The Wicked Problem of Climate Change

with Karl E. Peters, "Living with the Wicked Problem of Climate Change"; Paul H. Carr, "What Is Climate Change Doing to Us and for Us?"; James Clement van Pelt, "Climate Change in Context: Stress, Shock, and the Crucible of Livingkind"; Robert S. Pickart, "Climate Change at High Latitudes: An Illuminating Example"; Emily E. Austin, "Soil Carbon Transformations"; David A. Larrabee, "Climate Change and Conflicting Future Visions"; Panu Pihkala, "Eco-Anxiety, Tragedy, and Hope: Psychological and Spiritual Dimensions of Climate Change"; Carol Wayne White, "Re-Envisioning Hope: Anthropogenic Climate Change, Learned Ignorance, and Religious Naturalism"; Matthew Fox, "Climate Change, Laudato Si', *Creation Spirituality, and the Nobility of the Scientist's Vocation"; Christopher Volpe, "Art and Climate Change: Contemporary Artists Respond to Global Crisis"; Jim Rubens, "The Wicked Problem of Our Failing Social Compact"; and Peter L. Kelley, "Crossing the Divide: Lessons from Developing Wind Energy in Post-Fact America."*

CLIMATE CHANGE AND CONFLICTING FUTURE VISIONS

by David A. Larrabee

Abstract. Dealing with the effects of climate change requires the consideration of multiple conflicting moral claims. The prioritization of these claims depends on the vision of a desired future, eschatology broadly defined. These visions, sometimes implicit rather than explicit, shape our decision making by influencing our sense of how things "ought to be." The role of future visions in economics, technology, and preservation of nature are explored as secular eschatologies. Four aspects of such visions are especially relevant to climate change decisions: distributive justice, land use, the relationship among humans, and our relationship to the rest of nature. Effectively dealing with such wicked problems requires that we scrutinize our visions of how the future ought to be, both technically and morally. Finally, we must foster a dialogue between competing visions so that we can forge a path that strives for consent.

Keywords: climate change; distributive justice; economics; energy; environment; eschatology; ethics; land use ethics; lifestyles; technology

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The basic cause of climate change is simple enough: human beings are putting greenhouse gases into the atmosphere (largely by burning fossil fuels) and we are destroying natural sinks of greenhouse gases (deforestation being one example). The solution is also clear, stop emitting greenhouse gases and stop destroying natural carbon sinks.

Doing nothing would cause an environmental disaster, and avoiding such a disaster will require major changes on a short timescale if a global average temperature change of over 2°C is to be avoided. Eliminating fossil fuels without replacing them would be an economic disaster. The lifestyle of the developed countries is made possible by fossil fuels. Eliminating fossil fuels usage threatens that lifestyle. Who gets what, the distribution of goods and services, is an ethical issue. This makes climate change an ethical and moral issue with economic, technological, political, and social implications.[1]

The world of my great grandchildren will be very different than the world in which I grew up. The decisions that are made today will profoundly affect the world they will inherit. I believe we are spending too much time talking about the world we are trying to avoid, and not enough time talking about what kind of world we are creating. This is the unavoidable consequence of an apocalyptic vision of the future, which is a vision dominated by fear. There also are competing utopian visions. Utopian visions assume that current problems are the growing pains that will ultimately be solved. Utopian thinking puts its faith in the eventual solution of current problems by the object of its faith, whether it be technology, economics, politics, or a teleological view of history. Another alternative is to see opportunities to move toward a future vision within each and every moment, even within a crisis. Visions of the future inform decision making that attempts to avoid the apocalypse, create utopia, or move toward a better tomorrow. Future visions drive current decisions, influencing ethical and moral choices.

This article addresses the relationship between ethics and future visions, implicit or explicit. Examples of three implicit eschatologies are explored: economic and technological eschatologies, and the role of non-human nature in the future.

Having explicit visions allow for their critique. Sharing multiple visions is essential for coming to a consensus.

Ethics, Future Visions, and Eschatologies

Which climate change strategy comes closest to enabling the kind of world in which we would like to live? The answer requires a positive vision of the future that can motivate and guide decision making. Borrowing from religious terminology, it requires an eschatology.

The Greek word *eschatos* refers to the last in a series or sequence or to the end of a process. Such a process need not occur at the end of time, but rather an end of an era, say the era of fossil fuel usage. There are many futures that are imaginable. Some visions are dismissed as pure fantasy, others as unrealistic, and some as utopian dreams. Some visions can motivate decisions. It is this link between the vision and motivation that makes a particular vision eschatological, as I am using the term. Eschatological visions are not confined to religious thinking. The existence of a secular eschatological vision within a discipline points to a faith in that discipline. Placing one's faith in a discipline and an associated vision can take on the character of a religion.

An apocalyptic or dystopian vision leads to an ethical evaluation of the future based on our fears. Rarely do decisions based on fear turn out well. A utopian vision of the future, that everything will turn out okay regardless of what we do, can lead to a detachment from the world we inhabit and hence to decisions that do not consider the pressing needs of the here and now. Still, a vision of what the future could be can help us see opportunities to change directions even in a crisis, or as Jürgen Moltmann puts it, to "perceive(s) the chances in the crises" (Moltmann 2012, 4).

Different visions place their faith in different human institutions: technology, economics, politics, or personal lifestyle change. Consider the carbon pollution caused by the automobile. Faith in technology would create green cars with green fuel. Faith in economics suggests a carbon tax. Faith in politics creates standards for automobiles. Faith in individual lifestyles promotes the use of public transportation. Those with a high apocalyptic vision may suggest that we do all of these! However, these different visions can contain conflicting goals, which can prevent a consensus of how to proceed. An example regarding our orientation to nature will be examined below.

Before we can begin to formulate a vision of the future that is neither apocalyptic nor based on an unrealistic utopian ideal, we need to recognize that we already have at least an implicit eschatological vision.

Making Implicit Eschatologies Explicit

Three brief case studies will examine how implicit eschatological thinking can be made explicit. The first case involves two economists that have grappled with the eschatological foundations of economics. The second case explores the role of eschatological visions in the choices of which technological options are to be implemented. The third case explores the relationship of humanity to the rest of nature.

Economics: Nelson vs. Daly

Robert H. Nelson has made a career of asking if economics is a religion (Nelson 2001). His unequivocal answer is that economics is a secular religion (Nelson 2006) and that it is currently being attacked by another secular religion, environmentalism (Nelson 2010).

"The story of 'economic religion' is that human beings can produce an ideal world, or heaven on earth, by ending material poverty through productivity, efficiency and scientific management" (Nelson 2010, 348). The means to achieving that end lie within the market, whose operation effectively eliminates the inefficient, maximizing economic well-being. Historically this has led to economic growth as measured by gross domestic product (GDP).

The market allocates resources among competing business and individuals by balancing economic costs and economic benefits. Who gets what is a moral and ethical decision. Thus the market is the ethical and moral administrator. Not all economic costs are considered valid. For instance, the relocation cost of an individual who has lost his or her job due to a plant closing, and who has to relocate, is not a consideration of the plant which closed. The future health care costs due to pollution in the manufacture of a product are not a factor in the pricing of that product. Only those costs which affect the GDP in the short term are considered valid national economic costs. Individual freedoms are also subject to the market. Income and wealth largely determine what we can do, where we can live, the quality of our healthcare, and where we can travel.

Nelson seems to have accepted the fact that economic religion is in decline, largely because it has failed to deliver on its promises.

