theology argues that in order protect the earth all religions must be enlisted to help (1995). In his view, to pursue a discussion across the world's many religions the foundation should be a dialogue on our commitment to "global responsibility" or praxis that leads to the well being of human beings and the environment (Knitter 1995). The suffering of both the oppressed and the environment, in Knitter's view, represent a universal truth and norm, which all religious people of good will can speak. Unquestionably, the reduction of the oppressed and the protection of the environment align with Catholic social teaching, but this is also unquestionably an enormous challenge. As Berry points out the financial and industrial establishment have such an extensive control of the planet's resources that such a basic change demands enormous catalytic effort (1999).

6. Solar Photovoltaic Energy Conversion as Solution to Global Climate Change

In order to mitigate the negative repercussions that global climate change is having on the natural world, the human world, and will have on the world of our descendants, it is astute for Catholics to reduce the burning of CO₂-emitting fossil fuels as much as possible. One method to accomplish this is to utilize photovoltaic solar cells, which produce electricity directly from sunlight to provide our energy. PV modules are fabricated as either panels or as shingles that can be placed on, or built into: roofs, building facades, carports, highway sound barriers, etc. Any surface that is exposed to sunlight is a potential location for PV. PV electrical production is a technically feasible, environmentally benign, sustainable, and socially equitable solution to modern society's energy requirements (Pearce 2002).

There is a commonly-held misconception that sustainable energy via solar cells comes at the price of large surface areas in selected regions (Stoett 1994). This is simply untrue. It would not be necessary to cover an appreciable area of the planet with PV to provide for current world energy needs using current solar cells. The fossil fuel production of the entire planet could be replaced by hydrogen generated by photovoltaic arrays on an estimated 53 million hectares of arid land (less than 2% of the area of the world's deserts) (Carlson 1988). Assuming solar energy conversion efficiency of 15%, the total primary energy of all developing countries could,

in theory, be provided by 0.1% of their land area, an area less than is presently occupied by their hydroelectric reservoirs (Hulse 1993).

Solar photovoltaic technology is truly a sustainable and environmentally friendly method of producing energy. PV produces no atmospheric emissions or radioactive waste during use. Therefore, when it replaces fossil fuel energy production, it curtails air pollution, which produces acid rain, soil damage, and human respiratory ailments. PV electrical production also discharges no greenhouse gases, such as CO₂, so it will help offset emissions that contribute to global warming. Solar photovoltaic modules are net energy producers (Alsema 2000). The energy pay-back time for a typical system is conservatively less than five years, which is much shorter than the expected lifetime under warranty, which is generally 20-25 years (Pearce and Lau 2002). With respect to the near-future poly-silicon and amorphous silicon PV modules, the energy pay-back time was estimated at approximately 2 years or less. It is also noteworthy that the time that amorphous silicon PV modules need to recover the energy input drops to only a single year when the production scale reaches 100 Megawatt peak (million Watts peak or MWp) per year (Kato, Maruta and Sakuta 1998).

There is a well-documented Catholic basis for respecting and upholding the well-being of nature, and in the present ecological crisis, it is clear that action should be taken by the Church community.

Individual awareness and effort is also necessary, but not effective when separate from systemic changes. The Catholic Church currently has the opportunity to catalyze a major shift in energy production from one based on fossil fuels to a foundation of solar renewable, and thus greatly diminish humanity's negative impact on creation. By using solar power itself, the Catholic Church would maintain consistency with its values while mitigating damage to creation from the misuse of modern science and technology.

7. Opportunity, Responsibility, and Challenges: Can Catholics Save the World?

7.1. Opportunity

Although solar energy production only commands a small part of the energy pie, its slice is rapidly increasing as the price per unit power mea-

