The Energy Transition: Religious and Cultural Perspectives

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AN ENERGY PRIMER: FROM THERMODYNAMICS TO THEOLOGY

by Normand M. Laurendeau

Abstract. Scientific, technological, ethical, and religious issues confronting the human prospect are emerging as we encounter the inevitable shift from fossil to renewable fuels. In particular, we are entering a period of monumental transition with respect to both the forms and use of energy. As for any technological transition of this magnitude, ultimate success will require good ethics and religion, as well as good science and technology. Economic and political issues associated with energy conservation and renewable energies are arising in the context of climate change, sustainability, and human purpose. Specifically, we must consider (1) ethical and religious perspectives which might guide future energy choices and (2) energy choices which, in turn, might challenge ethical and religious perspectives. In this paper, I set the stage for subsequent articles by introducing thermodynamic and theological considerations relevant to our energy future. Scientific and technological aspects are covered within the context of the first and second laws of thermodynamics. Ethical and religious aspects are covered within the context of basic philosophical and theological motifs within our secular culture. My intention is to provide the necessary background, motivation, and perspectives for a fuller discussion of pertinent issues in the remainder of the conference papers.

Keywords: climate change; common good; energy policy; oil depletion; religion; sustainability; thermodynamics

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Global energy policy, now and for the immediate future, appears to be driven by two overriding issues: climate change and oil depletion (Rauckhorst 2006). Three solutions are usually offered to deal with these two basic issues (Mathews 2007): enhancing energy efficiency (Gardner and Stern 2008; Glicksman 2008), reducing energy consumption (Lovins 2005, 2009) and developing new energy technologies (Goldemberg 2007). However, in pursuing these three solutions, tension nearly always occurs between the rich and poor, both in the United States and throughout the world, so that distributive justice inevitably becomes a significant factor in structuring moral approaches to global energy policy. For this reason, science, technology, ethics, and religion are all germane to our energy future, with faith traditions being especially important as both watchdog and promoter—the former with respect to identifying morally unacceptable approaches and the latter with respect to supporting new ideas offering particularly holistic solutions to current energy problems.

Surprisingly, an interesting parallel exists between the two major conundrums of oil depletion and climate change. Oil is obviously a finite resource so that the principal concern in this case is consumption, whereas for carbon dioxide, the major culprit in global warming, the main concern is production. The key problem for oil depletion is peak oil, defined as that future year when half of all originally available oil will have been pumped from the Earth (Hirsch, Bezdek, and Wendling 2005; Sorrell et al. 2010; Tertzakian 2006). The key problem for climate change is $\Delta T > 2\text{–}3^\circ\mathrm{C}$, defined as that future year when the mean global temperature compared to preindustrial conditions will have risen by 2–3°C, which is taken by most scientists as sufficient to threaten irreversible warming of the Earth (Hansen 2009; Moriarty and Honnery 2008; Ritter 2009). The temporal horizon for both peak oil and $\Delta T > 2\text{–}3^\circ\mathrm{C}$ is variously estimated at only 10–50 years. The economics are also similar: the cost of oil and of fighting carbon emissions will rise, perhaps precipitously. Equity and justice will thus become problematic; that is, the poor will almost surely become poorer.

The challenges to global energy policy can be understood by modeling annual primary energy consumption as (Tester et al. 2005)

$$Energy = Population \times \frac{GDP}{Population} \times \frac{Energy}{GDP}, \tag{1}$$

where *GDP/Population*, or per capita gross domestic product (GDP), is a measure of affluence and *Energy/GDP*, often labeled the energy intensity, is a measure of technological development, typically associated with energy efficiency (Lovins 2009). Evaluating Eq. (1) for the years 2000 and 2100 for the entire planet, and taking a suitable ratio, I obtain

$$\frac{Energy\ (2100)}{Energy\ (2000)} = 2 \times 10 \times \frac{1}{4} = 5. \tag{2}$$

In Eq. (2), I have presumed a very conservative doubling in population over the next century, an estimated increase in global affluence, given the rapid growth of countries such as Brazil, India, and China, of a factor of 10, and a very optimistic reduction of a factor of 4 in energy intensity. Even under these relatively optimistic conditions, I estimate an increase by a factor of 5 in global primary energy consumption over the next century. This expectation is consistent with a more sophisticated prognostication from the Energy Information Administration (2010): 50% growth in the next 25 years!

Annual carbon dioxide production, analogous to Eq. (1), can be modeled as

$$CO_2 = \mathit{Population} \times \frac{\mathit{GDP}}{\mathit{Population}} \times \frac{\mathit{Energy}}{\mathit{GDP}} \times \frac{CO_2}{\mathit{Energy}}, \qquad (3)$$

where CO_2/Energy, taken as CO_2 intensity, identifies any technological development with respect to CO_2 emissions. Beginning from Eq. (2), and postulating no further rise in CO_2 emissions between 2000 and 2100, Eq. (3) leads to

$$\frac{CO_2(2100)}{CO_2(2000)} = 2 \times 10 \times \frac{1}{4} \times \frac{CO_2/\mathit{Energy}\,(2100)}{CO_2/\mathit{Energy}\,(2000)} = 1, \qquad (4)$$

so that a factor of 5 reduction in CO_2 intensity becomes necessary to stabilize CO_2 emissions over the twenty-first century. This is an extremely tall order and is indicative of the major challenges facing humanity as we plan our energy future. Indeed, this large reduction cannot be accomplished without an eventual shift away from fossil fuels, especially coal and oil, preferably over the next 10–50 years.

Now that we are familiar with the landscape of our future energy challenges, we are ready to explore the fundamental issues necessary to investigate the scientific, technological, ethical, and religious aspects of future energy policy. I begin by providing scientific background, mainly through thermodynamics, so as to understand energy efficiency. I then explore the necessary shift from energy efficiency to renewable energies, as mandated by thermodynamic principles. Next, I provide religious background, with a particular focus on energy consumption. Both science and religion are then applied to our two major issues: climate change and oil depletion. The oil transition, in particular, will provide a convenient platform for initial discussions of current energy policy, with concluding considerations of presumably evolving relations between religion and future energy policy, especially with respect to climate change.

SCIENTIFIC BACKGROUND: ENERGY EFFICIENCY

Any scientific or technological discussion of energy and its utilization in modern societies requires thermodynamics (Moran and Shapiro 2000).