> The more fundamental problem with economic religion, however, is moral and theological. The core tenet, that material progress will solve the problems of the human condition, did not fare well in the history of the twentieth century. It is still possible to believe that economic progress is desirable. . . . But it has become much more difficult . . . to believe that the full sources of human sinfulness lie in material causes and that the evils of the world can therefore be cured by economic solutions alone. (Nelson 2010, 341)

In an article for the *New Atlantic* in 2013 Nelson makes a note that hints at how his vision of economics has changed: "it may be that rather than the elimination of material scarcity, the central theme of our future civil religion should be the maintenance of human freedom" (Nelson 2013, 50).

If Nelson is a high priest of economic religion, Herman E. Daly is a prophet speaking to the need for economics to mend its sinful ways. "It is not enough simply to attack the progrowth orthodoxy; we must have an alternative vision. But neither is it sufficient to have an alternate vision; we must expose the errors of the prevailing view" (Daly 1991, xv).

Daly's basic premise is that the economic system is an open system embedded within the "total environment or ecosystem" (Daly 1973, 7). Consequently economics has to be rethought "along lines more congruent with a finite physical world." The iron ore in the mountain, the coal under the ground, and the sunlight shining on the wheat field all exist outside of the economic system. Once we mine the metal and transform it into a cell phone, which is used and ultimately discarded, the waste is returned to the environment outside of the economic system. Thus economic systems exists within larger systems, within ecosystems, and ultimately within our Planet Earth.

The concept of growth is replaced by one of an optimum situation. If society is "below" the optimum it should grow; if it is above the optimum it should shrink (Daly 1996, 48–52). The optimum hinges on the thriving of both humans and the rest of the biosphere—biocentric thriving.

Rather than accept gross national product as the measure of the health of the economy Daly advocates for three measures: costs, benefits, and capital (Daly 1996, 107–16). The cost account would measure all costs, the traditional economic costs as well as the externalities. The benefits account would seek to accumulate all the benefits. The capital account includes not only money, but resources, infrastructure, and all other forms of capital. This highlights how benefits are being attained. Is a transaction a direct deduction from the capital stock, essentially consuming the future? Is a current cost actually increasing the capital stock? It is the interplay of the three indicators that helps determine which costs are acceptable costs.

Daly considers the problem of determining how much energy is required by the economic system and identifies three variables that determine energy use: population size, per capita energy consumption, and the technology employed (Daly 1991, 141). Determining the optimum Daly uses a set of ethical propositions which I will rephrase as long-term stewardship, consuming just enough over unlimited desires, an ethical preference for the poor, and meeting the needs of the present population over reproductive freedom.

How do you manage the transition to renewable energy: outlaw fossil fuels, economic pressures (taxes), social pressures, or voluntary avoidance? Daly proposes a scheme very similar to cap and trade (Daly 1991, 61–68). Limits are placed on fossil fuels and quotas are distributed evenly among the populace and freely traded. To minimize inequality Daly proposes minimum and maximum limits on wages and wealth (Daly 1991, 53–56). The most controversial measure that Daly suggests is the establishment of transferable birth licenses to limit population growth, which Daly credits to Kenneth Boulding (Daly 1991, 56–61). Individual freedoms are limited by the government, but distributed on a market-based mechanism.

Daly has recently published an article in which he explicitly talks about eschatology in relationship to economics. At the end of the article he lays out his eschatology.

> Without growth the only way to cure poverty is by sharing. But redistribution is political anathema. Without growth to push the hoped for demographic transition, the only way to cure overpopulation is by population

> control—a second anathema. Without growth the only way to invest in environmental repair is by reducing current consumption—the third anathema. Three anathemas and you are out. . . . We will soon enough have to move from a failed growth economy to a steady-state economy—from idolatrous efforts to build a substitute "new creation" or "smarter planet"—to humble stewardship and sharing of the present creation, with the poor, with future generations, and with other species, for as long as it lasts. (Daly 2015, 181)

A side-by-side comparison of Daly and Nelson is given in Table 1. Daly and Nelson point to several issues that should be addressed in any economic vision with respect to climate change:

(1) How much growth, and whose growth, is important?
(2) What should be the role of the market in making ethical decisions?
(3) What is the role of sharing (redistribution) of wealth and energy use?
(4) How much consumption is enough?
(5) Do individual freedoms need to be restricted for a sustainable future?

Technological Options and Lifestyle Assessment

Because fossil fuels, a source of energy, drive climate change, let's consider the United States (US) energy budget. Lawrence Livermore National Laboratories publishes an annual graphic that tracks the flow of energy in the US economy. The energy from all sources consumed by each sector is split into waste (rejected) energy and useful energy. The data for 2016 is shown in Table 2 in the columns labeled useful energy and rejected energy (LLNL 2017). The efficiency is just the useful quads (quadrillion BTUs) divided by the sum of the useful and rejected energy. The first column gives the percentage of the input energy that is in the form of electricity for each sector. Electricity itself is generated with an overall efficiency of 34 percent,

Table 1. Comparison of Nelson and Daly

	Nelson	Daly
Economics	Independent system	Subset of a larger system
Purpose or goal (VISION!)	Elimination of material wants—will solve society's problems.	Biocentric thriving
Growth	Recognizes costs and benefits of growth	Only if below optimum situation—sharing
Measure of growth	GDP	Three indicators for health
Valid costs	Nationwide cost benefit	Quantifiable?
Ethical decision maker	The market	Outside considerations
Individual freedom	Market driven/economic	Macro limited, market

Table 2. United States usage of electricity (2016) and carbon emissions (2014)

End use	% Electric input	Useful energy	Rejected energy	Efficiency	% Total energy services	CO_2 emissions (2014)	CO_2 % total
Industrial	13%	12.0	12.5	49%	39%	962	18%
Commercial	51%	5.86	3.16	65%	19%	232	4%
Residential	44%	7.12	3.83	65%	23%	341	6%
Transportation	0.1%	5.86	22.0	21%	19%	1,830	34%
Electrical generation	N/A	In the above	24.9	34%	na	2,040	38%
Total		30.84	66.4	46%	100%	5,410	

Energy is expressed in Quads or quadrillion BTUs.
CO_2 emissions are expressed in millions of metric tons.

which not only includes the efficiency at the plant but losses in the delivery as well. The sum of all the useful quads is just the total energy services used by the economy (30.8 quads). The next column shows the percentage allocated to each sector. This is not the same as the total energy consumed by the sectors since the sectors have different efficiencies. For reference the last columns show the CO_2 emitted from each sector (not including that used to produce their electrical consumption) and the percentage of the total CO_2 emissions (LLNL 2015). As the United States increases the use of solar and wind energy to displace fossil fuels, the electric energy use will rise. If the sum of the inefficiencies in the use of electrical energy can be held to 15 percent we would need approximately 36.23 quads of electrical energy to run the country. This is an increase of 288 percent, just under three times the current 12.6 quads of electrical production.

Industrial plus commercial energy usage accounts for over half of our energy services. This is related to the material consumption of our society. We currently live in a society that puts a high value on material consumption, with marketing trying to convince us that our desires are in fact needs. To what extent are we to find meaning within the stuff that we use and own? Many religions warn against excessive wealth and ownership.