sured in Watts peak (Wp)⁵ continues to decline. The conservative annual growth rate of 25% estimated by the PV industry, while impressive, is relatively minuscule compared to the reality of the global energy market. The roadmap predicted that by 2020, the U.S. PV industry will be shipping 6 billion Watt per year (GWp/yr) and thus have cumulatively installed ~87 GWp (Energetics 1999). While a large amount to energy, this must be kept in perspective—the U.S. peak electrical generation capacity in 1999 was ~776 GWp and will likely grow by 2020 (Department of Energy 1998). If PV technology is going to supplant fossil fuels, it must become economically competitive by driving down costs with economy of scale (Pearce 2005; 2006; 2008). As the production volume of solar cells increases, the price per module falls rapidly, just as the price of computers plummeted from millions of dollars to only a few hundred when in mass production. This trend is already apparent from 1975 to the present. The past two decades have seen a sustained price reduction of 7.5%/yr during which the average worldwide production of modules increased by 18%/yr (Shah et al. 1999). In order to take advantages of economy of scale and to directly compete with fossil fuel as an energy source, it is generally agreed that 100 MWp amorphous silicon PV plants must be constructed (Schramm and Kern 2000; DeMeo 1997; and Payne, Duke and Williams 2000). For PV amorphous silicon modules produced at a 100 MWp plant once financing, capital equipment costs, direct and indirect manufacturing costs, installation, power conditioning, operation and maintenance costs, and tax benefits are all taken into account, the installed PV price is likely to fall under \$3.00/Wp (Payne, Duke and Williams 2001). This price makes solar cells economically attractive to a substantial portion of the United States' domestic energy market of approximately 8,000 MWp (Payne, Duke and Williams 2001). The enormous market generated from the first amorphous silicon 100 MWp/yr plant is very likely to have a catalytic effect, driving the construction of many more (and larger) PV plants. Specifically, by lowering costs through economy of scale and demonstrating the feasibility of a large plant, other companies would expand production. This would enable solar energy to be economically

⁵ Watt peak is the power output in Watts of a solar cell module when it is illuminated under standard conditions of 1,000 Watts/meter² intensity, 25°C ambient temperature and a spectrum that relates to sunlight that has passed through the atmosphere (AM or Air Mass 1.5).

feasible for everyone in the U.S. and then production could really take off, allowing people both in the U.S. and in the rest of the world access to reliable, affordable and non-polluting electricity. A 100 MWp/yr amorphous silicon fabrication plant is within reach of our current technology; unfortunately industry appears to be reluctant to take such a risk. If a market were identified, however, a plant would be quickly constructed. *A method to increase the production volume and thus decrease the cost of a PV system is necessary.*

If the U.S. Catholic Church made a focused effort for each parish in the country to place a PV array on the roof of their church, such a demand could be created. In order to obtain a rough estimate of the electrical generating capacity of the entire continental U.S. Catholic ensemble of churches, we utilized a Model Catholic Church or MCC.⁶ Even with the enormous available surface area, the percent of U.S. electrical production supplied by all the U.S. Catholic Church infrastructure completely outfitted with solar panels is far less than 1% of the total U.S. electricity production. However, to cover half the roof of an MCC with amorphous silicon solar cells with power densities of approximately $65\text{W}/\text{m}^2$ would require about 37kW of panels. There are 20,842 Parishes in the Continental U.S. (Cheney 2004). Assuming they are MCC and covered with such panels, they would place a demand of over 770MW on the solar industry.⁷ To reach the demand necessary for economy of scale, only about 65% or 500MW is necessary, so each parish would only have to install a 24kWp array. As multiple 100MWp/yr plants are constructed, the price of solar cells will continue to drop, opening the market to solar power generation even further and catalyzing a shift to renewable energy.

⁶ Following standard rules-of-thumb for church sizing requirements, and assuming an MCC with a 45° roof, and an average seating capacity of 400, the total roof area is $\sim 1,144\text{ m}^2$. Only half of total roof area is utilized (the half facing the most sun or the south in the U.S.) with PV. So the area available for a PV array is about 570 m^2 per church.

⁷ Choosing a conservative average solar flux of 4.5 peak sun hours the ensemble of solar-MCC's would generate over 1.2 billion kW-hrs/year. Peak sun hours are the equivalent number of hours per day, with solar irradiance equaling $1,000\text{ W}/\text{m}^2$, that gives the same energy received from sunrise to sundown. To convert power to energy simply multiply by the amount of time that the cell is illuminated at $1,000\text{ W}/\text{m}^2$. In this case 770MW illuminated for $4.5\text{ hrs}/\text{day} \times 365\text{ days}/\text{year}$. A greater degree of resolution is possible and will be discussed in section 8.

7.2. *Responsibility*

Although both the Papacy, the U.S. Catholic Bishops, and Catholic theologians have spoken and written extensively on the need for environmental stewardship or creation care, there remains fundamental disconnects between everyday experience of practicing U.S. Catholics, their faith, and their role in ecological degradation. At no time in history have the results of such disconnects been more critical. The United States holds a unique obligatory role to recognize our present ecological situation and initiate change; our history of innovating economic and technological change calls us to step up to the challenge in an equally inventive way (US Catholic Bishops 2001). The U.S. Conference of Catholic Bishops, stated:

All nations share the responsibility to address the problem of global climate change. But historically the industrial economies have been responsible for the highest emissions of greenhouse gases that scientists suggest are causing the warming trend. Also, significant wealth, technological sophistication, and entrepreneurial creativity give these nations a greater capacity to find useful responses to this problem. To avoid greater impact, energy resource adjustments must be made both in the policies of richer countries and in the development paths of poorer ones (11-12).

