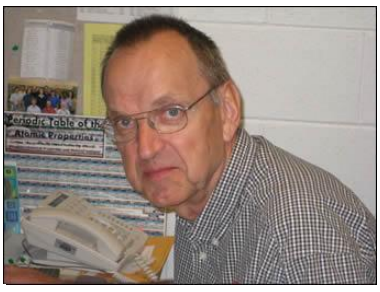
What I Wish My Pastor Knew About ...
Sustainability and the Environment



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Sustainability: What is it?

Sustainability will be one of the key issues, if not the preeminent issue, facing humanity in this century. Increasingly scientists, cultural commentators, journalists, and even some of our economists and political leaders are raising doubts about the survivability of modern civilization. Economic growth and expansion of human opportunity can no longer simply be assumed. Instead, we hear the opposite. Collapse is a word that is increasingly on the tongues of those who view our present pathway as unsustainable. In this essay I want to explore some of the reasons why these commentators have such a jaundiced view of the future of modern civilization and try to present some of the options we have for avoiding the collapse that some foresee.

The Brundtland Commission in their UN-sponsored report on global development[1] define sustainability this way:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Of course, numerous questions arise: Is development the same as growth? If not, how are they different? What would development without growth look like? What is it exactly that we owe future generations? What are needs? How do they differ from wants? Do such needs include the needs of non-human creatures? Does Scripture cast any light on sustainability questions?

A definition that I have developed is somewhat broader:

> A sustainable civilization: is one that can continue to unfold or develop into the indefinite future; one that can support the entire human population at a sufficient level of prosperity to enable life with dignity and responsibility, and does so without compromising either the health of the environment or the existence of other living creatures with whom we share this planet; and does not lead to irresolvable political conflict between or among the world's peoples and nations over access to necessary resources.

This definition not only recognizes the value of sustaining human culture but also includes the responsibilities that humans have for avoiding pollution of the physical environment (land, water, air) and for maintaining the well-being of other creatures. It recognizes that our well-being is intimately connected to the well-being of the natural environment and to fair access to natural resources for all humans.

Creation Care and Sustainability

Although Calvinist theology has a strong emphasis on the doctrine of creation and the prime place of humans within that creation, the CRC, along with the Christian church in North America in general, has been slow to take up the challenge of creation care in its life and ministry. Nevertheless, human responsibilities for the care of creation are clearly specified in the biblical story of creation as found in the first two chapters of Genesis[2]. These stories clearly teach us that humans are both intimately part of creation (made of the earth) and transcendent to it (made in the image of God) in a way not characteristic of any other creature.

Perhaps the best way to understand the obligations that humans have toward the rest of creation is by way of the ancient, but rich, Hebraic concept of **shalom**. Shalom is God's dream and promise for the fulfillment of His creation; the knitting together of all the brokenness in the cosmos. Shalom has to do with the healthy and fruitful development of all relationships relevant for life – including those between God and nature, God and humans, humans and humans, and humans and nature – as these were originally intended by the Creator. The picture of shalom is a picture of the mutual flourishing of both human and non-human

[1] Harlem Gro Brundtland, *Our Common Future*, Oxford, 1987, p xii; World Commission on Environment and Development

[2] In this discussion of the place of humans within the creation I am indebted to the authors of *Earthkeeping: Christian Stewardship of Natural Resources,* (Erdmann's, 1980) Chap. 14 and 15.

life (Ps. 8, Ps. 104, Is. 65).

A significant aspect of shalom is the biblical idea of stewardship. Genesis 1:28 makes clear the special responsibility humans have to manage the creation. Humans are commanded to subdue (Heb: *kabash* –to tread down, to bring into bondage, to overpower) and have dominion (Heb: *radah*, to prevail against, to trample, to rule over) over the earth. This so-called "cultural mandate" sets humans apart from every other one of God's creatures in their responsibility for the creation. We are God's stewards here on earth, and we alone among all of God's creatures are culpable for how we manage this task.

But the Garden of Eden story in the second chapter of Genesis immediately qualifies how humans are to exercise their stewardship of creation. In Genesis 2:15 we read that humans are to till (Heb: *abad*, to till, to plow, to serve, to be a slave to) and keep (Heb: *shamar*, to nurture, to keep, to preserve, to watch) the earth. Clearly we are to practice our stewardship of the earth in a manner such that the rest of creation flourishes. It would not be incorrect to say that human action is to be a blessing for the rest of creation. In any event, because of the special place of humans within the creation, we cannot do otherwise than to practice stewardship of the rest of creation. The only question left to answer is whether we will be good stewards or bad stewards of that which has been entrusted to our care. Since human care of creation is a biblically based human mandate, humans are also culpable when this care is not properly rendered.

By exercising a healthy sense of creation care, one would expect that human stewardship activities would help to usher in conditions that exemplify elements of shalom. However, entering the 21st century, it is now quite clear that modern civilization, which has been and continues to be constructed largely upon the foundation of the worldview of capitalistic modernism, is beginning to transcend the limits of what the global ecosystem can sustain. Perhaps we who live in the highly (or over)-developed West, must acknowledge that we have paid too much attention to the verbs of Genesis 1 (kabash, radah) and not enough attention to those of Genesis 2 (abad, shamar).

Wes Jackson and the Land Institute

An example of what healthy earth care and a sustainable agriculture might be in the future is illustrated by the work being done at the Land Institute in Salinas Kansas. Founded by Wes Jackson, a fellow believer, over thirty years ago, their mission statement reads:

When people, land, and community are as one, all three members prosper; when they relate not as members but as competing interests, all three are exploited. By consulting Nature as the source and measure of that membership, The Land Institute seeks to develop an agriculture that will save soil from being lost or poisoned while promoting a community life at once prosperous and enduring.

They write "Our purpose is to develop an agricultural system with the ecological stability of the prairie and a grain yield comparable to that from annual crops….Important questions have been answered and crucial principles explored to the point that we feel comfortable in saying that we have demonstrated the scientific feasibility of our proposal for a Natural Systems Agriculture. Because this work deals with basic biological questions and principles, the implications are applicable worldwide. If Natural Systems Agriculture were fully adopted, we could one day see the end of agricultural scientists from industrialized societies delivering agronomic methods and technologies from their fossil fuel-intensive infrastructures into developing countries and thereby saddling them with brittle economies."

Source: http://www.landinstitute.org/vnews/display.v

Ecological Footprint

The concept of ecological footprint was first introduced by the Canadian socio/economic-ecologists William Rees and Mathis Wackernagel in the early 1990s. Ecological footprint analysis compares human demand on nature with the biosphere's ability to regenerate resources and provide services. It does this by assessing the biologically productive land and marine area required to produce the resources that a population consumes and which is needed to absorb the resulting wastes, using prevailing technology. Essentially it is a measure of whether or not a population is living within or exceeding the carrying capacity of the region or the globe[3].

In 2005, the average available biologically productive area per person worldwide was approximately 2.1 global hectares[4] (gha) per person. The US footprint per person was over four times the global average and that of Canada was over three times larger, while China's was right at the global average. We Americans, with less than 5% of the world's population, demand over 20% of its bio-productive capacity to support our lifestyles.

Here is another way to look at North American demands on the earth. If everyone in the world had the same lifestyle as that of the average American, we would need an additional 3.5 planets like the earth to provide for all of the resources that would be required. The World Wildlife Fund has estimated that already today despite the great range of consumption levels that people in different parts of the world have, humans have exceeded the capacity of the planet to provide the needed resources by about 20-25%.[5]

Canadian Cod-fishing Industry

The cod fishing industry in Canada is a good example of how excessive human demands on the bio-productive capacities of creation can lead to ecological collapse. Cod fishing in Newfoundland was carried out at a subsistence level for centuries, but large scale fishing began shortly after the European discovery of the North American continent in 1492. After his voyage in 1497, John Cabot's crew reported that "the sea there is full of fish that can be taken not only with nets but with fishing-baskets." Around 1600, English fishing captains still reported cod shoals "so thick by the shore that we hardly have been able to row a boat through them." In 1951 factory fishing began with new super-trawlers. The cod catch peaked in 1968 at 810,000 tons, approximately three times more than the maximum yearly catch achieved before the super-trawlers. The industry collapsed entirely in the early 1990s owing to overfishing, due to greed, lack of foresight and poor local administration and cod fishing was suspended in 1993. After a 10 year moratorium on fishing, the cod had still not returned. The waters now appear to be dominated by crab and shrimp rather than fish.