The second largest category of energy consumption is our residence, where bigger seems to be better. Bigger homes require more energy to heat, to cool, and to light. According to the US census the median square feet of floor area for a single family house constructed in the previous four years was 2,422 ft^2 in 2016 (US Census Bureau 2017, 16), which is over twice the size of the average useful floor area in Germany (Dol and Haffner 2010, 51). Smaller houses require less energy to heat, cool, and light.

Transportation is the most inefficient energy usage in the list, consuming 19 percent of our useful energy and fully 34 percent of the CO_2 emissions, second only to electric generation. Designing an efficient transit system that did not depend on the internal combustion engine would seem to be nearly as important as transforming our electric system from fossil fuels to renewable sources of energy. Eliminating the automobile strikes at the very heart of US individualism, the sense of freedom and independence that the automobile gives. The automobile is such an integral part of the US lifestyle that this aspect of climate change is largely absent from the climate change discussion, with the assumption that adequate technological advances will be made to replace the current automobile by an all-electric one.

The easiest way to reduce our carbon emissions is to consume less, travel less, and live in smaller spaces. This is a reduced material standard of living. Will the populace of the developed countries accept a reduced material standard of living? The usual assumption is that the answer is no. The commitment to maintain our current lifestyle creates two moral issues: the ethics of delay and the ethics of adaptation.

Carbon capture and storage, fracking and improved natural gas electric generation, are examples of technologies that reduce emission of greenhouse gases per unit of energy. These technologies delay the inevitable transition to a fossil fuel–free economy but minimize present lifestyle disruptions. Should we invest in these intermediate technologies or go straight to renewable energy sources, with some lifestyle disruptions? Which is valued more, lifestyle or planetary impact?

How much effort is to be expended on adaptation, mitigation and remediation? Fertilizing the ocean, putting solar-reflecting particles in the upper atmosphere, building a solar shield for the earth are all examples of technologies proposed to mitigate damage caused by greenhouse gases. It is a moral choice that our present consumption today is more important than the potential problems it might create in the future.

The wicked nature of climate change is to a large extent the desire to maintain our current material consumption without bearing responsibility for the consequences of our actions.

Nature as a Participant

Human life is lived in relationship with the rest of the planet for the food we eat, the raw materials we consume, and the places in which we deposit waste. Non-human nature has been reduced to a provider of "eco-services" to humans—air, food, experiences, waste dumps, and raw material. Nature has been reduced to its instrumental value with little to no account taken of any non-instrumental value. We have maximized human welfare at the expense of the rest of the biosphere, and this has come back to hurt us.

Confronted with this reality, there are really only two visions. One vision is that we preserve the health of the existing biosphere as the primary priority. The other vision is that we engineer a new biosphere here on

Earth. Modifying the biosphere on a global scale started with agriculture. Terraforming the Earth runs the risk that during the process something will go terribly wrong. The Earth's biosphere is so intricately interconnected that it seems unlikely that one could terraform part of the Earth without requiring adjustments throughout the rest of the planet.

An eschatological vision that places a high intrinsic value on nature will want to minimize human interference in the biosphere. However, for someone who both wants a high material standard of living and has a strong trust in the ability of humans to manage nature, a strong interference with the operation of the biosphere will appear justifiable. Since the effects today are global, there is no way to partition the planet to satisfy both points of view. The visions of the environmentalist are fundamentally at odds with the visions of the geo-engineer. Environmentalism is fundamentally at war with the current economic system as highlighted by Nelson (Nelson 2010).

Critiquing Eschatologies

There are many possible visions of the future that can motivate our actions. If an eschatological vision is to be more than a utopian fantasy, it must be realizable. This requires technical critique. Visions also require an ethical and moral critique. Apocalyptic visions can lead to lifeboat ethics, where the needs of some are sacrificed for the needs of others (Hardin 1974). Utopian visions can ignore the suffering in the present as a necessary evil to bring about a better future. Both apocalyptic and utopian visions run the risk of silencing the "other" that is sacrificed for the greater good. Climate change is a systemic issue, a consequence of our past eschatological visions, secular and religious, that inform our ethics and our motivations for transforming our society into what it "ought to be." Changing such a system without challenging the underlying visions and ethical principles is unlikely to eliminate the detrimental consequences of those visions.

An ethical critique of a vision within the community that shares that vision is almost impossible. The solution is to listen to voices outside the community.

Lifeboat Ethics

The Earth is finite. The Earth can be likened to a spaceship, powered by the Sun, which provides all the necessary resources and waste recycling necessary to support life. Technological development is pushing against both the limited material resources of the planet as well as the planet's ability to absorb the waste of modernity. Carbon dioxide's relationship to climate change is only one example of modernity's challenge to the stability of the planet. The increasing challenge to the Earth's limitations is driven by an increasing material lifestyle of an increasing number of people. Garrett

Hardin likened the situation to a lifeboat in his essay "Lifeboat Ethics: The Case Against Helping the Poor" (Hardin 1974). Hardin likens the world to a lifeboat with a capacity of sixty people, with fifty people already on board and a hundred people in the water. He argues that the fifty people on board should not allow any more people on the boat, and retain the ten extra spaces as a safety margin against future calamity.

Lifeboat ethics is an apocalyptic vision of the future. It is the idea of a fixed number of positions on the lifeboat that draws attention to population growth, more people creating an increased demand for a fixed number of seats. The Earth is not a lifeboat with a fixed number of seats. The limitations of the planet depend both on the number of people and the lifestyle they choose to enjoy. The number of seats in the lifeboat depends on the lifestyles of those in the boat. The developed world's idea of a lifeboat is more akin to a luxury yacht when viewed from the perspective of those in the water.

To push Hardin's analogy, the Earth has a variety of lifeboats, some luxurious (the developed countries), some barely afloat (the least developed countries), with the poorest left in the water without a lifeboat. The history of the developed world is one that has exploited the world's resources, not only within their territories but beyond them as well. The developed world has assumed it has the right to deprive the less developed countries and the indigenous people of their traditional resources in order to maintain the developed countries' lifestyle. The current economic system supports the developed countries' expropriation of the world's resources. Climate change is a wakeup call that the current situation cannot continue much longer. The required changes challenge the vision of a modernized world living at an ever higher material standard of living. The ethical problems with trying to maintain that vision are most clearly seen by the developing countries and the indigenous peoples of the world.

Indigenous Voices

Environmental decisions tend to be made by governments and through treaties between governments. The developing and less developed countries are a party to this process, though in practice the less developed nations are dominated by the developed countries. The governmental process only minimally represents about 5 percent of the world's population, who are the indigenous populations within those countries (UNDESA 2009, 1). Indigenous people, who were originally associated with a place with their own distinct culture and beliefs, have been largely stripped of their sovereignty by an occupying culture. Indigenous peoples are present within the developed countries as well as the developing countries. Their culture and lifestyle practices are generally tied to a particular place. Indigenous peoples' traditional knowledge includes caring for their land, Mother

Earth. Current environmental problems, including climate change, are a result of modernity; yet indigenous people are suffering not only from the consequences of environmental degradation but from some of the strategies that the developed world is using to prolong its dependence on fossil fuels.