Thermodynamic principles, in turn, mandate an understanding of some basic physical quantities, particularly energy, work, and heat. Energy (E) represents the capacity to do work. Work (W), in turn, is energy transfer that potentially results in the raising of a weight. Therefore, any form of energy, whether chemical, electrical, or nuclear, is ultimately useful when converted into work. Heat (Q), in comparison, is energy transfer caused by a difference in temperature, whether by conduction, convection, or radiation.

The fundamental standard international (SI) unit for energy, work, or heat is the Joule (J). One kilojoule (kJ) is defined as 1000 J, which is approximately equivalent to 1 Btu (British thermal unit). Power represents work per unit time. The fundamental unit for power is the Watt (W), which is defined as 1 J/s. Power plants are typically rated in megawatts (MW), where 1 MW = 1000 kW = 1,000,000 W.

The First Law of Thermodynamics represents conservation of energy. When applied to any thermodynamic system, whether solid, liquid, or gas, the first law becomes

$$Q - W = \Delta E, \tag{5}$$

so that the difference between net heat entering the system and net work leaving the system represents the change in energy within the system. If, for example, heat enters the system without producing work, the internal energy rises, producing typically an increase in temperature for the substance within the system.

A power cycle, such as that produced by an automobile engine, jet aircraft engine, or electrical power plant, is designed to produce work by storing zero energy ($\Delta E = 0$); thus, from Eq. (5),

$$W_{cycle} = Q_{cycle}, \tag{6}$$

so that the net heat input is converted completely to net work output, which is, of course, the purpose of any power cycle. The power cycle can be represented generically by Figure 1, which shows a high-temperature reservoir, used to model the heat source, and a low-temperature reservoir, used to model the heat sink for any power cycle. In the case of a coal-fired power plant, for example, the heat source might be a coal combustor and the heat sink might be a nearby river. The heat input from the high-temperature reservoir (Q_H) represents heat into the system, while the heat output to the low-temperature reservoir (Q_L) represents heat out of the system, so that the net heat input for the cycle, $Q_{cycle} = Q_H - Q_L$. Hence, from Eq. (6), we obtain

$$W_{cycle} = Q_H - Q_L. \tag{7}$$

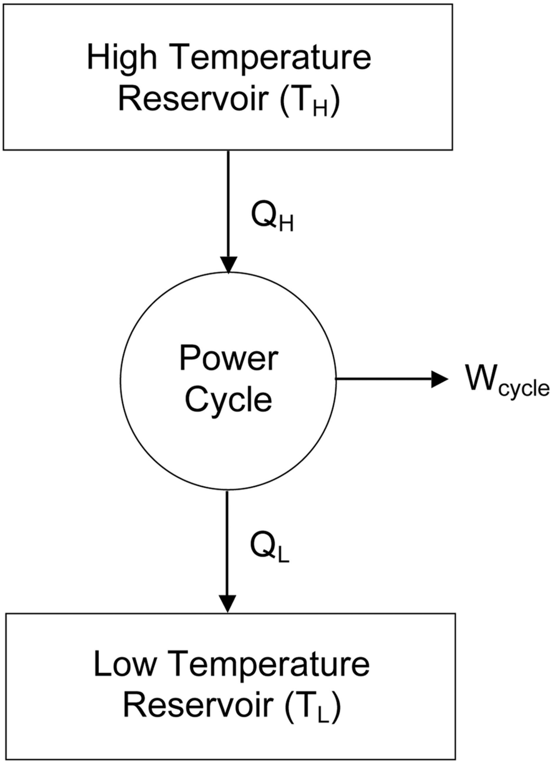

Figure 1. Schematic of generic power cycle.

The most important parameter arising from the First Law of Thermodynamics is the thermal efficiency, defined as

$$\eta = \frac{W_{cycle}}{Q_H}, \tag{8}$$

which thus indicates the amount of work produced per amount of heat entering the system. Since work output is the desired quantity and heat input typically results from the burning of fuel, the thermal efficiency is, in a manner of speaking, a measure of what you get for what you pay. Substituting Eq. (7) into Eq. (8), we find that the thermal efficiency can also be expressed as

$$\eta = 1 - \frac{Q_L}{Q_H}. \tag{9}$$

Therefore, the thermal efficiency can only reach 100% if heat losses are eliminated from the power cycle. Unfortunately, the Second Law of Thermodynamics makes this strategy ultimately impossible, even theoretically.

The Second Law of Thermodynamics provides the optimum thermal efficiency for a power cycle, which can be demonstrated to be (Moran and Shapiro, 2000)

$$\eta_{opt} = 1 - \frac{T_L}{T_H}, \tag{10}$$

where T_L is the temperature of the low-temperature reservoir and T_H is the temperature of the high-temperature reservoir. Unfortunately, this optimum thermal efficiency applies only when the power cycle operates with no friction or gradients in temperature, pressure, or concentration. Friction can surely be reduced through good design and proper use of lubricants, but zero friction is impossible. Gradients, especially those for temperature, can be minimized by operating the engine or power plant very slowly; however, such operation inherently implies low-power production. In other words, for practical power cycles, the actual thermal efficiency will always be significantly lower than the optimum thermal efficiency.

As an example, suppose that $T_H = 1500$ K and $T_L = 300$ K, where the required absolute temperature in degrees Kelvin (K) is °C + 273. Substituting these values into Eq. (10) gives $\eta_{opt} = 80\%$. A typical thermal efficiency for a power plant might be 40%, only half of the optimum thermal efficiency. Substituting for each thermal efficiency in Eq. (8) and then for W_{cycle} in Eq. (7), we find that $Q_L = 0.6Q_H$ for a typical power cycle and $Q_L = 0.2Q_H$ for our optimum power cycle. Hence, the heat loss is three times greater for a typical cycle as compared to an optimum cycle, a result of friction and gradients in the practical world. Note, however, that even for an optimum power cycle, heat loss is inevitable. In other words, according to the Second Law of Thermodynamics, no power cycle, even one with zero friction and gradients, can convert all input heat into output work. This is a major theoretical and practical limitation of any power plant that attempts to produce work from heat, for example, by burning a fossil fuel.