Source:
http://en.wikipedia.org/wiki/Cod_fishing_in_Newfoundland

[3] Source:
http://en.wikipedia.org/wiki/Ecological_footprint (last accessed 9-10-09).

[4] The global hectare (gha) is a measurement of the bio-capacity of the entire earth - one global hectare (a hectare is about 2.5 acres) is a measurement of the average biocapacity of all hectare measurements of any biologically productive areas on the planet. If you take the sum of the world's biocapacity, then divide it by the number hectares on the earth's surface, you get the biocapacity of one average earth hectare. When the term 'global hectare per person' is used, it refers to the amount of biologically productive land and water available per person on the planet. e.g. In 2005 there were 13.4 billion hectares of biologically productive land and water available and 6.5 billion people on the planet. This is an average of 2.1 global hectares per person. (Source: http://en.wikipedia.org/wiki/Global_hectare).

[5] Source:
http://news.bbc.co.uk/2/hi/science/nature/6077798.stm (last accessed 9-10-09).

Human Well-being and Ecological Footprint

The United Nations measures lifestyles using the Human Development Index (HDI, a UN-developed index based on a number of parameters (gross domestic product, education levels, life expectancy) . Figure 1 shows an interesting graph relating a nation's HDI to its ecological footprint. The graph shows that countries with a low level of development (low HDI) also have a low ecological footprint (less than the global average of 2.1 gha per person), and that nations with higher HDI also have larger ecological footprints. What is interesting is that once you get much beyond the global average ecological footprint, the HDI more-or less stops increasing; even though more environmental resources are used, this measure of human well being does not increase much.

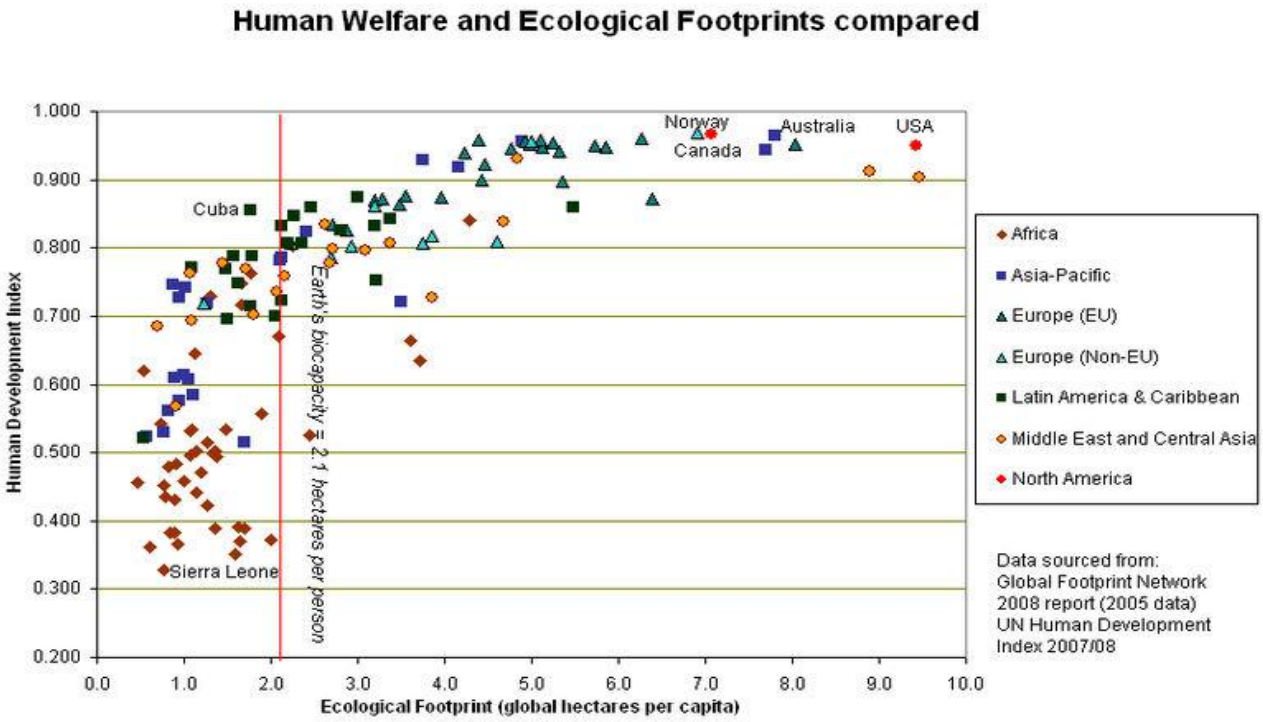

Figure 1. Source http://en.wikipedia.org/wiki/Ecological_footprint (last accessed 9-10-09).

From this graph we might conclude that it is possible to more or less meet the human needs of all people on the globe without exceeding the biological productive capacities of the planet.

Ecological footprint experts generally suggest that, in order for its people to have a comparatively high level of human well-being, a nation's HDI should be above 0.8. In order for that nation's people to be living sustainably, their ecological footprint should not exceed the global average. By these measures there is only one country in this entire list in Figure 1 that meets these criteria: Cuba. Now this does not mean that we all should aspire to a lifestyle of the average Cuban. But the conclusion seems unavoidable that we who live in the USA and Canada, must undergo a fairly substantial decrease in our demand on the biological capacities of the planet if we are to achieve a lifestyle that is sustainable into the future.

Implications for the Church

Clearly, the demands that we North Americans place upon the bio-productive capacities of the planet is a matter that ultimately becomes a moral/ethical issue. When each average American requires nearly 25 acres of bio-productive resources while over 1 billion people on this planet have access to virtually nothing, we have a

moral crisis.

We could, on the one hand, adopt a "survival of the fittest model" and claim that to the powerful go the spoils. This is a position that would be consistent with the worldview of evolutionary materialism, but is hardly consistent with the second great commandment - love your neighbor as yourself.

Or we could argue that our neighborly obligations are limited. Some might argue that neighborly obligations extend only to those within the fellowship of the Christian church – and it is true that we do have special obligations to such brothers and sisters. Others suggest that neighborliness extends to those who live within our community, or city, or state, or even country, but does not extend to all of humanity. There are limits to our neighborly obligations. If this were true, we might be able to justify ignoring the vast numbers of people who have no access to needed resources with which to provide for themselves.

However, I would argue that Scriptural teaching is consistent with the view that anytime I become aware another person or group of persons, especially if such persons are in need, such people become my neighbors. The seems to be one of the clear implications of the story of the good Samaritan (Luke 10:25ff), or of Christ's admonition that we should love our enemies (Matt. 5: 43ff), or even of the story of the feeding of the five thousand (Matt. 14:13ff). In today's world, with our access to nearly unlimited global media, the world is our neighbor – we have obligations to see to it that access to bio-productive resources is shared more equitably than they now are. This is one of the obligations that needs to be preached on our pulpits.

Does this mean that we may have to reduce our demand on such resources? Very likely. This reality must lead to a wholesale, critical evaluation of our individual and corporate lifestyles all the way from our material consumption levels to the type of diet we consume.

I now want to turn a brief look at three specific ways – human population, climate change, and energy resource use – in which our modern way of being in the world threatens the biophysical limits of the planet. Each of these has strong implications for the various lifestyle choices made by humans generally, but especially for those of us who are Christians.

Human Population

No discussion of sustainability can avoid a careful consideration of the increasing press of human population. Currently nearing 7.0 billion[6], some population experts are encouraged that global population growth rate has fallen to under 1.2% per year, down from 2.0% per year in 1965. However even with this declining growth rate, because of the ever-rising number of humans, the absolute number of people added to the world population in 2009 will be about 80 million people, where as in 1965 fewer than 70 million were added. Human population is expected to top 8 billion by 2025, barring catastrophes. Over 50% of the world's people now live in urban areas[7], a number that will grow to more than 75% in 25 years if trends continue.

Worldwide fertility rates have declined to an average of 2.6 births/female, but this is still well above the replacement rate of 2.1 births/female. But deeper analysis of these numbers shows that fertility rates range from a low of 1.7 in some of the more developed countries of the world to greater than 6.0 in some of the least developed and most troubled countries on this planet. This means that virtually all of the increase in

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[6] Population sources: http://www.prb.org/pdf09/09wpds_eng.pdf and https://www.cia.gov/library/publications/the-world-factbook/index.html (last accessed 9-9-09).