The United Nations Declaration on the Rights of Indigenous Peoples[2] (UNDRIP) recognizes indigenous peoples' rights to their lands (Article 10, 26), to utilize and control the resources (Article 26), "to participate in decision-making which would affect their rights" (Articles 18, 19), to "free and informed consent prior to the approval of any project affecting their lands or territories and other resources" (Article 32), "to the conservation and protection of the environment," (Article 29), and to have the right of redress (Article 28) (HRC 2007). The United Nations (UN) acknowledges that "Indigenous peoples are among the first to face the direct consequences of climate change, owing to their dependence upon, and close relationship with the environment and its resources" (UNPFII 2008). Indigenous peoples have not had direct representation within the United Nations climate change negotiations; however, the Indigenous Peoples' Caucus has observer status which gives them the right to lobby the delegates. Indigenous critiques of the climate change negotiations have been ongoing and published, from the Quito Declaration in 2000 (RIOLC 2000) through the Paris negotiations (IIPFCC 2015) and beyond.

One consistent theme is the exclusion of indigenous peoples from the decision-making process of the United Nations Framework Convention on Climate Change (UNFCCC). "Some current solutions to climate change such as those under the Clean Development Mechanism (CDM) have serious implications for the rights of Indigenous Peoples. Therefore, it is imperative that Parties recognize and respect the rights of Indigenous Peoples to their lands, territories and resources, their cosmo-visions and their rights to free, prior and informed consent (FPIC). With the right to say 'No'" (IIPFCC 2015). This would seem to be consistent with the articles in UNDRIP quoted above. Yet the indigenous peoples are not present at the bargaining table. Their hopes for a strong statement regarding the rights of indigenous peoples at COP21 climate talks in Paris were dashed when the language involving indigenous peoples was removed from the binding section of the final document (Rowling 2015).

The clean development mechanism (CDM), established by the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), "allows governments or private entities in industrialized countries to implement emission reduction projects in developing countries and receive credit in the form of 'certified emission reductions,' which they may count against their national reduction targets" (UNEP 2002, 4). The UNFCCC also established a program to reduce emissions from deforestation and degradation (REDD). This program is designed to reduce deforestation and maintain the ability of the forests to act as carbon sinks (UN-REDD 2009). Both of these programs are market-driven approaches that commodify the forests, enabling markets to decide on the best use of the forests. For indigenous peoples who live in the forests, land tenure is an ongoing struggle. Both CDM and REDD (and the subsequent REDD+) have the potential to interfere with those rights. There are many examples of indigenous people being forced off their land so that others can derive economic benefit from the land (Stavenhagen 2013, Chapter 8). Commodifying the land adds further incentive for such displacement. The forests are under national jurisdictions, and United Nations protections are not always sufficient to prevent economic interests from taking precedence over indigenous rights. If there is one bright light, REDD has brought indigenous rights into the conversations about the forests.

Modernity envisions forests as a commodity, something to be consumed, or not, depending on the needs of the developed world. "Eco-services" has become the term that describes valuing the environment, and forests, in terms of the financial benefits that the developed world derives from them. In an increasingly urbanized modern world, nature has become the "other," something to be used, samples preserved for ecotourism, places to be used for the benefit of cities, to be harvested for eco-services, not valued for itself. Nature is subjected to cost/benefit analysis and economic development. Nature only has value insofar as it benefits the modern city. There is a refusal to see human beings as a part of nature, with a kinship to all of life. On the other hand, the indigenous view of nature is closer to that of kinship, of a shared existence and history, of interdependent relationship, and reciprocity to all of nature (Salmon 2000). The world is something to be nurtured, preserved and cared for, not because of eco-services, but for nature's own sake. There is a fundamental clash of visions between the indigenous view of nature and that of the economic cost/benefit calculus of the developed countries.

To return to Hardin's lifeboat, indigenous peoples are not in the water, they are in their own sustainable boats. Global development is throwing them out of their boats, into the water, as the developed world's consumption continues to grow. The issue is the developed world's lifestyle, the usurpation of the world's resources largely for the benefit of the few, and the destruction of the environment on the altar of economic efficiency. Indigenous peoples have something to tell to the rest of the world's peoples.

Developing Countries

The developing countries are attempting to follow the developed world into a future with a higher material standard of living. Capitalistic, socialistic, or communistic, they share the vision of a future that incorporates the modern worldview of a consumer economy. The question becomes how we divide up the world's resources between the developed and the developing countries. That includes the remaining CO_2 emissions.

Developing countries do have a seat at the UNFCCC meetings and have played a major role in the negotiations. There is a limited amount of carbon that can be put into the atmosphere and maintain the average global temperature change to less than 2°C (Allen et al. 2009). Measured from the start of the industrial revolution, most of this space has already been taken up by the industrialized nations. The key issue between the developed and the developing nations is how to split up the remaining emissions. Without REDD and CDM the total amount of CO_2 that could be released would be lower and the CO_2 emissions pie would be smaller. The dominant issue is therefore one of distributive justice.

The Developed World's Response

The developed world's response has been a concern with "fixing" the symptoms rather than listening to a critique of the fundamental cultural issues that drive climate change, such as the following:

(1) The developed world is the cause of climate change and ethically must bear the burden of cleaning up the mess that has been created.

(2) The fundamental problem is our obsession with material wealth and the neglect of our obligations to the Earth. Therefore, any lasting solution needs to abandon the obsession with material wealth and must bring our obligations to the Earth to the forefront of our ethical concerns.

(3) Climate change issues are intimately tied to issues of distributive justice and land use. Solutions that impose additional burdens on those that are least responsible for the problem are morally bankrupt.

Distributive Justice Issues

As a child I loved mashed potatoes. One Thanksgiving dinner, when the extended family was gathered, the mashed potatoes were initially placed right in front of my seat. After grace, I took a sizable portion and passed the potatoes. As the various dishes were passed around I would both take my share and eat some mashed potatoes. Before we had finished passing around the meal I had eaten my mashed potatoes and asked for more. My father looked at me and declared "no one gets second servings until everyone gets their first serving." Although I didn't appreciate it at the time, my father was giving me a lesson not only in table manners, but in distributive justice as well.

Climate change is a global problem involving all the worlds' people and the non-human occupants of the planet as well. The analogy of a family dinner can provide us with some guidance.

Who Is Invited to the Dinner Table?

The trite answer is everybody, but seldom is this actually the case. In an economic vision, not everyone is invited to the table, only those that have sufficient economic resources to pay for the meal (or have someone else pay for their meal). The international conversations about climate change have involved governments, largely excluding the voices of indigenous peoples. The role of the non-human is reduced to providing "eco-services" for those at the table. This effectively puts non-humans on the table, to be consumed.

Who Gets What: Needs versus Desires

Our lifestyle, both as individuals and as a society, affects our carbon footprint. We can think of our lifestyles as being represented by how much food we eat from the table.

The first serving at the international table of economic development and energy usage would be the satisfaction of survival needs: healthy air to breath, adequate shelter against exposure, clean water to drink, adequate nutritious food, safety, and medical attention when needed.

Perhaps the second serving is that which allows for human flourishing beyond mere survival. A child that has musical talent, but no instrument to play, cannot develop that talent. A student with a gift for mathematics, who cannot afford college, cannot develop that gift. Where do we draw the line between flourishing and using material consumption as self-medication, self-gratification, economic empowerment, or as a status symbol?

Portion Control, or How Much Energy Do We Need?