FROM ENERGY EFFICIENCY TO RENEWABLE ENERGY

Based on the above thermodynamic analysis, we find that the thermal efficiency of standard power cycles is best improved by reducing heat losses (Moran and Shapiro 2000). This strategy has been and is currently being implemented to great effect for power generation. Consider, for example, the typical coal-fired power plant shown in Figure 2. Pulverized coal is burned in a combustor, which provides the heat needed to convert water into steam. The steam passes through a turbine, which rotates an electrical

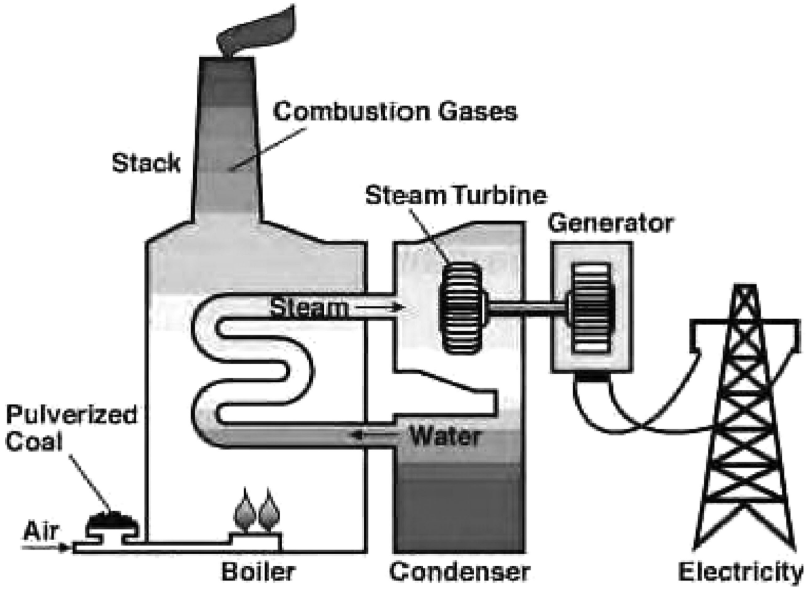

Figure 2. The electrical power cycle with coal combustion as the heat source.

generator. The steam leaving the turbine is converted back to water in a condenser, thus completing the cycle. Thermal efficiencies for such power plants typically approach 40%, so that 60% of the heat produced from burning coal is lost to the environment.

Two techniques are available for capturing this waste heat, thus improving the thermal efficiency. The first is the combined cycle, as shown in Figure 3. In this example, waste heat from a gas turbine cycle operating at higher temperatures is utilized in a heat recovery steam generator to reduce the amount of fuel needed for a steam turbine cycle operating at lower temperatures. A thermodynamic analysis of the combined cycle shows that its thermal efficiency can be expressed as (Moran and Shapiro 2000)

$$\eta_{COMB} = \eta_{GT} + \eta_{ST}(1 - \eta_{GT}). \tag{11}$$

Therefore, for typical gas and steam turbine efficiencies, η_{GT} and η_{ST}, of 25% and 40%, respectively, the combined cycle efficiency, η_{COMB}, becomes 55%, which is obviously a significant improvement.

Further improvements can be made by using the waste heat from the steam turbine cycle for various heating loads, such as for process heat, district heating of buildings, or a swimming pool. This second technique is called cogeneration, as shown schematically in Figure 4. The thermal efficiency of a cogeneration cycle is typically 55–70%, sometimes approaching as much as 85%. Hence, for the latter, only 15% of the heat

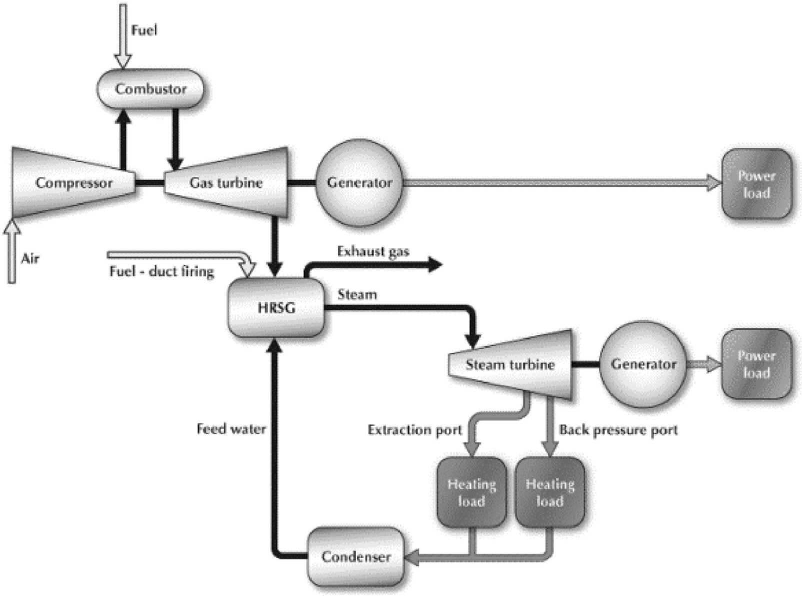

Figure 3. The combined gas-steam turbine cycle.

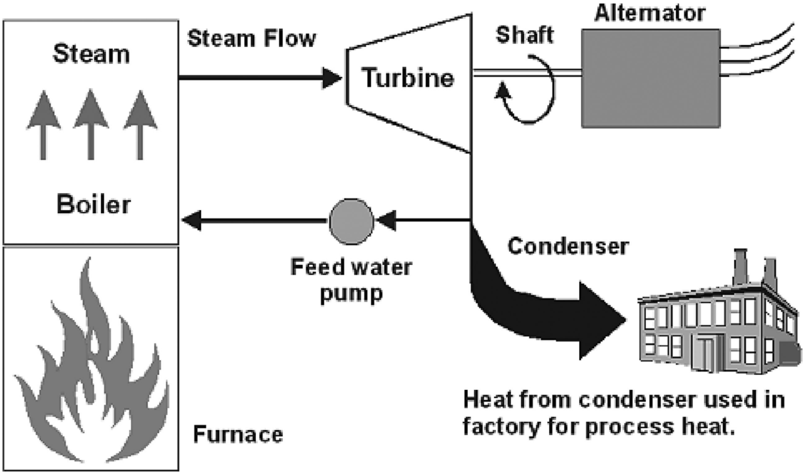

Figure 4. A typical steam cogeneration cycle.

produced by the fuel is sent to the environment—a reduction by a factor of 4 as compared to our original 60% waste heat.

We thus conclude that because higher thermal efficiencies reduce waste heat, less fuel is needed to produce the same amount of useful power. Less fuel implies less cost and less emissions of carbon dioxide. The thermal efficiency will always, of course, be less than 100% owing to temperature gradients, friction, and inevitable waste heat, even for a thermal power plant driven by solar energy.