[7] For a very striking visual that addresses the plight of the millions now living in urban slums see http://www.theplaceswelive.com/ (last accessed 9-28-09).

population over the next 25 years will occur in those parts of the world that already are hard-pressed to provide adequate resources for its existing population. In many of these nations, the population will more than double in the next 25 years. Even a rapidly developing country like India, which is slated to become the world's most populous country by 2020, will be severely challenged to meet the needs of its population. And China, even with its one child per family policy, is expected to add about 150 million souls to its population by 2025, placing even greater stress on its biological productive capacities.

Lest we think that the population problems are all in the developing world, both the US and Canada have slowly growing populations of about 0.5% per year. Thus the US population is expected to rise by about 50 million people to over 350 million by 2025. Given the very large ecological footprint (nearly 25 acres/person) demanded by the average American lifestyle, such an increase will result in an increased demand on the biologically productive resources of the planet equivalent to adding over 220 million Chinese people at current consumption levels.

Given the reality of these numbers, it is hard to avoid the conclusion that humans around the globe must take urgent steps to curb their numbers. As physicist Albert Bartlett in his lecture[8] on exponential growth says, either we must voluntarily undertake humane but effective steps to limit our numbers or else nature will do so for us in not-so-humane ways (famine, drought, pestilence, plagues, wars, genocide, etc).

Population Issues and the Church

Addressing population control is a sensitive issue for the church. Throughout its history, the Christian church has generally adopted a strong pro-natalist position. Large families have generally been seen to be a blessing from the Lord. In Gen 1:28 and again in Gen 9:1, humans are told to "be fruitful and multiply and fill the earth". Indeed, many Christians today still see the use of non-natural birth control methods (e.g. use of contraceptives) as a violation of God's command to be fruitful. And through much of the history of modern humanity, practicing our reproductive capacities was, from an ecological point of view, an acceptable –perhaps even necessary - thing to do. For most of human history, there was no real concern that humans were in danger of over-filling the earth.

But with close of the 20th century and the dawn of a new millennium, we are at a new stage in human history. We have reached the stage where no habitable part of the planet remains unoccupied by humans. Unlike in 17th century Europe, there are no new, nearly empty continents to "discover" and colonize. We have also reached the stage that human alteration of and impact on ecosystem-structure is leading to widespread extinction of animal and plant species. And we have reached the stage where human injection of wastes into the ecosphere is causing measurable changes in its composition and its health. In other words, we have reached the stage where the earth is more or less full of us. So, in this context, what does it mean to "be fruitful and multiply"?

I think it does not mean that we should seek to expand the human population to ever larger numbers. Rather, it is quite acceptable to understand the word "multiply" to mean that we should on average bear no more than 2.1 children per female (replacement level), or maybe even fewer. Nor should fruitfulness necessarily be understood as a feature of child-bearing. Instead it could be understood as a mandate to develop as fully as possible all of the capacities that each living human has to serve and praise God. It could also be understood as a mandate to steward the rest of creation in such a manner that other life-forms with whom we share the bounty of the earth are allowed to flourish each in their own creaturely way. Such flourishing can only occur if humans voluntarily undertake to stop the growth of their own numbers.

[8] Dr Albert Bartlett: *Arithmetic, Population & Energy*, DVD available from U of Colorado Bookstore, www.cubookstore.com .

So, the church has a task – a task to support family planning measures at home and abroad. Practices that have proven to be most effective in reducing birthrates involve empowering women in the local context via education, adequate healthcare, increased status in the society, equipping them to find jobs or undertake small business ventures, and providing them with modern birth control education and access to free contraceptives where necessary. These are policies and initiatives that the Christian church should strongly support and promote both at home and via its mission and development agencies.

Kerala, India

Kerala, a small, poor state in southwestern India with a population of 31 million people (almost equal to that of Canada) and a very high population density (819 people/km^2), doubled its population in the 40 year period from 1951 to 1991, but has since slowed its population growth dramatically and now has the lowest fertility rate (1.6 children per family on average) of all Indian states. How did it do this? It did not institute any draconian polices of birth control. Instead it has engaged in a vigorous program of education aimed at both boys and girls, established a healthcare system that provided healthcare and nutrition education to all its citizens - especially to women and families, and it has built a largely democratized economy aimed at eliminating the most severe pockets of poverty within the state. As a consequence, the human development index (based on educational attainments, gross state domestic product, and life expectancy) for the people of Kerala is now among the highest of all the states in India, despite the fact the Kerala remains one of the poorest states in the country.

Source: http://en.wikipedia.org/wiki/Kerala

Climate Change

Perhaps nowhere is it more evident that human civilization is already exceeding certain biophysical limits than the emergence of global climate change[9]. One aspect of this issue we should all have a clear view of from the outset, is the matter of public controversy regarding the issue of human-induced climate change. While it is true that there are a number of climate change skeptics among our politicians and a few vocal skeptics in the blogosphere and the popular media, there are very few climate skeptics among those who have most seriously studied the issue and have scientific and professional qualifications to make judgments on these issues, viz. the climatologists.

Any time there are competing claims about the status or validity of some finding or other that requires some level of professional expertise to evaluate, the general public is in a serious quandary, because we need to decide whom we should believe or trust. In the case of the climate controversy, whom do we trust? The scientific community? Popular media personalities? Our political representatives? Our pastors and church leaders? This is a challenge we all face.

An important difference between the claims made by the professional climatologists and those made by politicians and bloggers is that the climatologists generally must and do publish their findings in the refereed[10] scientific literature, whereas politicians, media personalities, and bloggers generally do not. This is a crucial difference. Science advances by means of refereed publications, the findings of which are debated, corrected, sometimes retracted, but often confirmed by further studies. So, when there is controversy, the scientific literature is about the most reliable and objective source of knowledge we have available to us. That is why, for climate science I rely[11] on publications such as those generated by the Intergovernmental Panel on Climate Change (IPCC), because their findings rest entirely upon work that has appeared in the refereed and published scientific literature. We have no better source of scientific information than refereed publications.

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[9] In my discussion of climate change I am following the findings of the Intergovernmental Panel on Climate Change (IPCC) in their most recently published update – the Fourth Assessment Report (AR4). The entire report is available online at http://www.ipcc.ch/ .

[10] Refereed literature means that when the scientist submits a new research paper to a Journal for publication, prior to publication it is reviewed anonymously by several other professionals whom the Journal editor believes to be qualified to make judgments about the new work. These reviewers may recommend rejection of the paper, but more often they suggest revisions or additional work that needs to be done before publication. Only after the paper passes the screening of the reviewers does it get published. Once published, the paper is subject to the criticism or accolades of the entire scientific community. While such papers may not always be correct in their conclusions – and that would certainly also be true of papers investigating human-induced climate change – such literature is probably the most reliable and trustworthy material we have available upon which to make judgments.

[11] I am a trained scientist (Ph.D. chemist) but, because I am not trained as a climatologist, I am unable to comprehend the primary scientific literature related to climate studies. Hence I rely on reports that appear in the secondary scientific literature for my information. The IPCC Assessment Reports are examples of secondary scientific literature - literature that is produced by persons able to read and comprehend the primary literature, but written at a level that educated persons with qualifications in other areas could understand what was being said.

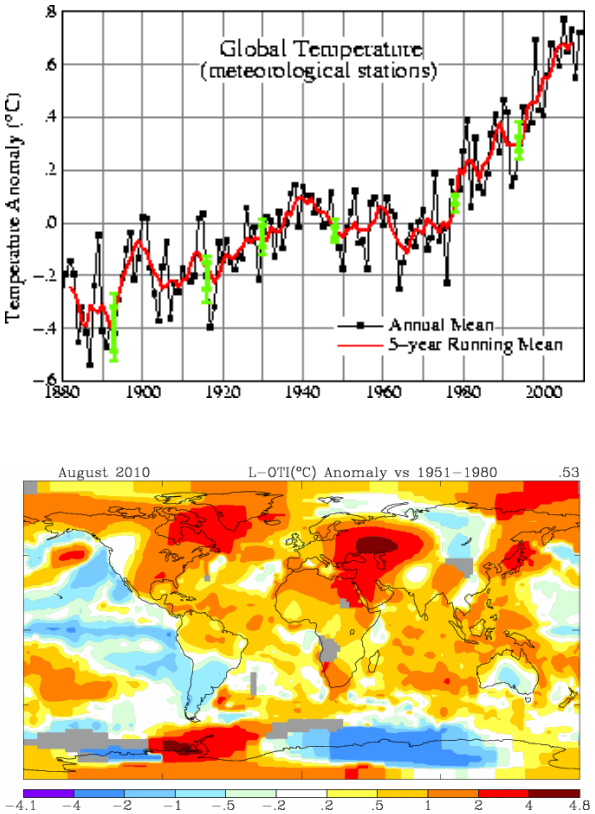

Figure 2. Note that the zero point in the graphs is the 1950 to 1980 30 year average global temperature. (Source: NASA Goddard Institute for Space Studies)

Almost no one disagrees with the claims that climate change is real. Figure 2a shows the annual average global temperature for the past 120 years (relative to the average temperature from 1961-2000). Figure 2b shows, in shadings, a map of the global surface temperatures for 2006 (again relative to the average temperatures 1961-2000). Notice the darker shadings in the high northern latitudes – these indicate very strong warming (as much as 3.3°C or 5.9°F) in these regions.