How much energy is needed to provide everyone with a first and second serving? We can start to answer this question by looking at the relationship between the UN Human Development Index (HDI) and energy consumption. The HDI uses three measures to gauge human flourishing. The first is life expectancy at birth. The second measure relates to education. Finally, the standard of living is measured by the natural logarithm of gross national income per capita. The HDI takes a geometric mean of a normalization of these three components, so the resulting index runs from a theoretical low of zero and a theoretical maximum of one. This index is correlated to the electrical energy use per year per capita. Hospitals, police stations, lighting, electric stoves, air conditioning, trains, and a host of other items require electricity to operate. As a country increases these services to its populace, the electrical consumption of energy per person also increases. Plotting HDI vs. electrical consumption per capita, measured in kilowatt

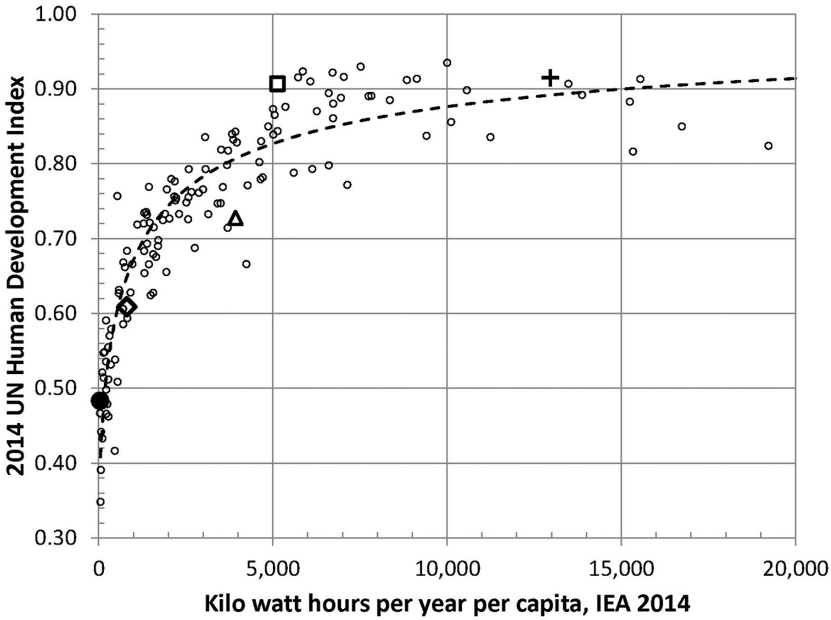

Figure 1. Human development index as a function of annual electrical energy usage per capita.

Table 3. Selected countries from Figure 1

Country	Kwh/y/p	HDI	Marker Shape on Chart
Iceland	53,896	0.899	Not shown
Norway	23,001	0.944	Not shown
United States	12,962	0.915	Plus sign
United Kingdom	5,131	0.907	Square
China	3,927	0.727	Triangle
India	805	0.609	Diamond
Haiti	39	0.483	Solid circle

hours per year per person (kwh/y/p), shows a correlation between the two measures as shown in Figure 1.

Figure 1 excludes two countries with very high electrical consumption per capita, and has separately indicated five countries (see Table 3). It is safe to say that HDI increases rapidly as the amount of electricity in a society rises. However, by the time we reach 5,000 kwh/y/p the curve is getting quite flat. Above 10,000 kwh/y/p there seems to be no noticeable increase in the HDI as electrical energy consumption increases.

Where along this curve should we place a line where energy consumption below the line is inadequate for human flourishing and above it is the excessive "third helpings" of energy? The UN uses a value of 0.8 for the HDI as the boundary between a high HDI and a very high HDI. This is about where the curve starts to turn over and saturate. This boundary corresponds to an electrical usage of a little over 3,500 kwh/y/p. A world with an equal distribution of energy resources with sufficient energy so that everyone could live in a country with an HDI of 0.8 would require 3,500 kwh/y/p times 7.5 billion people (at present) or 26,250 billion kilo watt hours (kwh) each year. The total electrical production worldwide was 23,812 billion kwh in 2014, with a worldwide consumption of 21,963 billion kwh (IEA 2016, 24, 48). Production would only have to rise about 20 percent to meet the demand. At the moment we do not NEED significantly more electrical energy if we are willing to share.

A non-sharing approach could bring all those countries below 3,500 kwh/y/p up to 3,500 kwh/y/p, and still allow those above that level to continue consuming at their present level. Global consumption would rise from 21,606 to 31,807 billion kwh per year, a 47 percent increase in the world electrical demand.

Neither of these scenarios has considered population growth. The population in 2035 is projected by assuming that present average population growth rates (2000–2015) for each country in this database remain fixed (Jahan and Jespersen 2015). Assuming that the current per capita electrical consumption figures remain fixed, the countries with lower energy consumption per capita will have to add an additional 1,397 billion kwh per year, a 32 percent increase. The higher per capita energy consumption countries will require an additional 3,059 billion kwh per year, an 18 percent increase. In this scenario the countries with the highest HDI will require more additional energy than the lower HDI countries. Maintaining the status quo requires more investment at the top than at the bottom (see Table 4).

If the countries with low per capita energy consumption are to raise their consumption to 3,500 kwh/y/p in 2035, without addressing their population growth, this will require an additional 16,365 billion kwh per year over the 2014 level. In this scenario the total energy consumption in the two cohorts would be about the same, but the numbers of people in the lower per capita cohort still outnumber those in the highly developed countries.

Does moving to a zero population growth (ZPG) scenario change the short range results significantly? If we assume that the population growth rates for each country decline in a straight line starting in 2020 until they reach zero in 2050, there will be about a 5 percent reduction overall. At least in the short run, population growth is less of an issue than the disparity between the energy budgets of the highly developed countries and the developing countries. The results are summarized in Table 4.

The HDI vs. electrical energy consumption curve in Figure 1 suggests that many countries with a high HDI could lower their electric

Table 4. Global energy growth scenarios

	<3,500 kwh/y/p	>3500 kwh/y/p	Total in Database
Population (IEA 2016)	4,153	2,786	6,939
2014 consumption	4,337	17,270	21,606
2014 minimum of 3,500	14,537	17,270	31,807
Straight Projection to 2035			
2035 population[a]	5,915	3,213	9,127
2035 consumption[b]	5,734	20,329	26,063
2035 minimum of 3,500	20,702	20,329	41,031
Approach to ZPG in 2050			
2035 population	5,540	3,126	8,666
2035 consumption	5,445	19,693	25,138
2035 minimum of 3,500	19,390	19,693	39,083

Energy consumption is expressed in billions of kwh.
Population is expressed in millions.
[a]Growth rate averages for 2000–2005 and 2010–2015 are used as presented in (Jahan and Jespersen 2015, Table 8).
[b]The effective kwh/person for the cohort declines due to some negative population growth in countries near 3,500 kwh/p/y.

consumption per capita without a significant reduction of HDI. The United States consumes almost 13,000 kwh/y/p and has about the same HDI as the United Kingdom which consumes less than half that amount (see Table 3). This suggests that there are significant energy savings in some countries with a high HDI that would both make the transition to renewable energy easier and free up capital to help develop the lower HDI countries. This raises two basic questions we should be asking about the future that is emerging as a result of climate change.

(1) Is an eschatological vision of a future with massive differences in human development acceptable? If not, how long are those at the bottom expected to wait before they are helped up the ladder?

(2) Do the developed countries have the moral right to continue developing when there is significant underdevelopment in much of the world?

There is an ethical principle that those who are responsible for a problem bear the primary responsibility for its solution or abatement. This historical approach has been rejected by the United States, even though the largest contributor to the historical cumulative emissions of CO_2 is the United States (about 28 percent) followed closely the European Union (30 countries) (about 24 percent). China, although the largest current contributor, has historically only contributed about 11 percent. India, much farther down on the list, has contributed less than 3 percent (Friedrich 2015).