The solution to the heat loss problem is to bypass completely the Second Law of Thermodynamics by implementing low- rather than high-temperature energy, for example, by not converting heat into electricity. A nonrenewable strategy along these lines is the fuel cell, for which the thermal efficiency is typically greater than 70% (Moran and Shapiro 2000). Renewable strategies to achieve similar results might include, for example, biomass fuels, wind turbines, and solar photovoltaic systems (Crabtree and Lewis 2007). As suggested in the next section, practical issues here include, but are not limited to, the availability and cost of low-temperature energy.

THE FUTURE OF ENERGY

Currently, primary energy in the United States (Energy Information Administration 2009) comes mainly from three fossil sources: petroleum (35.3%), natural gas (23.4%), and coal (19.7%), and two nonfossil sources: renewables (7.7%) and nuclear (8.3%). Hence, fossil fuels still account for nearly 80% of all primary energy, distributed over four major demand sectors: transportation (27.0%), industrial (18.8%), residential/commercial (10.6%), and electrical power (38.3%). Note that electrical power and transportation account for nearly two-thirds of primary energy consumption (65.3%), though the industrial and residential/commercial sectors cannot be dismissed owing to higher costs of primary energy for manufacturing, heating, air conditioning, and electronics.

From an economic perspective, we learned from the energy crisis of the mid-1970s that no firm correlation exists between energy use and GDP; indeed, energy intensity has dropped by 50% in the United States since 1975 (Lovins 2009). Furthermore, no free market exists in energy owing to various subsidies and externalities. Energy subsidies typically include federal investments, tax credits, liability limitations, and research and development (R&D). Energy externalities encompass effects on human health, air/water pollution, global climate, crop/fish losses, waste disposal, and military expenses. Total energy subsidies in the United States for 2007 were $16.6 billion, up from $8.2 billion in 1999 (Energy Information Administration 2008). Distributions in subsidies among various energy sources for both years are shown in Table 1. External costs when generating power, in cents per kilowatt-hour, are tabulated for primary energy sources inTable 2.

Expanded subsidies for renewable energy and efficiency/conservation are understandable given recent concerns with energy security and climate

Table 1. Federal energy subsidies for 2007 and 1999 in the USA (Energy Information Administration 2008)

Energy source	Percent (2007)	Percent (1999)
Coal	19.9	7.0
Oil and gas	13.0	25.3
Nuclear	7.6	9.0
Renewables	29.4	17.3
Hydropower	7.5	13.0
Efficiency/Conservation	22.6	28.4

Table 2. Energy externalities for electrical power in the USA (Koplow 2004; New Jersey Clean Energy Council 2004)

Energy source	Cost (US cents/kwh)
Coal	16
Nuclear	8.3
Natural gas	5.4
Biomass	5.7
Hydropower	3.9
Solar	1.0
Wind	0.4

change. Nevertheless, subsidizing all energy forms in one way or another seems ludicrous, as we are essentially misrepresenting the true costs of energy in the marketplace. The rather large subsidy for coal arises from its traditional importance in the United States as compared to oil and gas. Coal is also the major culprit when it comes to energy externalities, mostly owing to air and water pollution. At the opposite extreme, note the benign environmental effects of shifting to wind and solar. While nuclear energy is often advocated as a replacement for fossil fuels, its externalities are second only to coal.

A major externality for fossil fuels is, of course, global warming, mostly arising from CO_2 emissions. Despite political opinions to the contrary, "the compelling case that climate change is occurring and is caused in large part by human activities is based on a strong, credible body of evidence" (National Academy of Sciences 2010). Currently, the global atmospheric CO_2 level is approximately 30% above its preindustrial value. Moreover, CO_2 has been rising at about 15 ppm per decade, producing a mean atmospheric temperature rise of about 0.2°C per decade. As indicated previously, climate models generally predict abrupt climate change for $\Delta T > 2$–3°C (Ritter 2009). Leading evidentiary indicators consistent with climate predictions include decreasing sea ice cover, rising sea levels, ocean

Table 3. Household energy consumption in the USA (Gardner and Stern 2008)

End use	Percent
Private motor vehicles	38.6
Space heating	18.8
Water heating	6.5
Air conditioning	6.2
Lighting	6.1
Refrigeration	4.3

acidification, melting of glaciers, harsher rainfall events, and the northward shifting of many species habitats.

Unfortunately, realistic paths toward future CO_2 reductions remain murky. Recent MIT forecasts (Reilly and Crimmins 2011) suggest that fossil fuels will continue to account for approximately 80% of global primary energy, even to the year 2100. Moreover, future economics will probably still favor coal rather than nuclear for generation of electricity. Under such business-as-usual scenarios, the projected probability for $\Delta T > 5^\circ C$ by 2100 is a shocking 50%. Needless to say, this is a very sobering statistic, one that mandates worldwide consensus on a strong global energy policy. Toward this consensus, it is surely important to explore now potential blueprints for future amelioration of atmospheric CO_2.

Strategies for reducing CO_2 emissions typically include conserving energy, improving energy efficiency, switching from coal to natural gas or nuclear power, sequestering CO_2, and ultimately shifting to renewable energy (Pascala and Socolow 2004; Rotman 2009). According to Goldemberg (2007), efficiency improvements alone could reduce energy consumption by at least 25% for industry and appliances, 35% for buildings and transportation, and as high as 50% for power generation. Moreover, saving fuel usually costs much less than buying fuel, typically 35–40% less for transportation and electrical generation (Lovins 2009). Similar opportunities exist for residential and commercial buildings, which use 40% of all energy and 70% of all electricity (Gardner and Stern 2008; Johnson 2007; Voith 2008). As might be expected, household energy consumption is dominated by private motor vehicles and space heating, as shown in Table 3. Fortunately, for these two applications, energy conservation is considerably enhanced by implementing energy feedback displays (Farhar and Coburn 2008).

Switching from coal to nuclear would surely be significant; a 1000 MW nuclear reactor avoids 1.5 million tons of carbon emissions per year. Nuclear electricity could be used for recharging electric vehicles or converting water to hydrogen, but positive containment, proliferation resistance, and passive safety, especially following the recent Japanese experience, will eventually mandate standardized modular units of approximately 150 MW (Kemsley 2010; Wald 2010). In the long run, switching from uranium to thorium might also be advisable (Jacoby 2009) as thorium is four times more abundant and less costly, with little possibility of conversion to weapons. Nuclear wastes from thorium also pose much less danger; radioactive lifetimes are in tens of years, as compared to thousands of years when using uranium.