We also hope that the United States will continue to undertake reasonable and effective initiatives for energy conservation and the development of alternate renewable and clean energy resources. New technologies and innovations can help meet this challenge (U.S. Catholic Bishops 2001: 14).

The Catholic Church holds considerable, varied, and widespread influence. The Catholic Church is capable of raising the money to make the investment for the switch to solar PV. This investment would be a sacrifice for the greater good—a catalytic act of charity.

For many American Catholic parishes the capital costs of a solar photovoltaic system may at first appear prohibitive. For example, to ‘solarize’ the MCC used in our calculations at the current price of \$5/Wp, would cost ~\$120,000. Several factors need to be considered for this price. First, this price would be an upper limit. Each diocese could already purchase panels in bulk, taking advantage of present discounts. Similarly, the campaign could be coordinated on the national scale, with the U.S. Catholic bishops purchasing the panels for all parishes in bulk—giving massive bulk orders to a single company or a group of companies willing to construct the

necessary enormous fabrication facility. Then the panels could be allocated to the parishes with the most solar flux first (thereby having the greatest energy production and CO₂ emission reduction). The parishes with the most need for decreased utility costs could also be retrofitted first. Second, and more importantly, the solar electricity which the individual churches are paying for is *not* actually what is being purchased. The offset in electrical costs for the individual parishes is a side bonus. It should also be noted that individual parishioners and their families also have the option of installing PV on their own homes⁸ thereby adding approximately 650MW⁹ of demand, enough to drive the catalytic effect itself. Collectively, the U.S. Catholic Church is buying the solar photovoltaic revolution, which will make clean, renewable energy available for *all* people throughout the world and take a forceful stab at quelling the ecological crisis.

But why should the U.S. Catholics be responsible for shouldering the brunt of the financial hardship? One might argue that it is an American responsibility because they consume the most energy per capita of any nation. According to the Energy Information Administration, although the U.S. makes up only 5% of the world population, Americans use more than 25% of the world's energy. Thus, Americans are most responsible for the human-induced greenhouse effect and global warming. A more solid argument is based on the concept of alms. The concept of alms, frequently used in the New Testament, is probably the best example from scripture. Alms was an ancient practice in which the most powerful members of society took care of the neediest in the community—the orphans, widows, and strangers—providing a means of subsistence for them. This concept

⁸) The average American home could accommodate 5kW of solar cells at \$5/Wp this is \$25,000 and a substantial investment for most families. There are currently many low cost incentive programs that could make the installation affordable for the average homeowners. For a current review of comprehensive source of information on state, local, utility, and federal incentives that promote renewable energy and energy efficiency see the Database of State Incentives for Renewables & Efficiency at <http://www.dsireusa.org/>. In addition, there are several programs that operate like leases or renting programs from several commercial vendors, which involve no upfront costs. For example, <http://renu.citizenre.com/> has a rental program.

⁹) There are over 69 million U.S. Catholics (OCD, 2005) out of a total population of approximately 300 million is 23%. The U.S. is made up of about 105 million households and the home ownership rate is 66% (U.S. Census Bureau, 2008). For a first approximation if it is assumed that Catholics own homes at the same rate and have the same family size, there are roughly 197 million Catholic households and 130 million Catholic homes. If each Catholic home were to install a 5kWp PV system this would create an additional potential 650 MW of demand.

expresses the moral responsibility of one who has more toward those who have fewer possessions (DT 15:7-8, 10, 11). In this case, as the United States of America is the wealthiest nation in history, American Catholics are in the best position to do this of any national religious group in the world. Any group in a position to effect such enormous change has the responsibility to the world's poor, and to all of creation, to solve the ecological crisis and push towards a more just world. It should be clear that this article does not mean to insinuate that the Catholic Church is morally culpable for climate change if this proposal is not implemented—only that the Church has the opportunity to contribute to a global solution using the method outlined here.