The United State and the thirty European countries bear the bulk of the historical responsibility. Since the atmosphere is a shared resource and the developed world has used up its fair share, an immediate reduction in CO_2 emissions, even at the expense of lifestyle reductions, is the correct moral response.

Land Use

Viewed from space the Earth looks like it has a lot of unused land. When we drive through the countryside, or visit a national park, the unused space on the planet seems vast. It seems that there is plenty of land on which to place solar cells, windmills, biofuel farms and still have room for parks, agriculture, places for wild animals to roam and space for indigenous peoples. But the land use of an urban center is far larger than its physical footprint. As an example, the city of New York consumes about 1.2 billion gallons of water a day, serving 9 million people, extracted from a 2,000-square-mile watershed area (NYDEP n.d.). This represents a land footprint of about one-seventh of an acre per person outside of the city just for water use alone. The land use footprint also includes the land for agricultural crops, pasture land for animals, and waste disposal. Energy generation also requires land for solar panels, wind farms, dams for hydroelectric, land to grow biofuels, oil wells, fracking sites, coal mines, and siting for power generation facilities. The land use associated with an urbanized world dwarfs the actual footprint of the city.

There are three important questions that need to be asked in any such future vison with respect to land use. First, since land is in limited supply, from what other application will this land be taken? Second, what will be the impact on the inhabitants of the land? This includes animals and plants as well as humans. The third question is one of scale. How does the size of the proposal compare to other human endeavors that modify the landscape?

To focus on only one land use issue, consider the land that would be required to meet the US energy requirements by using solar panels. Lowering US energy consumption would reduce the land area footprint of the energy source. Thus the size of the footprint is an ethical decision about land use versus lifestyle.

How Much Land Is Required to Power the United States from Solar Panels?

Renewable energy is part of the solution of climate change, so it is only natural that champions of a given energy source make the best possible argument. But this is marketing, not science. To evaluate the implications, realistic figures that reflect actual implementation are required.

The simplest calculation of the land area required for powering the US from solar panels is to pick an area with a lot of sunlight, use a high-efficacy solar panel, and calculate the square area necessary to power the current

US electrical grid. If we take the US electrical grid in 2014 (31.2 kwh per person per day), the highest efficiency solar cell available (about 46 percent), and place it in the Southwest with a high solar insulation (6.5 kwh per square meter (m^2) per day), we find that this requires an amazingly small square that is about thirty-six miles on each side. Express that as a percentage of the total land area of the United States and you get a figure of less than 0.1 percent. Sounds great!

There are a number of problems with this calculation. First, the typical conversion efficiency in a photovoltaic panel today is 10–15 percent, not 46 percent. Second, we cannot locate all the solar cells in one place due to the cost of building the network of transmission lines and the losses in the lines themselves. Relocating the solar panels to local users lowers the effective average solar insulation to perhaps 4.25 kwh per m^2 per day. Third, if we pack the panels too close together one panel will sometimes be in the shade of another panel. The previous calculation gives the panel area, not the ground area. Taking all of these factors into account, the calculations yield a square 111 miles on a side, or about 0.35 percent of the land area of the United States. (See Appendix 2 for details.)

The National Renewable Energy Laboratory (NREL) has looked at the solar possibilities in each state. Their average figure is that the United States would require about 181 m^2 per person (Denholm and Margolis 2007, 18). Since the electrical energy required by the United States per person has fallen by about 5 percent since this report, a more current estimate might be about 172 m^2 per person. US population is about 323 million people, so if you put all the local squares together, NERL's estimate results in 55.5 billion square meters; a square 146 miles on a side or 0.61 percent of the land area in the United States.

However, the NREL only considers current electrical use. If we wean ourselves off of fossil fuels, the renewable resources need to account for all of our energy services, or approximately three times our current electrical use, as discussed earlier. We would need to grow the electrical system to handle all transportation. All houses, factories, and commercial establishments would have to be converted to electrical heat. Thus if we powered the United States from solar photovoltaics alone it would require an area (distributed over the United States) the size of a square 254 miles on a side, about 1.8 percent of the US land area, quite a bit larger than the initial estimate.

Comparing the total land area required for solar photovoltaics to the total land area of the United States is a comparison designed to yield low numbers, rather than reveal the extent of the project. NREL has estimated that the solar potential of rooftops amounts to about 39 percent of annual electric sales in 2013 (Gagnon et al. 2016, viii). This is a significant contribution, but not sufficient to power the US electrical grid from solar energy. Covering parking lots with solar panels represents another option that requires building the support structure to hold the solar panels above the automobiles. Mikhail Chester et al. estimate, in their second scenario, that there are approximately 520 million surface-level parking spaces in commercial parking lots, residential spaces, and parking spaces associated with buildings (Chester et al. 2010, 2–4). If each parking space was ten feet by twenty feet this represents 3,730 square miles of area. Adding 33 percent to the area of the parking spaces to account for access to the parking spots gives an estimate of just under five thousand square miles of area that could be covered in solar panels. Solar covered parking might supply a little under 24 percent of the electrical needs of the US electrical grid in 2014 ($\frac{5000}{146^2}$). Rooftop solar plus solar-covered surface parking areas together might optimistically supply 63 percent of the current (2014) electrical grid. In 2016, the total contribution of nuclear, hydroelectric, geothermal, and generation of electricity from waste was a little less than 27 percent (EIA 2016, 109). Adding this to the contribution for solar you arrive at about 90 percent of the electrical sales for 2014. Current installations of wind would add about another 4.5 percent, bringing the total to about 95 percent. The construction and integration into the grid would have to be accomplished with in the next thirty-three years if the United States is to wean itself off of fossil fuels by 2050. Electrical energy usage only accounts for about 35 percent of the total US energy services. Therefore, all of these changes represent about 33 percent of the needed energy if all fossil fuels are to be replaced by renewable energy sources. If solar were used to generate the remaining 67 percent of the energy, the additional land required would have to come from somewhere else.

Another comparison would be to compare the size of the required solar arrays to the size of something that humans have built over an extended period of time. The total paved road area (not including parking areas) in the United States is estimated to be about 18,500 square miles as shown in Table 5. This road system is the result of about a hundred years of effort. To meet current needs, we would need solar arrays larger than the size of all the paved roads in the United States. If we wanted to convert to an all-electric economy we would need to triple that number. The results are summarized in Table 6.

Table 7 lists the various uses of land in the United States in millions of acres. The total area of the solar arrays required is about 41.2 million acres. From where are we to get the required 41.2 million acres? This is more than 10 percent of the cropland in the United States. We could stop eating meat, which would free up grazing land! Perhaps almost one–third of the forests in which livestock graze could be cut down and replaced by solar panels. Perhaps we could level 16 percent of the rural parks, recreation areas, and wildlife areas. If the full potential of rooftop solar was realized, and all available surface parking facilities were covered in solar panels, these numbers would be cut by 33 percent. If our eschatological vision

Table 5. Estimation of the surface area of US roads (2015)

	Source	
Total lane miles of urban roads	(1)	2,710,533
Total lane miles of rural roads	(1)	6,026,054
Total lane miles of roads	(1)	8,736,587
Total lane meters of roads lanes		14,057,168,483
Width of a lane in meters	(2)	3.4
Total square meters of road		47,794,372,842
Total surface are of road in square km		47,794
Total Surface of the road in square miles		18,453
2016 Surface area of the US in square km	(3)	9,831,510
2016 Land area of the US in square km	(4)	9,147,420
Roads as % of US land area		0.52%

(1) (Nguyen 2017, Tables 1–4, 6, and 5).
(2) (US Department of Transportation, Federal Highway Commission 2007, 28) This is a value that is a little lower than freeways (3.6) but higher than the mean of local roads (2.7–3.6).
(3) (FAO 2017b).
(4) (FAO 2017a).