At the same time, the carbon dioxide concentrations in the atmosphere are increasing at greater rates as time goes on. Figure 3 shows the change in atmospheric carbon dioxide concentrations since 1958 as measured[12] at Mauna Loa, Hawaii. Carbon dioxide concentrations are currently increasing at a rate of a about 2.0 ppm per year.

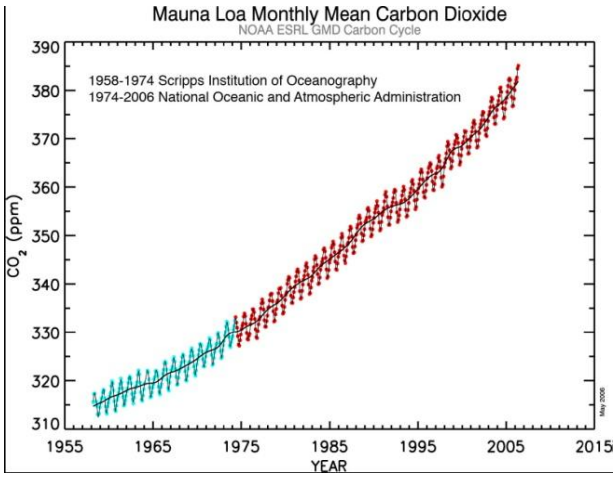

Figure 3 (Source: NOAA Earth System Laboratory)

Here is where most of the public controversy arises: Is the increase in temperature (Figure 2) due to the increase in carbon dioxide levels (Figure 3)? And if so, is the increase in carbon dioxide levels due to human activity? Yet this is not a significant controversy within the scientific climate-study community, despite what some have claimed. The IPCC reports the scientific consensus that there is a greater than 90% probability that human activities – burning of fossil fuels (coal, petroleum, natural gas) and changing land use patterns (modern agriculture, deforestation) – are the principal causes of globally warming temperatures and a globally changing climate.[13]

[12] The figure also shows variations within each year due to seasonal changes – concentrations fall throughout the summer due to plant photosynthesis but rise again during the winter.

[13] For a presentation and discussion of some of the main evidence for climate change and its expected impacts on human society see Appendix A.

Addressing Climate Change

The changing climate is the not the only environmental event in recent times that requires a global response. Another event, begun in the 1980s and continuing today, is the threat to the protective stratospheric ozone layer due to human use of synthetic refrigerants (chlorofluorocarbons - CFCs). Addressing the ozone-depletion problem was successfully negotiated with an international agreement adopted in Montreal in 1988. Success was achieved mainly because the problem had a relatively simple technical solution – the manufacture of new, alternative materials that posed a lower environmental threat to the ozone layer. Today, the ozone hole has begun to close and ozone levels are expected to return to 1980 levels by about 2070. Unfortunately, no such simple technical solution exists for addressing climate change today. And if some of the major economies of the world do not participate and cooperate, a successful address to the challenges of climate change is very much in doubt.

Two approaches, sometimes seen in competition with each other, have been suggested as realistic ways for humans to address the challenge of climate change – *mitigation* and *adaptation*.

- *Mitigation* implies that we should make efforts to reduce the causes of climate change; specifically, it means that we should reduce to acceptable levels the emission of greenhouse gases that arise due to human activities – especially carbon dioxide.
- *Adaptation* implies that we should find ways to adapt to the climate as it changes, taking steps to prevent the worst effects of climate change from harming people.

IPCC believes that both of these strategies can and should be undertaken.

To mitigate climate change[14], many climatologists believe the level of greenhouse gases in the atmosphere (currently increasing as shown in Figure 3) should not be allowed to exceed 450 ppm. This limit is necessary to avoid the very worst effects of climate change and to reduce the risk of irreversible and surprising changes. All climatologists say that the sooner we can bring the rise to greenhouse gas concentrations to a stop, the better chance there is for a sustainable future. In order to reduce the chance of greenhouse gas levels rising above 450 ppm, it will be necessary to reduce annual emissions to about 75% below their current levels[15]. This means that by 2050, greenhouse global greenhouse gas emissions must be only one quarter of what they are now– a tall order indeed! The challenge is made more severe by the presumption that the economies of the world's nations must (and will) continue to grow throughout this period.

Adaptation includes steps undertaken to reduce the impacts of negative effects of climate change[16]. An example could have been efforts to reinforce the levees protecting New Orleans before the onslaught of Hurricane Katrina in 2005. Unfortunately such adaptive possibilities were ignored, with disastrous consequence for all the residents of the city but especially for its poorest residents.

Mitigation and adaptation strategies both are matters about which we need to have local, regional, national and global discussions. Pretending that climate change is not real or not caused by what we humans are currently doing is no answer. I believe that it is essential that we begin enacting both the mitigation and adaptation

[14] For a presentation and discussion of some of the ways IPCC considers as potential strategies for mitigating carbon releases to the atmosphere see Appendix B.

[15] Human generated greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). The current annual total of emissions is about 40 billion tons of CO_2-eq per year. The unit CO_2-eq stands for "carbon dioxide equivalent" and is the amount of carbon dioxide that would cause the same amount of warming as the actually-emitted mixture of carbon dioxide and the other greenhouse gases.

[16] For a presentation and discussion of some of the ways IPCC considers as potential strategies for adapting to a changing and warming climate see Appendix C.

Farmland and Climate Change

Since time immemorial, farmers have planted their crops according to the seasons. "That is what my forefathers have been doing," says Mohammad Ilisasuddin in Shibganj, in northern Bangladesh, but now "the weather does not seem right for what we have done traditionally." Seasonal planting is "useless", agrees Florence Madamu, a smallholder in Bulirehe, in western Uganda. "The sun is prolonged until the end of September and whenever it rains, it rains so heavily it destroys all our crops." Oxfam, a British charity, has compiled a litany of laments by poor farmers. John Magrath, a researcher, says they all say similar things: "moderate, temperate seasons are shrinking…rainy seasons are shorter and more violent…making it more difficult to grow crops [and] difficult for them to know when best to plant." As the earth warms up, many have feared that farmers will pay a high price.

Excerpt from "Seasonally Adjusted" *The Economist,* October 1st 2009.

strategies, beginning with the least costly options. There is no doubt that action with respect to climate will require policy actions by governments. Leaving matters to individual initiative or to the market will not be sufficient. This does not mean that we as individuals can do nothing or have no responsibilities. So what are some of the things we can do?

Personal Action on Climate Change

We can (and must) educate ourselves on the basics of climate change and energy resources. For most of us that will involve finding trustworthy sources who are not overly married to either the worldview of unending human progress through economic growth (which relies on technology and expanding levels of consumption to pull us through the tough spots), or the biocentric worldview of new-age nature worshippers who put the needs of humans below the ecosystem-needs of other species with whom we share the earth. For Christians this means that we must be thoroughly grounded in a theology of creation care that is unabashedly theocentric. (A lovely book that describes a biblically based theology of creation care is Steven Bouma-Prediger, *For the Beauty of the Earth: A Christian Vision for Creation Care*.)

Every one of us makes consumption choices nearly every day of our lives – from the food we eat to the clothes we wear, from the appliances we buy to the entertainment and recreational choices we make, from the house we build to the type of neighborhood we live in, and so forth and so on. The mode of transportation we choose to use has strong implications for the environment. So does the food we eat – deciding to reduce consumption of animal products is a step toward a more sustainable society. Eating food that is produced locally or that is not processed is a step toward sustainability. Every one of the lifestyle decisions we make has implications for creation care – especially for energy use and climate change[17].