The ultimate solution to CO_2 emissions is, of course, conversion to renewable energy—biomass, wind, or solar, though full implementation demands a computer-controlled or so-called smart electrical grid (Talbot 2009). Biomass fuels include alcohols, gasoline, and diesel, as typically produced from nonedible cellulosic materials through biological or chemical conversion (Johnson 2010; Luque et al. 2008; Voith 2009). Electricity from wind turbines (0.5–2.0 MW modules) can be generated at 4–10 cents/kwh, roughly the same as for biomass, natural gas, coal, nuclear, or hydroelectric (Glicksman 2008; Johnson 2008). Solar electricity, however, costs three times more for thermal and six times more for photovoltaic designs, as compared with wind-based electricity, even for modular 500-MW systems operating at $\eta = 30\%$. For this reason, solar technology probably requires renewable portfolio standards, which typically mandate 10–25% renewable electricity by 2025, thus creating compliance markets and raising funds to build renewable energy projects (Apt, Lave, and Pattanariyankool 2008; Bogdonoff and Rubin 2007).

RELIGIOUS BACKGROUND: ENERGY CONSUMPTION

Enhancing energy production through technology has so far been our primary motif. We now turn to its flip side, energy consumption (Smil 2009), for which religion can play a more prominent role. In particular, while energy efficiency is a technical fix, requiring only minor changes in values, energy consumption is a social fix, necessitating major restructuring of values. Such value changes are part-and-parcel of religious traditions, particularly in their ascetical dimensions. Indeed, ascetical values are clearly relevant when dealing with utilization of resources, including consumption of energy and the development of future energy policies.

From a technical viewpoint, the potential for reducing energy consumption is significant (Goldemberg 2007). In the United States, for example, overall energy efficiency is only half that in Europe and Japan (Lovins 2005; Smil 2009). Efficiency studies indicate a potential 50–100% improvement in the United States for electrical generation (Goldemberg 2007), a 40–100% improvement for transportation (Plotkin 2007), and a 25–33% improvement for manufacturing (Jefferies 2009). Despite such opportunities, the overall energy efficiency in the United States is remarkably three times that in typical developing nations (Lovins 2005).

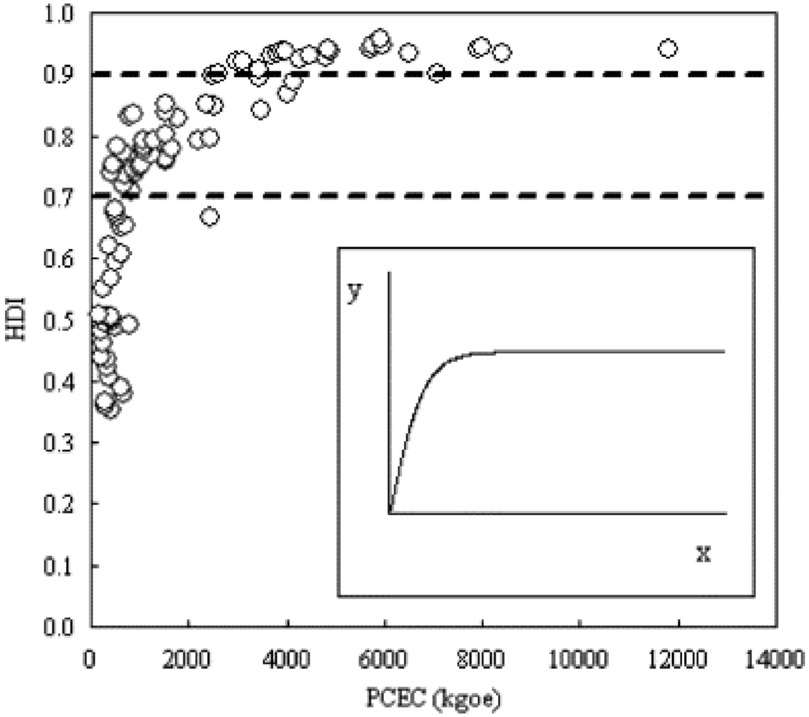

Figure 5. Human development index for various nations versus corresponding per capita energy consumption, in kilograms of oil equivalent; insert demonstrates saturation behavior (Martínez and Ebenhack 2008). Reprinted with permission.

Hence, whether from the perspective of Europe, Japan, or the United States, here rests the impulse for both nation-to-nation and religion-to-religion aid, whether at the denominational or personal level. The key is recognizing that for poorer people, energy is imperative for human dignity and development, as explored next (Love 2010).

Practical insights regarding the relation between human development and energy utilization can be obtained by plotting the human development index (HDI) versus per capita energy consumption (PCEC) for various nations, as shown in Figure 5 (Martínez and Ebenhack 2008). The HDI, established by the United Nations, basically accounts in a systematic fashion for access to health care, education, and capital (Jess, 2010). PCEC is expressed here in mass of oil equivalent, thus accounting for all energy sectors in a given economy. The remarkable, but perhaps not unexpected, feature of this curve is the roughly linear relation between HDI and PCEC for poorer nations, with eventual saturation owing to greater marginal utility for richer nations. Hence, a doubling of PCEC doubles HDI for

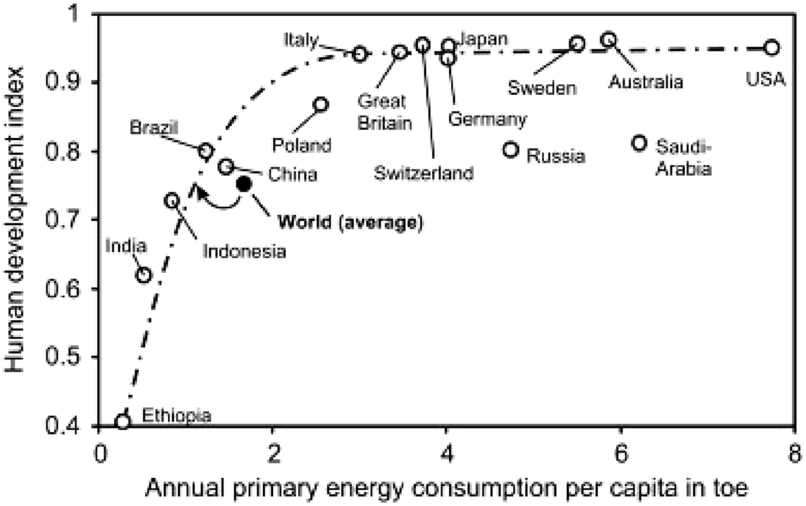

Figure 6. Human development index for various nations versus corresponding annual primary energy consumption per capita, in tons of oil equivalent (Jess 2010). Reprinted with permission.

poorer nations, while human satisfaction eventually becomes independent of additional energy consumption for richer nations.