Table 6. Solar land use under various assumptions

Correction	Side of Square in Miles	% of Total US Land Area	As % of US Road Area
Original calculation	35.8	<0.1%	7%
15% efficiency	63	0.11%	21%
4.25 solar insulation	78	0.17%	33%
Land area with tilt	111	0.35%	67%
NREL calculation	146	0.61%	116%
NREL all electric economy	254	1.82%	349%

of maintaining a consumer-driven lifestyle is to continue to consume, then choose we must. If we want to grow and consume more and more, manufacturing the products within the United States, the energy system will have to grow as well. The land footprint of a society that insists on continually growing its material standard of living will continually increase until it runs out of room.

Other Considerations

There are many other considerations that are important in evaluating future visions, among them the following:

- Population growth is a serious long-term issue. But with whose population growth should we be most concerned?

Table 7. United States land area by use

United States Land Use (millions of acres)	2002	2012	% Total (2012)
Cropland	380	379	17%
Grassland pasture and range	649	668	30%
Forest-use land			
Forest land not grazed	517	502	
Forest land grazed	134	130	
Total forest land	651	632	28%
Urban areas	59	70	3%
Special-use areas			
Recreation and wildlife	242	254	
Transportation	27	27	
Defense and industrial	17	27	
Farmsteads and farm roads	11	8	
Total special-use areas	297	316	14%
Miscellaneous other land	228	196	9%
Total land area	2,264	2,260	

Data include all fifty states. Miscellaneous land includes "uses not inventoried, and areas of little surface use such as marshes, open swamps." 2002 data is from Lubowski et al. 2006; 2012 data is from Bigelow and Borchers 2017.

- The scaling up of technologies to a global level often raises serious obstacles. One example is the limited supply of lithium available for electric car batteries (Vikström et al. 2016).
- Does the vision meet the needs of the rest of the planet? Not all of these needs are currently well defined (Rockstrom et al. 2009).
- Does the vision meet the needs of all the people on the planet?
- To what extent does the vision limit personal freedom? How does it accomplish the required limitations?

Sharing Visions to Create New Possibilities

When speaking with others who have different visions, it is tempting to assume that they don't really understand the problems, and that lack of understanding is the source of the differing visions. But this need not be the case. Two people can agree on the problems, agree on the causes, agree on who is responsible, and disagree on what should be done. To come to any consensus we must be able to discuss differing visions without attacking each other. This means both listening and being listened to.

A common approach to ethical decisions is to start with an assumed ethical outcome and then search for arguments that support that outcome, putting an initial gut instinct ahead of careful thought. If the arguments supporting the initial reaction are shown to be weak, the search begins for another argument supporting the initial gut instinct. If that argument is found to be weak, still another is sought, and another, and another. Any dialogue partner is frustrated because argument after argument is shown to be weak, without any effect on the proposed outcome. Discussion becomes an endless dancing around the problem. One possibility is that the vision of what "ought to be" is not well thought out. We rely on gut instinct rather than a clear vision. When the vision itself is honestly put on the table for discussion, true dialogue becomes possible, and the dancing argumentation can end.

When we understand our own visions well enough, we can share them with others who have a different vision. Coming to a consensus on climate change requires that all parties to the discussion develop a clear eschatological vision which is honestly put on the table. Once the visions are thought out and on the table they can be evaluated for their effectiveness in achieving the stated goals. The visions can also be evaluated for the moral consequences of their implementation, their effect on other people, animals, plants, oceans, air, and the biosphere as a whole. Below are a few considerations that such a dialogue might pursue.

First, not all visions are sustainable. We must subject our visions to scientific scrutiny to ascertain that our proposed solutions really are solutions rather than simply delaying the problem for the next generation to solve. Are we solving one problem, only to create a worse problem somewhere else? Are the materials needed actually available?

Second, eschatological visions can and must be subjected to moral scrutiny to make sure that the demands of justice and compassion are not swept under the rug.

Third, human beings have not finished with the acquisition of knowledge. Too often we are blindsided by ignorance of the correct question, let alone the answer. Visions need to be examined for their dependence on what we do not know and what is beyond our control.

Hopefully, a dialogue of visions will allow us to forge a path that strives for consent. It is not the ideal vision that needs to be found; that may indeed be a fool's errand. Rather, we need to find a vision to which we can all consent, as the best we can hope for now, given the situation. Everyone needs to be at the table.

Final Comments

> An ethics of fear sees the crises; an ethics of hope perceives the chances in the crises. In the exuberance of hope, the temptation is utopianism; in fear, the temptation is alarmism. (Moltmann 2012, 4)

Crisis brings about the necessity of change. It is possible to look toward one's eschatological vision, examine the present condition, and see possibilities that bring the world closer to how it "ought to be"—in Moltmann's words, to see the "chances in the crisis." Such an ethics requires a vision of what the future should look like, a future vision, a secular or religious eschatology. It is only when eschatological visions are explicitly expressed that the possibility of transformation from what is to what should be can be evaluated. Hope is derived from our eschatology, not from the evidence at hand. In the words of Paul, "Now faith is the assurance of things hoped for, the conviction of things not seen" (Hebrews 11:1 NRSV).

Climate change is primarily an ethical and moral issue that calls into question the magnitude of the highly developed world's material consumption. All climate change decisions are ethical decisions within at least an implied eschatology. The invitation is to look within our hearts, within our religious traditions, and within our activism, to make the implicit explicit. Then, and only then, can we subject our visions to both moral scrutiny and technical analysis. At the most fundamental levels there are at least three issues that all eschatologies, religious or secular, need to make explicit: the role of material wealth, our relationships to each other, and our relationship to the rest of creation. Religious eschatologies should also address the relationship between God and nature (including human beings). Can we reject the idol of material wealth as the center of our being, and replace it with a culture of "enough"? Can we create a society that is just on all levels? Can we learn to live in harmony with all of creation, taking our rightful place as a creature, rather than viewing ourselves as demigods above the rest of creation?

What is your vision of what the future should hold?

Appendix 1: Computational Techniques, HDI vs. Energy

The United Nations publishes the data for the Human Development Index (HDI) each year. The HDI for 2014 included 188 different countries and 7.18 billion people in those countries (Jahan and Jespersen 2015). The HDI is the geometric mean of three indicators—life expectancy at birth, education, and income. The three indicators are ratios, which before 2014 were based on observational data in both the numerator and denominator. In 2014 the denominator was changed to reflect aspirational goals (UNDP 2015). The result was a slight shift in the curve. This makes detailed comparisons with previous years difficult.

Unfortunately, the HDI reports do not include the electric consumption per capita; this data was obtained from the International Energy Agency *Key World Energy Statistics* report. The 2016 report contains the electrical energy consumption per capita of 144 countries in 2014 with a combined population of 6.99 billion of 7.25 billion people; 96 percent of the world's estimated population (IEA 2016). The overlap between these two sources is 137 countries containing 6.94 billion people.