While none of these efforts will save the world, practicing such behaviors do provide a sense of personal satisfaction that we are making efforts to reduce our demand on the creation's resources and they also give a sense of integrity to the message we try to carry about living a sustainable lifestyle.

Climate Change and the Church

The wider evangelical community has split into two main groups[18] with respect to how we should address climate change. On the one hand there is the group arising from the Evangelical Environmental Network represented by the signatories of The Evangelical Climate Initiative[19]. This group believes that climate

[17] For a list of things my family has undertaken in the last several years to try to reduce our carbon footprint and live a more creation-friendly lifestyle see Appendix D.

[18] For an in depth essay comparing these two different approaches see: http://muse.jhu.edu/journals/american_quarterly/v059/59.3mccammack.html

[19] The climate statement of this group can be accessed at http://christiansandclimate.org/learn/call-to-action/

change is real, is caused by human activities, and will affect the poor most strongly and negatively. They believe that seeking to mitigate climate change is a moral requirement. For example they write:

> *In the United States, the most important immediate step that can be taken at the federal level is to pass and implement national legislation requiring sufficient economy-wide reductions in carbon dioxide emissions through cost-effective, market-based mechanisms such as a cap-and-trade program.*

On the other hand, the Interfaith Stewardship Alliance[20] (or the Cornwall Alliance) doubts that human actions will have negative impacts on climate. In fact they point to potential positive impacts of rising carbon levels in the atmosphere such as the potential for increased rate of plant growth. This group believes that adopting a program of climate mitigation would be disastrous for the world's developed economies just at a time when the need to grow world economies is urgent – the better to assist poor nations if there are any negative effects associated with a changing climate.

So how do we choose between these two views? They differ not just in politics and strategy, but at a fundamental level in the way they view the scientific evidence. For scientific questions, once again I suggest that we adopt the consensus position of science as reported in peer-reviewed publications, the position that is best supported by the observational and the conceptual evidence. Climate change is real, it is mainly caused by human actions, it poses a severe threat to the future well-being of all forms of life on this planet and needs to be addressed in a most timely and effective manner.

So what is the church's responsibility in this?

Obviously, the local church cannot espouse or encourage any particular climate policy or action. However it does have both the opportunity and the obligation to proclaim the good news of creation care. Christ's death and resurrection are efficacious not just for the redemption of humans but also for the restoration of creation (Col 1:20). Indeed, the entire creation "waits with eager longing for the revealing of the children of God" (Rom 8:19). For humans this means that we have an obligation to see to it the human actions do not lead to the demise of civilization or the devastation of other species with which we share this planet. This obligation is first of all an obligation to our Creator and our Redeemer, and will remain so until Christ's return. It is also an obligation to all of the fellow humans with whom we live on earth. And it is an obligation to the generations of life that we expect to follow us in the future.

So earth-care is a message that needs to be preached. In the context of climate change, earth-care here in the developed world means seeking ways to undertake a change in our lifestyles. All of us will have to undergo a radical simplification of our lives and a reduction in luxury consumption and convenience, if there is to be any kind of a transition to a more sustainable world and civilization which also is able to provide for the needs. For Christians who affirm that our hope is in God and not in the corruptible goods of this world, such a message should be welcome.

Models of Change

Matthew Sleeth, author of *Serve God, Save the Planet*, who with his family gave up the lifestyle of a successful, consumptive suburban doctor in favor of a much simplified lifestyle driven by creation-care principles is good model of the kind

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The list of signatories can be found at http://christiansandclimate.org/learn/call-to-action/signatories/

[20] A website providing some information on this group can be found at http://www.traditionalvalues.org/print.php?sid=2512 Their response to the statement drafted by the Evangelical Climate initiative can be found at http://www.cornwallalliance.org/docs/an-open-letter-to-the-signers-of-climate-change-an-evangelical-call-to-action-and-others-concerned-about-global-warming.pdf

of changes that might be needed. On his website[21] he writes:

> *In my family, spiritual concerns have filled the void left by material ones. Owning fewer things has resulted in things no longer owning us. We have put God to the test, and we have found his Word to be true. He has poured blessings and opportunities upon us. When we stopped living a life dedicated to consumerism, our cup began to run over. We have seen miracles.*
>
> *Today I preach about God and his creation. I am one of a growing number of those whom the Lord is using to educate people about his love for them and his love for the natural world. The earth was designed to sustain every generation's needs, not to be plundered in an attempt to meet one generation's wants.*

Another excellent model for change is the Newberry Place cohousing community on the near northeast side of Grand Rapids, Michigan. This is an urban community of Christians consisting of about 20 houses. The people living here are committed to developing a community-based model of living that places lower demands on the creation. Their website states[22]

> *Residents own their own homes in a pedestrian-friendly community, with parking on the perimeter. The community's dense design fosters strong relationships among neighbors, and creates shared and private green spaces. Neighbors also share ownership of a large "common house" where they can enjoy group meals several times a week or participate in social events and other activities.*

These are the kind of actions that many environmentally sensitive people, and especially young people, are beginning to undertake. All of these are signs of hope. The challenge is great but Spirit-led living can produce lifestyles that are healthful for the planet, fulfilling for ourselves, affirming of community and pleasing to God.

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[21] Source: http://www.matthewsleethmd.com/

[22] Source: http://newberryplace.org/

Energy

Energy is what enables us to do things and stay alive. Without the use of energy nothing can change – not even the blink of an eyelid. The rise of industrial civilization could not have occurred without access to cheap and useable energy resources. And modern civilization can not be sustained without access to such resources.

Primary Energy Sources

A primary energy source is a resource provided by nature which we make use of to enable us to do things we want done. Prior to about AD 1750, civilization's primary energy sources were the sun (warming, plant growing), wind (windmills), and water (water wheels, mills). The latter two energy forms should also be understood as forms of solar energy, since the sun drives both the hydrological cycle and the wind. Since these forms of energy are based on the Sun, they are renewable: they will not be depleted over time, no matter how much they are used.

Today our primary energy sources are the fossil fuels: coal, oil, and natural gas. Coal use began about 1750, oil use began in earnest about 1900, and natural gas use became common after 1950. Today, nearly 85% of the modern world's energy is obtained form these three fuel sources. Essentially, we live in a fossil-fuel-powered civilization.

We use all fossil fuels in precisely the same way – we burn them, releasing heat energy that can be used to accomplish work (move a car) or boil water to make electricity, as in a steam-driven power plant. Burning fossil fuels (combustion) converts the carbon in the fuel into carbon dioxide which is released into the air. That is the major source – about 70% -- of the growing levels of atmospheric carbon dioxide that impact the earth's climate.

Fossil fuels are not a renewable resource. There will come a time when their supply will become less available. In fact, not a few professional oil geologists believe that the world's capacity to extract oil from the ground will soon begin to decline[23]. Because oil provides the energy resources for nearly all of the world's mechanized transportation systems and for our modern system of agriculture, declining availability of oil will represent an exceedingly grave challenge for modern civilization.

How Much Energy Do We Use?

In 2006, global energy consumption[24] was increasing at a rate of 2% per year. At this rate, energy consumption will double in the next thirty-five years, by 2041. Of the total energy used by people all over the world, we here in the USA use roughly one quarter of it, even though we have less than 5% of the world's population.

American energy consumption per person is the highest in the world, closely followed by Australia and Canada. On average each of us uses about one million kiloJoules of energy per day. To get a feel for this amount, consider that one person's physical activity (from the food we eat) is about ten thousand kiloJoules of energy per day. That means that our total consumption is the same amount of energy that 100 adults working for us would provide. Some have said that it is as though each of us has about 100 "energy slaves" tending to us 24/7. The average Chinese adult, on the other hand, has less than 10 such "energy slaves" available to her or him. So it is hard to avoid concluding that we here in the North America are the energy consumption "elephants in the living room."

Our Energy Future

Because the fossil fuels are not renewable in historic time (their abundance on earth is limited), because the heavy use of fossil fuels has

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[23] For a more extended discussion of "peak oil" see Appendix E.