Further insights come from identifying selected countries in a similar HDI plot, as shown in Figure 6 (Jess 2010). For the United States, we find that human satisfaction would basically be unaffected by halving energy consumption. The energy thus made available could then be transferred to where it would do the most good—in the poorer nations of the world where HDI is directly proportional to PCEC. Indeed, studies show that only 7% of global energy utilization would significantly improve life for the poorest 25% of people on Earth (Martínez and Ebenhack 2008). For these folks, satisfaction would surely rise, and perhaps even human happiness, as more time would become available for the gift of friendship, both human and divine (Makant 2010).

Even within the United States, poorer families need greater energy security as energy costs constitute a larger percentage of income for poorer people (Margonelli 2009). For this reason, improving household energy efficiency is challenging for poorer folks without federal tax rebates or municipal loan programs because of high upfront costs, including energy audits and contractors. Municipal loan programs are particularly effective, as discussed by Fuller, Portis, and Kammen (2009). For such programs, municipal tax bonds are repaid over a 20-year period via special deductible taxes collected on participating properties, thus matching payments with benefits. Beyond innovative taxing schemes, religion might also play an important role, as houses of worship can provide people-to-people services, so that the poor have access to appropriate energy information before applying for such municipal loans (Barrera 2008).

CLIMATE CHANGE: SCIENCE AND RELIGION

The strongest link between science and religion in the energy arena continues to be climate change. According to the most recent IPCC Working Group Report (2007), climate warming is unequivocal, most likely due to human beings, and with little potential for mitigation by natural processes (Liverman 2007). Carbon dioxide is by far the most significant greenhouse gas owing to its magnitude and long lifetime in the atmosphere (Moriarty and Honnery 2008; Ritter 2009). However, much uncertainty remains regarding carbon cycle feedbacks and regional modeling. Two key queries are: (1) what level of CO_2 must be maintained to avoid dangerous climate change and (2) what are the likely regional climates? Despite such uncertainties, the consensus is that significant weather changes will occur if the mean global temperature rises above its preindustrial level by more than 2–3°C (Hansen 2009). Since the dawn of the industrial revolution, the mean global temperature has so far risen by nearly 1°C.

Religious reflections on climate change build on ethical deliberations, focusing especially on the so-called precautionary principle (Weiss 2007). This principle states that when human activities might lead to *morally unacceptable harm* to humans or to the environment that is *scientifically plausible* but uncertain, *proportionate actions* shall be taken to avoid or diminish that harm. Morally unacceptable harm means a threat to human life, irreversibility, inequity to future generations, or inadequate concern for human rights. Scientific plausibility mandates ongoing scientific analysis, with openness to changing course. Proportionate actions must tally the seriousness of harm, including the moral implications and consequences of both action and inaction. In a nutshell, the precautionary principle mandates long-range thinking so as to mitigate risks without forgoing possible benefits—if you will, being safe rather than sorry!

From the perspective of ethics and religion, factual knowledge concerning energy typically gives way to critical values such as stewardship, social justice, and sustainability (Abbasi 2006). For many religious people in the United States, scientists themselves are not credible messengers owing to their career agenda and purportedly humanistic values. The most successful messengers, on the other hand, are fellow parishioners with appropriate scientific training. In other words, for many churchgoers, the scientist that you know is more trustworthy than the scientist that you do not know!

The current focus on climate change by religious bodies is mostly based on recognizing that the atmosphere is a global commons (Hogue 2007; Northcott 2007). By invoking a global perspective on love of neighbor, a shared theme is that human beings have an important responsibility for global stewardship (Skylstad 2009). This responsibility includes avoiding conspicuous consumption and dealing effectively with both positive and negative aspects of climate change, especially with respect to geo-political stability. Positive ramifications might include international cooperation to mitigate global warming while negative aspects would encompass universal support of environmental refugees (Biermann and Boas 2008; Love 2010). From a religious perspective, wealthier nations must recognize their moral responsibility to reduce CO_2 emissions and to share renewable technologies with the poorer nations of this world.

Religious bodies have generally focused on the energy mix needed to ameliorate climate change and on policies needed to reduce both energy use and CO_2 emissions. As might be expected, various faith traditions have also advocated for protection of vulnerable people and of future generations affected by climate change. While encouraging effective preaching on global warming, religious groups, as a whole, have made few calls for lobbying or for specific actions, probably owing to their overall lack of political power. The Judeo-Christian perspective has been dominant, with few attempts to reach out to Islamic, Hindi, or Buddhist practitioners. Moreover, the focus has typically been on greening houses of worship rather than on helping the laity to recognize their personal responsibilities for climate change at home and office.

The primary issues and proffered solutions raised within Judeo-Christian traditions are best approached by summarizing some key statements on climate change released by various religious bodies (Yale Forum on Religion and Ecology 2010). The Jewish perspective owes much to Maimonides, who famously opined that actions must be taken to protect others from potential danger causing fatal harm, even when the danger is not imminent or certain (Coalition on the Environment and Jewish Life 2000). In assessing potential dangers from global warming, Jewish pronouncements have typically supported a carbon tax to lower demand for fossil fuels while also advocating research funding for renewable energy. Similarly, Unitarian-Universalist congregations, while pushing for green sanctuaries and voluntary simplicity, have also promoted active lobbying for sustainable energy policies, especially advocating for greater energy efficiency, more renewable energy, and elimination of federal subsidies for fossil fuels (Statement of Conscience 2006; Weiss and Bonvillian 2009).

The U.S. Conference of Catholic Bishops has addressed two central moral queries when considering climate change (U.S. Conference of Catholic Bishops 2001). First, “how are we to fulfill God’s call to be stewards of creation in an age when we may have the capacity to alter that creation significantly, and perhaps irrevocably?” Second, “how can we as a ‘family of nations’ exercise stewardship in a way that respects and protects the integrity of God’s creation and provides for the common good, as well as for economic and social progress based on justice?" In posing such moral questions, the Bishops are clearly searching for a proper balance between self-interests, whether individual or national, and the greater common good (Christiansen 2011). Major concerns are solidarity with the poor and obligations to future generations (Northcott 2007). Their overarching perspective is that prudence, that is, practical wisdom, must guide preventive actions on climate change; in other words, preventive actions are always justified if the consequences of not acting cause significant harm.