Installing a PV system on each Catholic Church in the U.S. will also have several tangential benefits beyond the catalytic transformation of the solar energy economy. First, it will garner considerable good public relations in both the national and international press. The Church could “re-brand” itself as the universal religion that played a pivotal role in saving the world. This would be in contrast to the negative stories that media outlets continue to press on the Catholic faith (e.g. on Catholic clergy sexual abuse). The negative press associated with sexual abuse severely hurt the image of the Catholic Church, decreased donations, hindered recruitment, and impaired morale. Positive press could have an opposite and beneficial effect. It could encourage current Catholics to donate more to the social mission of the Church. Non-Catholics may be encouraged to convert because of being exposed to our social teachings and activity. There is already significant evidence that the green sisters movement underway to encourage ecological-responsibility is reinvigorating the Church (Taylor, 2002). It is likely that other Christian denominations would follow the Catholic Church's lead in integrating PV into their own places of worship. Solar cells on the roof would serve as a sign that the Church cares and is attempting ecologically responsible action. Many Catholics may be inspired to follow the Church's example and install a PV system on the roof of their own homes. PV could be the 21st century symbol of Christianity—a constant reminder of sacrifice for the greater good and thanksgiving for God's creation. Similarly other religions that have a respect for life could accomplish this same act and garner the same benefits as those that are available to the Catholic Church. One can only hope that besides catalyzing an energy revolution it would also similarly affect a social revolution based on life and the dignity of God's creation.

7.3. *Challenges*

Although the preceding proposal is both technically viable and ethically well supported there remains many challenges to actual implementation. Despite a large body of literature showing that true mass scale production of photovoltaic cells will be profitable at costs competitive with fossil fuels (Schramm and Kern 2000; DeMeo 1997; Payne, Duke and Williams 2000; 2001; Pearce, 2006), the energy industry has been extremely slow to move towards solar photovoltaics. Distributed generation technologies, like solar, challenge the centralized and controlled paradigm of the electrical generation industry. With distributed generation, energy consumers can also become suppliers empowered within the market. This is a perceived threat to profits for some of the world's largest and most politically powerful companies. The perceived threat and the leverage of those with political power in the U.S. has resulted in many regulations, laws, energy subsidies, and utility rate structures specifically designed to reduce deployment of distributed generation (Koplow and Dernbach 2001; Pearce and Harris 2007; Sovacool 2006). These barriers to entry into the market are weakening, but still represent a formidable retarding force on full scale rapid deployment of solar across the entire church infrastructure.

The economic investment to deploy the necessary number of cells per church will be economically difficult or impossible for many congregations and represents another serious challenge. This challenge can be overcome by aggregating funds and deploying solar on either a) the churches with the most need of reduced electric bills or b) those with the greatest return on investment as will be discussed below. Regardless, the positive benefit of the expected catalytic effect for solar energy will have to be weighed against the good that could be generated by other means for use of the approximately \$120,000/parish investment. This is the largest challenge as the social will of the Church will need to be focused on this one major global political change.

8. Future Work

This paper is a preliminary study of the viability of the U.S. Catholic Church driving mass production of solar photovoltaic panels. Additional research is needed to implement this concept to optimize the benefits.

Here the study focused only on the installed power of the solar systems to drive production up, not on the energy that the systems would generate. The energy generation, which initially will be directly proportional to the greenhouse gas emission reduction benefit, should also be optimized to obtain the largest impact for the least resource investment. This will limit the installation in some churches as they will be shaded by trees, buildings or other obstructions or have poor orientation. However, for those parishes it might be possible to cover the parking lots with solar awnings or the roofs of Catholic schools, rectories, or other church owned buildings.¹⁰ In addition the average daily solar flux varies widely across the U.S. Thus, the geographical distribution of churches and how this corresponds to the available solar flux intensity is of extreme importance for maximizing energy output with a given number of panels. If it is assumed that all of the churches could not be retrofitted at once due to fiscal constraints, the capital invested in the panels should be deployed at locations offering the highest energy output first. Web2.0 open source or free software like Google Earth (Pearce et al. 2007) could be used by congregations to input their data church's data. This data could then be used to construct maps for the triage solar deployment. With enough funding, nearly every church could be partially covered with solar cells. Finally, the regulatory regimes and electric rates for electricity generation by use of solar power would also need to be considered. Historically the electric utility industry has attempted to prevent distributed generation of any kind including solar by preventing small users from generating electricity and feeding their excess back on the grid. Even in those jurisdictions that allow the practice there is also an enormous discrepancy between the amount utilities will pay for solar electricity and the purchase price of electricity for the consumer. More equitable rules such as net metering (currently in 42 states and D.C.)¹¹ are spreading and will reduce the complexity of a national deployment.