[24] The total global energy use in one year is roughly 140,000,000,000,000 (140 trillion) kilowatt-hours (your electricity bill lists the electrical energy you use in kilowatt-hours). Source: Energy Outlook 2009, US Energy Information Agency, http://www.eia.doe.gov/oiaf/ieo/highlights.html

substantial negative impacts for the biosphere, and because we depend on fossil fuels for 85% of our primary energy supply, modern civilization must be judged unsustainable from the standpoint of its use of energy resources. And without a sustainable energy supply modern civilization will ultimately collapse. So what are the options?

First, a strategy of drill more and dig more is not the right strategy for the 21st century. It is a 20th century answer for a 21st century problem. It will only lead to further depletion of fossil fuels, to greater security risks for the USA and Western Europe, and to greater threats to a livable future from the standpoint of climate and ecosystem health. As alluring, convenient and seemingly economical (if we neglect climate change and other bio-impacts of fossil fuel use) as fossil fuels have been, we must begin the transition away from their use sooner rather than later. The 21st century challenge is to develop a civilization that relies on clean, abundant, renewable and inexhaustible supplies for its energy.

Given these constraints, the available options are fairly few in number although the resources are in ready supply for nearly everyone on the planet. The options are[25]:

- Direct solar
  - passive systems
  - photovoltaic systems
  - thermal systems
- Indirect solar
  - Wind
  - Biomass
  - Hydropower.
- Non solar
  - Geothermal
  - Tidal

Technologies for harnessing and managing all of these renewable sources are already known and available. Currently, all of these renewable technologies combined provide only 8% of the world's energy. Water (via hydropower) provides about 5-6% of our primary energy supply, the burning of biomass (typically wood) provides 1-2%, and wind, direct solar, and geothermal provide less than 1% each. (Another 7-8% of our primary energy is supplied by nuclear fuels (uranium).[26]) Obviously making the transition away from a fossil fuel-based energy system will require vast investments in renewable energy systems as well as continuing research and development

Solar Panels
A southern Californian spent over $30,000 having photovoltaic solar panels installed on the roof of his house. When neighbors asked about whether this was a wise investment he said "Many of my friends spend as much or more money buying themselves power boats which they use for pleasure. These boats require a lot of fuel which contributes to global warming. Is that a wise investment? Instead, I choose to spend my money in doing something that might have a positive benefit for nature. And there is a good chance that I will recover much of my investment if and when I sell my house. Besides, I like watching the dials and I especially get a kick out of watching the electric meter run backwards when the sun is shining."

[25] For further discussion of the potential of renewable energy resources see Appendix F.

[26] I do not list nuclear power as one of the main options for two reasons. First, nuclear power is not renewable since uranium (or thorium) is a finite resource. Second we have not yet agreed on how to solve the issue of the management of spent fuel once it has come out of the nuclear reactor. However, I do not preclude the expanded use of nuclear power generation in the future, at least as a way to help reduce greenhouse gas emissions without jeopardizing essential electrical services to society.

Energy Resources and the Church

Let there be light! This is God's original act of creation (Gen. 1:3). How should we understand this simple sentence? In our everyday lives we understand light as something that enables us to see, like the sun or a lightbulb. But light itself is a form of energy. Thus, we might say that "In the beginning, God created energy." In fact, we can trace all forms of energy back to that original creative act. Solar and wind power are continually renewed by the Sun. Fossil fuels originated from decaying marine organisms and plant matter which gained their energy from the Sun. Geothermal power comes from heat deep within the earth. Thus, when God made the Earth and Sun, he provided for all our energy needs.[27] Because energy is conserved, the amount of energy present at the moment of creation must be the same as the amount of energy present in the universe today.

Thus, the fossil fuels that we so heavily use today ultimately should be understood as a one-time energy inheritance of the original creative act. It was not until the dawn of modern civilization in the 18th century that humans learned how to harness these for the purposes of constructing modern civilization. But this energy endowment must truly be understood to be an inheritance – once used up it will be gone and no human population will ever be able to make use of it again. This is one of the most important reasons why we should be good stewards of these energy resources and should not use them in a profligate manner.

When considering the myriad ways in which we make use fossil fuels in the developed world, I am often reminded of the story of the prodigal son, but now understood in a national and not a personal sense. With respect to our use of energy resources it is as though we in America have received our inheritance (fossil fuels) from our father (God) and have now engaged in a period of riotous and profligate living – squandering much of our inheritance and ultimately polluting our atmosphere. While modern civilization has achieved much we have also squandered much. And without continuing access to suitable and sustainable primary energy resources this civilization cannot continue. Unfortunately there appears to be no sign of any kind of national repentance from this style of life.

Yet it is repentance that is sorely called for. Preaching that calls the Christian church to such repentance is essential. Preaching that leads its hearers into greater efforts at conservation and preservation, into reducing human demands on the biocapacities of the planet, into avoidance of gratuitous consumption, into reconstructing the urban environment to make it more suitable for community development, into greater reliance on local and regional resources for meeting basic needs is an essential component of leading the church into a new kind of society.

Conclusion

I have identified human population, climate and energy resources as three aspects of our present way of being in the world that portend an unsustainable future. I could as easily have chosen to discuss several other topics – availability of fresh water, ability to produce food for expanding populations, the modern system of industrial agriculture, loss of ecosystem habitats, species extinction and, underlying all of these issues, the global belief that continuous exponential economic growth is the way to lead humanity into a better future. All of these are challenges that are on the near horizon of modern civilization; they proclaim that the 21st century will be different from the 20th century. We are entering an era of global challenges that will require radical and

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[27] In fact, the energy can be traced back further. According to astronomers, the Earth and Sun formed from interstellar gas and dust in the Milky Way (it would not be incorrect to say that God made us from star dust.) The energy in the gas and dust originated even further back, much of it in the earliest moments of the universe (the Big Bang) when the entire universe was exceedingly hot and filled with high energy – in the beginning, God created energy.

courageous behavior from all our leaders and from human society itself.

While a transition to a more sustainable civilization will be turbulent, filled with uncertainty, and not assured of success, we have an obligation to each other, to future generations, to the other creatures with whom we share this planet, and above all to Jesus Christ, the King of creation, to make the effort. - and the church has a crucial role to play in this drama.

Further Reading

Earthkeeping: Christian Stewardship of Natural Resources (Erdmanns, 1980)

Steven Bouma-Prediger, ***For the Beauty of the Earth: A Christian Vision for Creation Care***, 2001 (Baker Academic)

Appendix A. Evidence for Climate Change and Implications for the Future

In Appendices A, B, and C, I summarize the key findings of the Intergovernmental Panel on Climate Change (IPCC) in their most recently published update – the Fourth Assessment Report (AR4) in 2007. The entire report is available online at http://www.ipcc.ch/.

Evidence for Climate Change

For the 12 year period from 1995-2006, **eleven of them rank among the 12 warmest years since temperature records were begun** (1850)

- The average global temperature from 1900 to 2005 rose by 0.76°C. (1.37°F)
- From 1900-2005 global temperature rose at the rate of 0.07°C (0.13°F)/decade
- From 1950-2005: it rose at the rate of 0.13°C (0.23°F)/decade
- Less than 10% of the temperature increase can be attributed to changes in solar output
- Warming is more pronounced over land than over water.
- Warming is more pronounced in the arctic north than at mid-latitudes.

Over 90% of alpine land-based **glaciers are in retreat.** *Comment:* At current rates of decline, Glacier National Park may well be glacierless within 25 years. Over 2 billion people globally are dependent on glacier runoff for fresh water, most of them in drainage basins of the Himalayas and the Andes.

The extent of summer **Arctic Ocean sea ice is declining** at increasing rates. *Comment:* In 2007 there was a dramatic drop in the extent of Arctic Ocean sea ice to a record low area for modern times – a low that was nearly matched in 2008 and in 2009.

Ocean levels are rising at increasing rates – 1.8 cm (0.7 in)/decade from 1961 to 2005 but 3.1 cm (1.2 in)/decade since 1993. *Comment:* Almost all of this rise is due to thermal expansion of the ocean water due to warming water temperatures in the upper reaches of the world's oceans. IPCC does not include the impacts of potential melting of the Greenland ice sheet or the West Antarctic ice sheet, which contain enough ice/water that if either of them melts ocean levels will rise by more than 20 feet, due to insufficient data.

Arctic permafrost area has declined by 7-15% since 1900 and is melting at increasing rates.

There is very good evidence that **spring is arriving earlier** in the northern hemisphere and fall later.

Habitats of various organisms are changing – moving northward or to higher elevations as temperatures rise.