The application of Catholic social teaching to climate change is best summarized by a letter sent from the Bishops to congressional leaders on February 7, 2007 (U.S. Conference of Catholic Bishops 2007).

> The traditional virtue of prudence suggests that we do not have to know with absolute certainty everything that is happening with climate change to know that something seriously harmful is occurring. Therefore, it is better to act now than wait until the problem gets worse and the remedies more costly. This precautionary principle leads us to act now to avoid the worst consequences of waiting. Prudence sometimes keeps us from acting precipitously. In this case, it requires us to act with urgency and seriousness.

Surprisingly, the evangelical perspective on climate change does not differ substantially from the previous viewpoints of purportedly more progressive denominations (Evangelical Climate Initiative 2006). While evangelicals care more deeply about U.S. energy security and long-term regulatory certainty, they nevertheless advocate for stable R&D programs and also energy prices reflecting the true costs of CO_2 emissions (Weiss and Bonvillian 2009). Key theological themes of their Evangelical Call to Action include care of creation, care of neighbor, and even redemption of creation (Wilkinson 2010). Applying these themes to global warming, evangelicals aver that (1) human-induced climate change is real, (2) the consequences will be significant, especially for the poor, (3) Christian morality demands an appropriate response, and (4) government, businesses, churches, and individuals all have a role to play—starting now!

As we have seen, statements regarding climate change by various religious denominations tend to focus on stewardship. Recently, Paul Santmire (2010) has suggested that stewardship is problematic owing to its financial, consumerist, and anthropocentric attributions. The implication, in other words, is that we are simply managing our climate household, as for any other commodity. Santmire (2010) suggests that it is time to move beyond stewardship to an actual desire to serve nature. He advocates a partnership with nature, focusing instead on earthcare and ecojustice. Interestingly enough, such movement is actually beginning under the auspices of the United Nations Development Program (UNDP), which is working with faith representatives to create action on climate change (Rollosson 2010). The hope is that faith traditions can work with UNDP to inspire actions rather than pronouncements. Current projects include, for example, green energy, tree planting, and green pilgrimages. Eco-twinning is of special interest and apparently growing; here, faith groups in developed nations partner with and provide resources for faith-based projects related to climate change in developing nations.

THE OIL TRANSITION AND ENERGY POLICY

In response to the oil crisis of the 1970s, the National Council of Churches argued that energy needs should take priority over energy desires (Birch 1978). Key ethical concepts such as participation, equity, and sustainability were offered, with special concern for avoiding high-risk technologies, which benefit the present at social costs to future generations. The Pontifical Academy of Sciences, in contrast, focused on how energy shortages could menace world peace (Hodgson 1981). It advocated conservation, coal, and nuclear in the short run, but renewable energy, particularly solar, in the long run. Some 40 years later, as we contemplate peak oil, these early religious rumblings on energy policy still hit the mark.

The biggest difference between now and then is the much greater current importance on resources as compared to marketplace. In the 1970s, OPEC could manipulate the market by controlling production; in the next 20 years, actual shortages of light sweet crude will likely dominate the marketplace, though the long-term implications of peak oil with respect to future energy policy are probably more significant than its exact timing (Farrell and Brandt 2006). The most important long-term trend will be the transition, despite enhanced oil recovery, not from abundance to scarcity, but from high- to low-quality hydrocarbons. In essence, the future portends heavier crude and synthetic liquid fuels from tar sands, coal, and oil shale—not a desirable scenario owing to much higher costs and emissions of CO_2 (Farrell and Brandt 2006). Beyond peak oil, the expectation is that oil production will decline at roughly 2–5% per year (Friedrichs 2010; Hirsch et al. 2005; Sorrell et al. 2010). Hence, the key question is whether or not renewable liquid fuels capable of reducing CO_2 emissions will be available in sufficient quantities to avoid dramatic cost overruns when we actually need them (Smil 2009).

According to Peter Tertzakian (2006), only four strategies are available for peak oil: (1) complain and pay, (2) conserve and become more efficient, (3) adopt alternative sources, or (4) make societal and lifestyle changes. Presuming that most people in the United States would like to move beyond complaining and paying, reducing demand for oil certainly appears to be the best short-run strategy. Currently, the United States imports some 10 million barrels of oil per day (MBD), mostly for transportation. Annual oil consumption per GDP for the United States is three times that for Europe. The hidden cost of our oil dependence, mostly environmental and military, has been estimated at $2–5 per gallon (Weiss and Bonvillian 2009). Furthermore, each barrel of oil saved costs only $12–15, as compared to $60–100 for its consumption. Enhanced efficiency alone would save 3.5 MBD, while mass transit and telecommuting would probably save an additional 1.0 MBD (Sovacool 2007).

In the long run, energy sources other than oil are needed for transportation (Friedrichs 2010; Heiman and Solomon 2007). Oil substitutes include synthetic liquid fuels, alcohols, and advanced biofuels (Luque et al. 2008; Rotman 2008; Sperling and Yeh 2009). Energy substitutes include electric vehicles, batteries, and fuel cells (Plotkin 2007). While substantial R&D is currently occurring in these arenas, no guarantee exists that alternative sources can make both timely and sufficient contributions to the required energy mix for transportation (Matutinović 2009). Uncertainties regarding peak oil only add further perplexity to an already mysterious conundrum. This leaves only the fourth strategy—societal and lifestyle changes. Enter religion!

RELIGION AND ENERGY POLICY

Why should religion be involved in energy policy? Three reasons come to mind. First, religion has always had an historical role in solving tendentious moral issues—recall, for example, the debates over slavery. From this perspective, at its best, religion proclaims truth, not political expediency; moreover, religion can often act as a source of will to promote new policies. Second, climate change represents an unprecedented moral challenge, especially given rising tensions between painful current measures and potential future catastrophes. Such moral challenges typically require synchronization of responses from various multinational entities; the necessary brokering may best be done by existing religious institutions, as religion itself already exercises a common binding power among many nations. Third, the strategies needed to effect cooperation on both climate change and oil depletion may best lie with virtues rather than with politics. Beginning from religious sensibilities, wellsprings of courage could percolate upward to move us beyond fear and guilt; similarly, hope could be generated to foster action rather than helplessness. Courage and hope are always key virtues—virtues of special importance to an ethic of responsibility (Barrera 2008).