¹⁰⁾ Including these additional buildings and surface areas to determine the limit of power demand on the solar PV industry that is able to be generated by the U.S. Catholic Church is also a interesting avenue for future work.

¹¹⁾ Current Net Metering Policies can be found here: <http://www.eere.energy.gov/greenpower/markets/netmetering.shtml>.

9. Conclusions

The catastrophic environmental impact of humanity's interference with creation is underway and well documented in the scientific literature. Although there are many sources of anthropogenic environmental harm, our choices on energy sources are currently the most important in limiting that harm. Many species and ecological habitats have been irrevocably destroyed, yet the majority of the God's creations in the biosphere are still intact, so the motive behind making a catalytic change in humanity's energy use is clear. The Bible, Catholic theologians, Catholic bishops, and the popes all agreed that this environmental crisis is not an isolated concept, but critically relevant to both human survival and following God's will in our daily lives. The U.S. Catholic Church faces an opportunity to apply its social teachings for the betterment of humanity and creation by investing in solar photovoltaic technology for the U.S. Catholic Church infrastructure. By accepting the risk and doing so, the Church would accelerate the availability and economic viability of solar photovoltaic technology while upholding Christian doctrine mandating respect for the earth.

Bibliography

- Abramovitz, J. 1997. *State of the World 1997*. New York: Worldwatch Institute.
- Alsema, E. 2000. "Energy pay-back time and CO₂ emissions of PV systems". *Progress in Photovoltaics: Research and Application* 8: 17-25.
- American Museum of Natural History. 1997. "National survey reveals biodiversity crisis—scientific experts believe we are in midst of fastest mass extinction in Earth's history" New York, NY: American Museum of Natural History.
- The Australian Bishops' Committee for Justice, Development, and Peace. 1991. "Christians and their duty towards Nature". *Occasional Paper*, No. 7 Available: <http://www.socialjustice.catholic.org.au/Content/pdf/christians_and_their_duty_towards_nature.pdf>.
- Ayers, E. 2000. "Four Spikes". *Futures* 32: 539-554.
- Barnett, T.M. 2002. *Greening Congregations Handbook*. Seattle, WA: Earth Ministry: A3-A9.
- Bauckham, R. 2002. "Joining Creation's Praise of God", *Ecotheology: The Journal of Religion, Nature and the Environment* 7, No. 1:45-59.
- Bazzaz, F.A. 1998. "Tropical Forests in a Future Climate: Changes in Biological Diversity and Impact on the Global Carbon Cycle". *Climate Change* 39: 317-336.
- Bennett, D. 2003 "Global warming and farming...". *Delta Farm Press*.
- Berry, T. 1988. *The Dream of the Earth*. San Francisco: Sierra Club Books.
- . 1999. *The Great Work: Our Way into the Future*, New York, NY: Bell Tower.
- Berry, W. 2002. "Christianity and the Survival of Creation" in Norman Wirzba (ed.) *The Art of the Common Place: Agrarian Essays by Wendell Berry*, Counterpoint Press.