To provide a visual guide for the data an analytic function was developed that provided the correct shape, and could also be fit to the curve using Excel's best fitting procedure. The curve shape is given by the function

$$HDI = H_o + \alpha E^{\beta} \frac{1 - H_o}{1 + \alpha E^{\beta}}.$$

H_o, α and β are constants to be determined and E is the electrical energy consumed per capita in kwh/y/p. The best fit is obtained by rearranging this formula so it is a function of energy:

$$\alpha E^{\beta} = \frac{HDI - H_o}{1 - HDI} = z.$$

Then taking the natural log of both sides yields

$$\ln(\alpha) + \beta \ln(E) = \ln \left\{ \frac{HDI - H_o}{1 - HDI} \right\} = z.$$

Doing a linear fits of z verses the ln (E) yields the coefficients β and $\ln(\alpha)$ as a function of H_o. The chosen values of H_o, β, and $\ln(\alpha)$ yielded the best fit. The values obtained for the plot were: $H_o = 0.3026$, $\alpha = 0.01614717$ and $\beta = 0.61442441$.

Appendix 2: Solar Calculations

The simplest calculation to determine the required size of a photovoltaic array to generate a given average daily energy output divides the total required energy by the average daily energy generated per m^2 by the array. The average daily energy generated per m^2 by the array is the product of the efficiency of the array and the solar energy arriving at the array (the solar insulation). The values for the solar insulation for a given location and time of year, as well as yearly averages, are available from National Renewable Energy Laboratories (NREL n.d.).

It turns out we cannot effectively locate all the required solar panels at one location in the United States and distribute the power over transmission lines. A line stretching from Arizona to New Jersey would be about 2,000 miles long and would be the longest transmission line on the planet by about five hundred miles. The cost per mile rises with line length due to losses in the line. For a line this long, the transmission system cost is comparable to the cost of the photovoltaic system. The solution is to locate the photovoltaic systems near the current electrical generation facilities and then use the existing infrastructure. Not being able to locate all the solar photovoltaic panels in the Southwest will drop the average solar insulation value from 6.5 to something closer to 4.25 kwh/m^2/day. This increases the total size of the photovoltaic array from thirty-six miles on a side to

Table 8. Sample spreadsheet for simple solar panel area

Ref	Calculation			Units
		Input data		
A	input	Assumed US population	318,900,000	people (p)
B	input	Amount of energy per capita per day	31.20	kwh/person/day
C	input	Average solar insulation per day	4.25	kwh/m^2/day
D	input	Efficiency of PV panel	15%	
		Model Results		
E	A*B	Total required energy	9,949,572,266	kwh/day
F	C*D	Kwh generated per m^2 per day	0.6375	kwh/m^2/day
G	E/F	Total required area	15,607,172,182	m^2
H	sqrt(G)	Length of one side of a square	124,929	meters
I	H/1609	Length of side in miles	78	miles

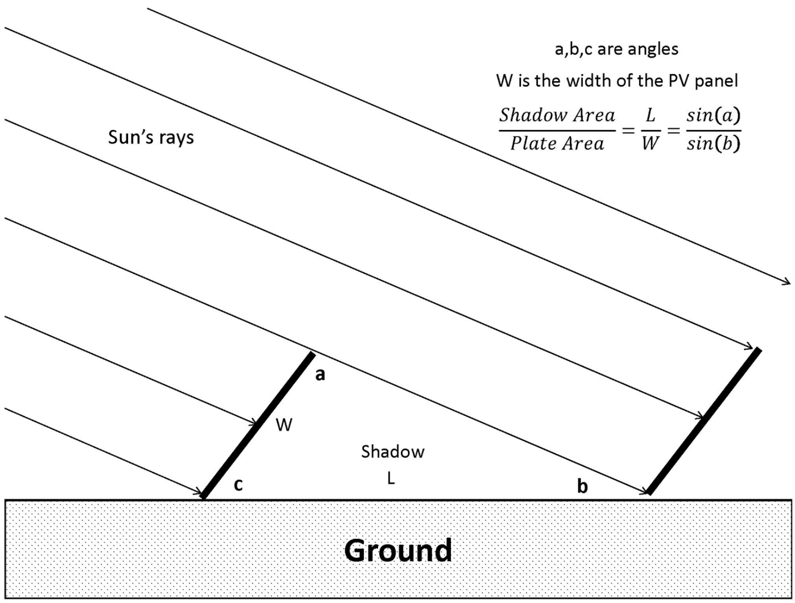

Figure 2. Shadow size of a tilted solar panel.

seventy-eight miles on a side, about 0.2 percent of the US land area. A spreadsheet to calculate these values is shown in Table 8.

The calculations above have been for the size of the panels and NOT for the size of the land they occupy. The solar insulation tables are usually given for a fixed panel, facing south, slanted at an angle to the ground equal to the latitude of the panel. This tilt maximizes the annual energy of a stationary panel over the course of a year. This assumes that the panel is never in the shadow of the panel in front of it. In Figure 2 we show

Table 9. Spreadsheet to calculate the land area occuped by a solar panel

Ref	Calc			Units
		Input data		
A	input	Assumed US population	318,900,000	people (p)
B	input	Amount of energy per capita per day	31.20	kwh/person/day
C	input	Average solar insulation per day	4.25	kwh/m^2/day
D	input	Efficiency of PV panel	15%	
O	input	Latitude of the panel	40.000	deg
		Model Results		
E	A*B	Total required energy	9,949,680,000	kwh/day
F	C*D	Kwh generated per m^2 per day	0.6375	kwh/m^2/day
G	E/F	Total required PV panel area	15,607,341,176	m^2
Gp	G/1609^2	Total required PV panel area	6,029	sq miles
P	90-lat-23.5	Solar minimum elevation	26.500	degrees
PR			0.463	radians
Q	Panel angle	Panel orientation to horizontal	40.000	degrees
R	180-Q-P	“a” angle	113.500	degrees
RR			1.981	radians
S	Sin(RR)/sin(PR)	Ratio shadow area to PV area	2.055	
T	G*S	Amount of land required of the array	32,077,409,338.426	m^2
TP			12,390.453	sq miles
H	sqrt(T)	Length of one side of a square	179,102	meters
I	H/1609	Length of side in miles	111	miles

the trigonometry that gives us an estimate of the panel size to the shadow size. Because we never want the panels to be in each other’s shadow, b is the smallest angle that the sun makes with the horizon. At the winter solstice in the Northern hemisphere this angle is ninety degrees (straight overhead) – latitude – 23.5 (the tilt of the Earth’s axis). At forty degrees latitude (roughly the center of the United States) this angle is the lowest at winter solstice and at that time is equal to 26.5 degrees. C represents the tilt of the panel, and is usually equal to the latitude of the panel which faces south. If we take the latitude of forty degrees (roughly through the center of the United States), the land area now becomes a square 111 miles on a side, about 0.35 percent of the land area of the United States and roughly equal to the area of the paved roads in the United States. The spreadsheet used to calculate these numbers are shown in Table 9.

Acknowledgments

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Notes

1. Ethics refers to rule or standards imposed from outside of the individual. These standards might be imposed by society, your workplace, or a religious institution. Ethics can also be imposed by our thinking through a situation and deciding what the ethical response is to a situation. Morals are principles that have been internalized that govern our behavior.
2. For the sake of consistency this article will use the term "indigenous peoples," with the understanding that when it is particularized to a specific people we should use the term with which they self-describe.

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