There is an increasing incidence of **extremely heavy rain events** in regions that normally get adequate rainfall and an increasing incidence of severe drought in regions that normally get little rainfall.

Impacts of Climate Change

While it is not possible for humans to predict the future with any certainty, increasingly powerful computer-based climate models do suggest a range of possible outcomes depending on how we respond to the challenge of a changing climate. IPCC reports possible outcomes of climate change according to six different possible scenarios that are processed by way of computer models. I will present some minimum (based on a scenario in which societies make a drastic change away from fossil fuels toward renewable energy systems) and maximum (based on a scenario which assumes continued rapid growth and high use of fossil fuel energy systems) possible outcome that IPCC reports from these models runs of the different scenarios along with some comments.

Predicted Global Impacts:

The average **global temperature will increase 3.2 to 7.2 °F** (1.8 to 4.0°C) by 2100. *Comment:* These results do not take into account melting of

Arctic permafrost which could release vast quantities of methane – a greenhouse gas with over 20 times the warming potential of carbon dioxide – into the atmosphere (a positive feedback to climate change). Too much is still unknown about the possible impact of permafrost melting. Most climate scientists believe that a rise in average temperatures much above 2°C could possibly set off irreversible and potentially catastrophic changes, such as melting of the Greenland and/or West Antarctic ice cap, or slowing/stoppage of the Labrador Current which carries warm tropical ocean waters northward toward Europe[28].

The average **sea level will rise 0.6 to 1.9 feet** (0.18 to 0.59 m) by 2100. *Comment:* These results do not take into account potential rapid changes in the melt-rate of either the Greenland or West Antarctic ice sheet. Complete melting of either of these, which would no doubt require several centuries, or even millennia, under any scenario, would lead to a rise of about 7 m (21 ft) in sea level.

Predicted Regional Impacts:

Warming is expected to be greatest over land and the high northern latitudes and least over water in southern and northern oceans. *Comment:* Since land warms much more rapidly than water and 70% of the earth's land area is in the northern hemisphere, warming will be strongest over land and in the north.

Snow cover is expected to decrease and Arctic sea ice will decline, with possible complete disappearance during the summer months toward the end of the century. *Comment:* Snow and ice reflect a lot of sunlight (have a high albedo); their disappearance will expose more land and water to the sun. Since both land and water are warmed much more strongly by sunlight than snow and ice, this is expected to lead to increased warming – another positive feedback to climate change.

It is very likely that **hot extremes, heat waves, and heavy precipitation events will become more frequent**[29]. It is likely that tropical storms (typhoons, hurricanes) will become more intense, with higher wind speeds and greater precipitation. *Comment:* As ocean waters warm (especially in the tropics) water evaporates more rapidly. The warmer atmosphere can also carry greater amounts of water vapor so as the climate warms, on average there will be higher amounts of water vapor in the air. As warm air rises, it cools and water vapor condenses and forms cloud droplets. This condensation releases energy and warms the surrounding air, causing it to rise more leading to further condensation, etc. Since overall, the atmosphere is carrying more water vapor (than a cooler atmosphere), more energy will be released during condensation, and more water droplets form. This is the origin of the more intense storms with higher winds (more energy) and greater rainfall (more water vapor to condense into water droplets).

It is very likely that there will be **increased precipitation at higher latitudes,** while decreases are likely in sub-tropical latitudes. *Comment:* In mid to northern latitudes, storm tracks are expected to move poleward resulting in changed patterns of wind and rainfall.

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[28] A very recently published study(http://www.unep.org/compendium2009/PDF/compendium2009.pdf) by the United Nations Environment Program (UNEP) which assesses climate developments since the publication of IPCC-AR4, now states that "Climate researchers now predict the planet will warm by 6.3 degrees Fahrenheit (3.5 °C) by the end of the century even if the world's leaders fulfill their most ambitious climate pledges, a much faster and broader scale of change than forecast just two years ago". The implication is that what we have agreed to do about climate change so far will not be enough o avoid potentially catastrophic warming.

[29] The UNEP report referred to in the previous footnote contains a chart that displays no less than 62 extreme weather events that have occurred globally in the past two years.

Predicted Impacts on Systems and Sectors:

Ecosystems

- The resilience of many ecosystems is likely to be overwhelmed by the impacts of rising temperatures and its associated effects (flooding, drought, wildfires, ocean acidification, insect infestations, etc.).
- About 20-30% of plant and animal species assessed so far are likely to be at risk for extinction if global temperature increases go much beyond 1.5-2.5°C.
- Global temperature increases much beyond 2.0°C and rising atmospheric carbon dioxide levels are likely to lead to major changes in ecosystem structure and function. *Comment:* Such changes may lead to shifts of species geographical ranges and could lead to collapse of entire ecosystems resulting in strongly negative impacts on the availability of food and water.

Food

Crop productivity is projected to rise modestly in mid to high latitudes, for temperature rises of between 1 and 3°C (depending on the crop) and then decrease beyond that. At lower latitudes, crop productivity is expected to decrease even for small rises (1-2°C) in temperature. *Comment:* In North America, the most fertile land now lies within a few hundred miles north or south of latitude 40°N (central Iowa). If climate change shifts the most favorable growing conditions very much northward, what is now the most fertile land in the nation may become less productive, while the less fertile land to the north may become more productive. Whether such a change results in a net increase or decrease in the overall productivity of the land is debatable.

Coasts

It is very likely that coastal areas will be exposed to increasing risks of erosion and floods. *Comment:* These impacts will be due both to rising sea levels and to increased intensity of ocean-based storms that make landfall. Coastal areas are subject to ever increasing population pressures. Approximately 500 million people live within 20 miles of a coast. Within the US over half the population resides in a coastal county.

Water

- Retreat of mountain glaciers and snowpack will accelerate during the 21st century. *Comment:* Approximately one third of the world's population currently depend on mountain glaciers and snow pack for their fresh water. During the early years of this century glacier run-off will likely increase due to more rapid melting and river levels may rise increasing access to fresh water and facilitating hydropower .However, toward century's end we should expect declining run-off from glaciers and decreasing availability of such water resources.
- Changes in precipitation patterns will impact water availability. Water runoff is very likely to increase by 10-40% by mid-century at higher latitudes and in some wet tropical regions, but decrease by 10-30% in dry regions at mid-latitudes and the dry tropics due to decreased rainfall and increased evaporation rates. *Comment:* The southwestern USA is almost entirely dependent on snowpack melt for its fresh water supplies. However as climate warms, precipitation will likely decline in this region and more of it will be in the form of rain which runs off rapidly and less in the form of snow which melts slowly through the summer. The great reservoirs –Lake Meade and Lake Powell - along the Colorado River basin are currently well more than 100 feet below their full level and, given the ever increasing demand on these resources, may well be dry within the first half of this century unless vastly improved water management is enacted.
- It is very likely that the future will see increases in heavy rainfall events in many regions, including some in which overall annual rainfall will decrease. The result will be increased risk of floods during this century with resulting negative impacts on food production, water quality, and physical infrastructure. Upwards of 20% of the world's population will undergo increased stress due to such

events. *Comment:* The current (9-20-09) flooding occurring in the southern states of Arkansas, Texas, and Georgia is an illustrative example. After a summer of near record-breaking drought and high temperatures, several days of storms with very heavy rainfall (12 to 20 in.) has set off serious flooding in many areas. Another example is the flood that swept through Cedar Rapids, Iowa last year after an extremely heavy rainfall event

These are only some of the findings that IPCC discusses in AR4. There are many others related to specific geographic regions – all very interesting reading. Perhaps I have presented enough findings to turn to the question of how to address climate change.

Appendix B. Addressing Climate Change through Mitigation

The IPCC's AR4 synthesis reports tabulates seven different areas in which we can achieve significant reductions of carbon emissions without exacting crippling economic costs.

Energy supply: In this area we can achieve improved efficiency of distribution, switch fuels from coal to natural gas or to nuclear power, make vastly more extensive use of renewable (and inexhaustible) energy sources such as wind and solar or possibly geothermal (using deep earth heat to boil water for electricity generation) and capture carbon dioxide from coal generating power plants and put it into deep storage underground (known as carbon capture and storage (CCS) technology). *Comment:* All of these technologies except CCS are known and already in commercial operation. We do not yet know if CCS is feasible or affordable on a commercial scale[30].