- Blake, D. 1996. "Toward a Sustainable Ethic: Virtue and the Environment" in Drew Christiansen and Walter Grazer (eds.), *And God Saw That It Was Good: Catholic Theology and the Environment*, Washington DC: United States Catholic Conference Inc.
- Boff, L. 1995. *Ecology & Liberation: A New Paradigm*, Translated by J. Cumming. Ecology and Justice Series. Maryknoll, NY: Orbis Books.
- . 1997. *Ecology: Cry of the Earth, Cry of the Poor*, New York: Orbis Books.
- Carlson, D. 1988. "Fossil Fuels, the Greenhouse Effect, and Photovoltaics". *IEEE Photovoltaic Specialists Conference Proceedings*: 1-7.
- Cheney, D.M. 2004. *Catholic Hierarchy, Statistics by Province*. Available <<http://www.catholic-hierarchy.org/country/spcusp1.html>>.
- Christiansen, D. 1996. "Ecology and the Common good: Catholic Social Teaching and Environmental Responsibility" in Drew Christiansen and Walter Grazer (eds.), *And God Saw That It Was Good: Catholic Theology and the Environment*, Washington DC: United States Catholic Conference Inc.
- Christiansen, D. and Grazer, W. 1996. Preface to *And God Saw That It Was Good: Catholic Theology and the Environment*, Washington DC: United States Catholic Conference Inc.
- Clifford, A.M. 1996. "Foundations for a Catholic Theology of God" in Drew Christiansen and Walter Grazer (eds.), *And God Saw That It Was Good: Catholic Theology and the Environment*, Washington DC: United States Catholic Conference Inc.
- Clifford, R.J. 1998. "Genesis 1-3: Permission to Exploit Nature?" *Bible Today*: 135.
- Comiso, J. and Parkinson, C. 2004. "Satellite-observed Changes in the Arctic". *Physics Today* 57, no 8: 38-44.
- Cubash, U.G. et al. 2001. "Projections of future climate change". 525-582 *Change 2001: The Scientific Basis, Third Assessment Report*. Working Group I of the Intergovernmental Panel on Climate Change, IPCC, Geneva, Switzerland.
- Day, C. 2004. "Sea-Level Rise Exacerbates Coastal Erosion". *Physics Today*, 57, no. 2: 24.
- DeMeo, E. 1997. "PV: Cost Reduction Prospects". *Renewable Energy Consulting Services, Inc. for the International Finance Corporation*.
- Department of Energy. 1998. *Annual Energy Outlook 1999*. DOE/EIA-0383(99), Energy Information Administration.
- . 2008. *Annual Energy Outlook 2008*, Report #:DOE/EIA-0383(2008), Energy Information Administration.
- The Dominican Episcopal Conference. 1987. *Letter on the Relationship of Human Beings and Nature*, The Dominican Episcopal Conference.
- Energetics Inc. 1999. "U.S. Photovoltaics Industry PV Technology Roadmap Workshop". Available: <<http://www.nrel.gov/ncpv/pdfs/30150.pdf>>.
- Energy Information Administration. 1998. *International Energy Annual 1996*, DOE/EIA-0219(96) Washington, DC. Table E1.
- Haught, J.F. 1996. "Ecology and Eschatology" in Drew Christiansen and Walter Grazer (eds.), *And God Saw That It Was Good: Catholic Theology and the Environment*, Washington DC: United States Catholic Conference Inc.
- Hoffert, M.I., Caldeira, K., Benford, G., Criswell, D.R., Green, C., Herzog, H. et al. 2002. "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet". *Science*, 298: 981-987.
- Hoffert, M. and Covey, C. 1992. "Deriving Global Climate Sensitivity from Palaeoclimate Reconstructions". *Nature* 360: 573.
- Hulse, J.H. 1993 "Agriculture, Food, and the Environment". *Food Research International* 26: 455-469.
- Ignatius of Loyola. 1914. *The Spiritual Exercises*, translated by Father Elder Mullan, S.J. Contemplation to Gain Love, Second Point, Available: <<http://www.ccel.org/i/ignatius/exercises/exercises.html>>