Such an ethic of responsibility must be based on fundamental moral principles. According to the International Energy Agency, five ethical principles derived from international law are important for energy policy: stewardship, participatory decision making, prudence/vigilance, fairness/justice, and optimality (Bérubé and Villeneuve 2002). Stewardship implies ensuring a healthy and sustainable environment; participatory decision making means respecting the diverse rights of affected peoples;

prudence/vigilance suggests making good judgments and faithfully monitoring consequences; fairness/justice implies equity, both among nations and generations; and optimality means choosing the best options. As in most deliberations over public policy, major issues include wealth, poverty, resources, and lifestyles, aspects of energy policy that clearly take us beyond climate change. Nevertheless, from both an economic and ethical perspective, global warming demands prompt attention, as according to British economist Sir Nicholas Stern a 1% GDP investment now to build a low-carbon economy could well avoid a 5–20% reduction in GDP over the next 10–15 years owing to the inevitable consequences of global warming (McDonagh 2007).

If faith traditions are to responsibly apply these five ethical principles to future energy policy, they cannot do so without effective interactions with scientists, technologists, and economists. These professions, in turn, would surely benefit from religious perspectives, which typically highlight ascetic impulses, vulnerable populations, and distributive justice. Unfortunately, even with such wide-ranging input, the challenge of crafting, for example, an effective U.S. energy policy is enormous, mostly because we have three major constituencies with substantially different agendas (Long 2008). The first constituency focuses primarily on economic vitality; its concerns are free markets, energy production, and reduced regulations. The second constituency worries about energy security; its primary goal is energy independence, despite the complicated geopolitics of oil. The third constituency cares mostly about climate change; its concerns are consumption, equity, and sustainability.

So how do we bridge the obvious gaps among these three constituencies, especially for oil, which seems so much more imposing than electricity? Any shift from supply- to demand-side economics appears nearly impossible given the disparities among the three positions. And yet, renewable energy does seem to offer some real hope. After all, renewable fuels are touted as engines of economic growth, as a homegrown response to energy security, and surely as a prime ingredient in addressing climate change (Weiss and Bonvillian 2009). The nearly unanimous support for renewable energy by our religious traditions perhaps reflects a sensed opportunity to broker effectively among the three constituencies. The path necessary for a pragmatic energy policy, on the other hand, remains elusive; there seems to be no clear religious perspective, other than flexibility!

A pragmatic energy policy naturally seeks affordability and reliability, but because the economics of energy are so complicated and unpredictable, flexibility appears mandatory. Consider, for example, the debate between a carbon tax and a cap-and-trade permit system for reducing our overall carbon footprint (Parry 2007). Both promote a shift to less carbon-intensive fuels, but relative revenue and effectiveness remain perplexing. A cap-and-trade system is better at efficiently signaling the marketplace, so substantially lower CO_2 emissions at 60% less cost appear possible as compared to renewable portfolio standards (Palmer 2010). A carbon tax, on the other hand, is probably more cost effective; revenues can be used to reduce the federal budget deficit or to lower income taxes for the poor, thus compensating them for higher energy costs. A $30/ton carbon tax, for example, would reduce CO_2 emissions by 8.5% and raise $150 billion in revenue, which represents approximately 30% of the projected deficit in 2020 (Parry and Williams 2010). Similar tax reductions might be feasible with cap-and-trade, but permits must be auctioned rather than free. A hybrid policy, involving both cap-and-trade and a carbon tax, might be optimum, with perhaps 25% of revenues used to support conservation and renewable energy (Mathews 2007; Matisoff 2010). To ensure flexibility, safety valves could also be designed via variable permit allowances, compliance periods, or tax structures (Bogdonoff and Rubin 2007).

An ethic of responsibility, as highlighted by various religious traditions, is wholly consistent with the required flexibility in energy policy. William Schweiker (1995), for example, contends that "the imperative of Christian responsibility lies in our making choices that demonstrate respect for the intrinsic worth of all life before God. Moral life is a dialectical relation between self and others as mediated by social roles; moral identity arises from a commitment to those social roles." Similarly, I have previously offered the following (Laurendeau 2003): "Responsibility theory asks what action is most harmonious considering the context, complexity and ambiguity of human relationships. The bumper sticker version of responsibility theory might be: Do the most good and the least harm." We thus see that prudence, or practical wisdom, is key to an ethic of responsibility, as it must be for any flexible energy policy. Along these lines, Roman Catholics are currently being asked to sign the St. Francis Pledge to Protect Creation and the Poor, thus potentially moving them beyond economic expediency and utilitarianism when it comes to developing a more flexible and ethical future energy policy (Rauckhorst 2009; Skylstad 2009).

One of the most forward thinking religious organizations in this regard is Christian Aid, a progressive Protestant group in London, which seeks an appropriate balance between climate mitigation and poverty reduction. While carbon markets are no panacea, Christian Aid (2011) still feels that a global CO_2 agreement of some type is necessary to prevent high-carbon development. Moreover, because developed nations have been responsible for 75% of historic CO_2 emissions, they should eventually contribute 75% toward the costs of CO_2 reduction in developing nations. Such restitution payments for low-carbon development are needed to alleviate risks, prevent poverty, and mitigate climate impacts, including the preservation of rain forests.

Figure 7. Francisco de Goya, "Fight with Cudgels." c. 1820–1823. Oil mural transferred to canvas, currently in the Museo del Prado, Madrid. Reprinted with permission.

CONCLUDING REMARKS

Goya's famous black painting, *Fight with Cudgels*, is a powerful commentary on civil war (Figure 7). Two men, intent on killing one another, hardly notice that they are sinking in quicksand, an obvious metaphor on the destruction of Spanish civilization. The metaphor also works well for the continuing battle over energy policy (Hogue 2007). The different constituencies are battling with no end in sight; in the meantime, no oil policy is being implemented, CO_2 emissions go unabated, the poor get poorer, and the global mean temperature continues to rise. Here is a real role for religion—moving the combatants beyond their narrow constituencies and making them aware of the important repercussions for all of us.

An equally important role for religion is its confrontation with the big lie: science and technology can fix energy problems with no lifestyle changes (Moriarty and Hannery 2008; Northcott 2007). Au contraire, lifestyle changes will clearly be needed; moreover, religious sensibilities probably constitute the best impulse for willingness to make such changes. The problems are tremendous and the negotiations required to solve them are particularly challenging. It is easy to give up in the face of overwhelming technical, political, and ethical obstructions. Therefore, in so many ways, the most important role for religion is providing hope—hope that will keep us going despite setbacks, uncertainties, and vested interests. It is only hope that prepares us for the challenges ahead—the challenges that we dare not shy away from, lest we drop the ball and fail our children and grandchildren.

NOTE

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