- The Intergovernmental Panel on Climate Change (IPCC). 1995. *Climate change 1995: the science of climate change, summary for policy makers and technical summary and IPCC Second Assessment Report: Climate Change*. New York: United Nations Environment Program and World Meteorological Organization.
- . 2001. *Summary for Policymakers, Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Available: <<http://www.usg.crp.gov/ipcc/wg2spm.pdf>>.
- Jaowska, S. 1986. Roman Catholic Teaching and Environmental Ethics in Latin America". p. 134 in Eugene C. Hargrove (ed.) *Religion and Environmental Crisis*, Athens, Ga: The University of Georgia Press.
- Karush, S. 2008. Public Transportation Sees Increase. Associated Press. September 09, 2008.
- Kato, K., Maruta, A., and Sakuta, K. 1998. "Energy pay-back time and life-cycle CO₂ emission of residential PV power system with silicon PV module". *Progress in Photovoltaics: Research and Applications* 6: 105-115.
- Knitter, P.F. 1995. *One Earth Many Religions: Multifaith Dialogue and Global Responsibility*, Maryknoll, NY: Orbis Books.
- Koelle, K., Rodo, X., Pascual, M., Yunus, M., and Mostafa, G. 2005. "Refractory Periods and Climate Forcing in Cholera Dynamics". *Nature* 436: 696-700.
- Koplow, D. and Dernbach, J. 2001. "Federal Fossil Fuel Subsidies and Greenhouse Gas Emissions: A Case Study of Increasing Transparency for Fiscal Policy", *Annual review of Energy and the Environment*, 26:361-389.
- McDaniel, C.N. and Borton, D.N. 2002. "Increased Human Energy Use Causes Biological Diversity Loss and Undermines Prospects for Sustainability". *Bioscience* 52, No. 10: 929-936.
- McDonagh, S. 2003. "The Death of Life: A Challenge to Christians". *Ecotheology: The Journal of Religion, Nature and the Environment* 7, No. 2:202-212.
- McMichael, A.J., Campbell-Lendrum, D.H., Corvalán, C.F., Ebi, K.L., Githeko, A., Scheraga, J.D. and Woodward, A. 2003. *Climate change and human health—risks and responses*, World Health Organization.
- Nicholls, R., Hoozemans, F.M.J., and Marchand, M. 1999. "Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses". *Global Environmental Change*, 9: S69-S87.
- Official Catholic Directory (OCD). 2005. "Official Catholic Directory 2006", New Providence, N.J.: P.J. Kenedy & Sons.
- O'Niell, B.C. and Oppenheimer, M. 2002. "Dangerous climate impacts and the Kyoto protocol". *Science* 298: 1971.
- Pasternak, A. 2002. "Global Energy Futures and Human Development: A Framework for Analysis", Lawrence Livermore National Laboratory rep. no. UCRL-ID-140773 (October 2000).
- Payne, A., Duke, R. and Williams, R. 2000. "The Impact of Net Metering on the Residential Rooftop PV Market" *Proceedings of the 28th IEEE Photovoltaic Specialists Conference*: 1391-1394.
- Payne, Adam, Duke, Richard and Williams, Robert. 2001. "Accelerating PV expansion: supply analysis for competitive electricity markets". *Energy Policy* 29, no. 100: 787-800.
- Pearce, J.M. 2002. "Photovoltaics—a path to sustainable futures". *Futures* 34: 663-674.
- . 2005. "Using the Internet to Reduce Market Risk for Alternative Energy Sources: The Case of Large-Scale Solar Photovoltaic Production", *First Monday* 10(8).
- . 2006. "Catalyzing Mass Production of Solar Photovoltaic Cells Using University Driven Green Purchasing", *International Journal of Sustainability in Higher Education*, 7(4): 425-436.

- . 2008. "Industrial Symbiosis for Very Large Scale Photovoltaic Manufacturing", *Renewable Energy* 33: 1101-1108.
- Pearce, J.M. and Harris, P.J. 2007. "Reducing greenhouse gas emissions by inducing energy conservation and distributed generation from elimination of electric utility customer charges", *Energy Policy*, 35: 6514-6525.
- Pearce, J.M., Johnson, S.J., and Grant, G.G. 2007. "3D-Mapping Optimization of Embodied Energy of Transportation", *Resources, Conservation and Recycling*, 51: 435-453.
- Pearce, J.M. and Lau, A. 2002. "Net Energy Analysis for Sustainable Energy Production from Silicon Based Solar Cells". *Proceedings of Solar 2002 Sunrise on the Reliable Energy Economy*. Available on CD from The American Society of Mechanical Engineers.
- Pico della Mirandola, Giovanni, 1486. trans. Charles Glenn Wallis. *On the Dignity of Man*. Indianapolis: Bobbs-Merrill, 1965.
- Pope Benedict XVI. 2006. Address to the Members of the Pontifical Academy of Sciences. Available: <http://www.vatican.va/holy_father/benedict_xvi/speeches/2006/november/documents/hf_ben-xvi_spe_20061106_academy-sciences_en.html>.
- Pope John XXIII. 1963. "Pacem in Terris". Given at Rome, at St. Peter's. Vatican City: Vatican. Available: <http://www.vatican.va/holy_father/john_xxiii/encyclicals/documents/hf_j-xxiii_enc_11041963_pacem_en.html>.
- Pope John Paul II. 1979. "Redemptor hominis: On Redemption and the Dignity of the Human Race" Given at Rome, at Saint Peter's. Vatican City: Vatican. Available: <http://www.vatican.va/holy_father/john_paul_ii/encyclicals/documents/hf_jp-ii_enc_04031979_redemptor-hominis_en.html>.
- . 1981. "Laborem Exercens". Given at Castel Gandolfo, on the Feast of the Triumph of the Cross. Vatican City: Vatican. Available: <http://www.vatican.va/holy_father/john_paul_ii/encyclicals/documents/hf_jp-ii_enc_14091981_laborem-exercens_en.html>.
- . 1990. "The Ecological Crisis: A Common Responsibility: Peace with God the Creator, Peace with all Creation". World Day of Peace Message. Vatican City: Vatican. Available: <http://www.vatican.va/holy_father/john_paul_ii/messages/peace/documents/hf_jp-ii_mes_19891208_xxiii-world-day-for-peace_en.html>.
- Pope Leo XIII. 1891. "Rerum Novarum". Encyclical on Capital and Labor, Given at St. Peter's in Rome. Vatican City: Vatican Available: <http://www.vatican.va/holy_father/leo_xiii/encyclicals/documents/hf_l-xiii_enc_15051891_rerum-novarum_en.html>.
- Pope Paul VI. 1964. "Lumen Gentium", Vatican City: Vatican. Available: <http://www.vatican.va/archive/hist_councils/ii_vatican_council/documents/vat-ii_const_19641121_lumen-gentium_en.html>.
- . 1965. "Gaudium et Spes". Vatican City: Vatican Available: <http://www.vatican.va/archive/hist_councils/ii_vatican_council/documents/vat-ii_cons_19651207_gaudium-et-spes_en.html>.
- . 1971. "Octogesima Adveniensi". Vatican City: Vatican. Available: <http://www.vatican.va/holy_father/paul_vi/apost_letters/documents/hf_p-vi_apl_19710514_octogesima-adveniensi_en.html>.
- Pope Pius XI. 1931. "Quadragesimo Anno". Given Saint Peter's in Rome. Vatican City: Vatican Available: <http://www.vatican.va/holy_father/pius_xi/encyclicals/documents/hf_p-xi_enc_19310515_quadragesimo-anno_en.html>.
- Scharper, S.B. 2002. "Green Dreams: Religious Cosmologies and Environmental Commitments", *Bulletin of Science, Technology & Society* 22: 42-44.
- Schramm G. and Kern, E. 2000. "Accelerating photovoltaic production through grid connected applications in developing countries". *Proceedings of the 28th IEEE Photovoltaic Specialists Conference*, 36-39.

- Shah, A., Torres, P., Tscharnner, R., Wyrsh, N., and Keppner, H. 1999. "Photovoltaic technology: the case for thin-film solar cell". *Science* 285, no. 5427: 692-698.
- Singh, A., Dieye, A., Finco, M., Chenoweth, M.S., Fosnight, E.A., and Allotey, A. 1999. *Early Warning of Selected Emerging Environmental Issues in Africa: Change and Correlation from a Geographic Perspective*. Nairobi, Kenya: United Nations Environment Programme.
- Sovacool, B.K. 2006. "The Power Production Paradox: Revealing the Socio-Technical Impediments to Distributed Generation Technologies". Blacksburg, VA: Virginia Tech (Doctoral Dissertation), available at <http://scholar.lib.vt.edu/theses/available/etd-04202006-172936/>.
- St. Augustine. 1467. *City of God*, David Knowles (ed.), First published 1467, current published 1984, New York: Penguin Books.
- Stoett, Peter J. 1994. "Global environmental security, energy resources and planning". *Futures* 26, no. 7: 741-758.
- Taylor, S.M. 2002. "Reinhabiting Religion: Green Sisters, Ecological Renewal, and the Biogeography of Religious Landscape", *Worldviews: Environment, Culture, Religion* 6(3): 227-252.
- Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C. et al. 2004. "Extinction Risk from Climate Change". *Nature* 427:145-148.
- Uhl, C. 2003. *Developing Ecological Consciousness: Path to a Sustainable World*, Oxford, UK: Rowman and Littlefield Pub.
- U.S. Catholic Bishops. 1991. *Renewing the Earth: An Invitation to Reflection and Action on Environment in Light of Catholic Social Teaching*. Available: <http://www.usccb.org/sdwp/ejp/bishopsstatement.htm>.
- . 2001. *Climate Change—a Plea for Dialogue, Prudence, and the Common Good*. Washington DC: U.S. Catholic Conference Inc. Available: <http://www.usccb.org/sdwp/international/globalclimate.htm>.
- U.S. Census Bureau. 2008. U.S. Census Bureau: State and County Quick Facts. Data derived from Population Estimates, Census of Population and Housing, Small Area Income and Poverty Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits, Consolidated Federal Funds Report, Last Revised: Friday, 25-Jul-2008 15:42:44 EDT. Available: <http://quickfacts.census.gov/qfd/states/00000.html>.
- White, L. 1967. "The Historical Roots of Our Ecological Crisis". *Science* 55: 1203-1207.
- Wilson, E.O. 1992. *The Diversity of Life*. Cambridge, MA: Harvard University Press.
- The World Conservation Union, the Smithsonian Institution, the World Wildlife Fund, the Nature Conservancy, and the Royal Botanic Gardens of the United Kingdom. 1998. *IUCN red list of threatened plants*.