Transportation: Improve the efficiency of private transport vehicles by using hybrid or plug-in hybrid technology, diesel, diesel hybrid or diesel plug-in hybrid technology, resurrect the railroad system both for freight and passenger transport and increasing non-motorized transport (bicycling and walking). *Comment:* It would not be difficult to envision a transport system that was more or less completely electrified and running on non-carbon-based renewable or nuclear power sources. We could have electric cars for local urban travel, an electrified railroad system, and electric buses (trolleys) for public transport in urban centers. Obviously this would require enormous changes in personal habits but such things are possible

[30] The very first commercial demonstration project in which an operating coal-fired power plant in West Virginia is using CCS was reported in the 9-22-09 NY Times. It is trying to sequester about 1% of its carbon emissions in this test program. Source: http://www.nytimes.com/2009/09/22/science/earth/22coal.html?_r=1&th&emc=th

Buildings: Increase the use of passive solar lighting and heating; use more efficient light bulbs, and increase the efficiency of household and commercial appliances, water heating systems, air heating and conditioning systems, improve insulation of all buildings and adopt energy efficient standards for all new construction; provide "smart metering: of energy use so the user is aware of what is being used at any time. *Comment:* 40% of our current energy use is in buildings, so there is much to be gained by making adjustments in this area. Again, all of these technologies are already available and many of them would have a payback that could result in a net savings of money over time. Obviously many old building will need retrofitting for energy efficiency, since new buildings and appliances have a fairly long lifetime, this would need a significant phase-in time.

Industry: Make more efficient use of energy by resorting to combined heat and power systems, engage in more material recovery and recycling and reduce/eliminate outputs that pollute the environment. *Comment:* Much progress has already been made in many industries in the developed nations. It is safe to say that industry/commerce is ahead of the general populace in adopting more sustainable practices[31].

Agriculture: Improve the natural fertility of soils by increasing the level of organic matter in soils through improved cropping and grazing patterns; improve rice cultivation techniques; improve animal waste management for concentrated animal feeding and keeping operations; reduce fertilizer use or improve its efficiency of use. Adopt more integrated/organic pest management strategies. *Comment:* Unfortunately, the modern American system of agriculture has become one of the heaviest polluters of the creation – greenhouse gases, pesticides, herbicides, fertilizers, animal wastes, soil depletion, groundwater contamination and so forth. Industrial scale agriculture has been structured to produce a meat-based diet for modern Americans. Another substantial way to reduce both fossil fuel inputs into agriculture and reduce the outputs of greenhouse gases and many other pollutants, while at the same time producing a healthier diet[32], would be to begin a transition toward a food system that features a more vegetarian (or even vegan) diet that is more locally and regionally produced. Given how our system of agriculture operates today, growing corn to generate ethanol as a fuel for transportation is not sustainable and should be phased out.

Forestry/Forests: Reforesting logged out areas and planting trees in low-fertility, unforested land; improve forest harvesting and management methods; reduce clear cutting and deforestation; judicious use of forest products for energy production. *Comment:* Actively growing trees are one of the most effective ways of removing carbon dioxide from the atmosphere. Ideally burning wood products for heat or for energy production can be close to carbon-neutral. As of now there is no commercially operating system that turns wood or grassy products (cellulose) into liquid fuels

Waste: Recover methane (a potent greenhouse gas) from human-produced landfills and use it to produce energy; burn waste directly to produce electricity; reduce waste, composting organic materials. *Comment:* There is no doubt that we in North America are the largest per capita waste producers on the planet. Bill McDonough[33] talks about cradle-to-cradle design for all industrial/commercial manufacturing processes. He says that in a sustainable society, the design of a product needs to take its next life (its reuse) into account. The concept of waste, he says, must disap-

[31] A good example of a business that is committed to becoming a sustainable company is Herman Miller. It has the following environmental goals for all of its operations: Zero emission of volatile organic compounds to the air, Zero generation of hazardous waste, Zero solid waste to landfill, Zero net process water consumption, 100% renewable electrical energy use 100% carbon-neutral operations, 100% of sales from Design for Environment approved products. Source: http://www.hermanmiller.co.uk/our-business/environmental-concerns/#ProductReUse

[32] See T. C. Campbell, T. M Campbell, *The China Study*, BenBella Books, 2005

[33] Bill McDonough, Michael Braungart, *The Next Industrial Revolution*, Earthome Products or see www.thenextindustrialreveolution.org

pear. Each product, when it reaches the end of its useful life must become the raw material for the next stage of its life – a very attractive notion but challenging in both concept and execution. Perhaps we will end the throw-away society.

While many of these mitigation efforts are technically achievable, most will have costs associated with their implementation. As a result some of those nations most in need of economic development will be least able to afford the implementation of new energy generating systems. Without substantial, if not massive, assistance from the developed- world nations, many such mitigation technologies may well be beyond their reach. Nonetheless, since we in the developed world are responsible for about 90% of the increase in atmospheric greenhouse gases during the past century, justice requires that we provide as much financial and other forms of assistance as is needed.

Appendix C. Addressing Climate Change through Adaptation

IPCC in AR4 identifies seven different areas in which adaptation could be undertaken.

Water: Expand rainwater harvesting (dams, cisterns, etc), storage and conservation techniques; reuse water; improve water use efficiency especially in irrigation; reduce urban lawn area, desalination of ocean and other salt waters. *Comment:* All of these are necessary steps and some of them are already underway in various places. Desalination is highly energy demanding and a costly way to produce fresh water. Agricultural irrigation continues to be the heaviest user of fresh water. In many places (notably northern China, the grain-belt of India), water withdrawals for irrigation and human use are occurring at such high (and unsustainable) rates that underground aquifers are being depleted at alarming rates.

Agriculture: Adjust planting dates to accommodate changing climate; crop relocation; change crop variety, develop drought and/or pest and/or salt-resistant crops; improve land management and erosion control. *Comment:* Several of these initiatives are not difficult to achieve, but developing resistant crops of various types requires genetic engineering and there is not any where near universal acceptance of genetically modified crops.

Infrastructure/Settlement: Relocate people living in high-risk coastal areas; Build or reinforce seawalls, storm barriers, levees, dunes; acquire crucial land to construct/preserve protective sea-front wetlands and marshes; protect all existing natural barriers. *Comment:* The Netherlands and Venice, Italy are examples of regions already taking steps to shore up coastal protective areas by means of adaptation strategies. In many regions, human settlement, protection and resettlement promises to be the thorniest and costliest issue in adaptation strategies. At the very earliest we should at least take steps to see that additional settlement and development does not take place in high-risk areas. In Bangladesh, some 80 million

people live in the flat alluvial plains along the coast scarcely more than a meter or two above sea level. Rising seas are a major threat to such an existence and it seems difficult to conceive of a strategy of building protective dykes or structures along the many river deltas of the region. Relocation may well become necessary – but where to?

Human Health: Develop heat-action plans; enhance emergency medical services; conduct surveillance and treatment of climate-change promoted incidence and spread of disease; provide adequate safe water supplies and improved sanitation for all. *Comment:* Providing safe water and adequate sanitation systems for poor urban populations remains one of the unmet challenges of the 20th century and these challenges will increase with expanding urban populations under the stresses of climate change.

Tourism: Diversify tourist attractions taking into account the changing climate; shift ski slopes to higher elevations; make artificial snow. *Comment:* A major challenge to non-essential entertainment and recreational activities is to find structures that are less fossil fuel intensive. For example, in a climate and energy constrained world, it seems likely that professional and college sports will need to reduce air travel and therefore become more regional in nature. IPCC does not address this issue.

Transport: Realign or relocate major transportation arteries and other transport infrastructure (e.g., airports) to cope with warming, coastal storm surges, and flood events. *Comment:* There is no doubt that major coastal transport routes and some that follow river flood plains will need to reconfigured at unknown cost in a world with rising ocean levels and increasing flood risk.

Energy: Strengthen overhead transmission and distribution lines, increase underground cabling for utilities, enhance energy efficiency and increase use of renewable [or nuclear] energy systems. *Comment:* There is no doubt that strengthening energy supply and distribution systems will be key because without access to energy modern civilization will soon grind to a full stop.

Appendix D. Personal Actions to Reduce Climate Change

Here are some of the things I or both my wife and I have done over the past 8-10 years to reduce our (my) own personal carbon footprint.

- Try to reduce, reuse and recycle – especially reduce! - as much as possible – still a work in progress.
- Moved from a large suburban home to a small urban home which is close to (my) workplace, to church, and to most of the shopping we do.
- Purchased an energy efficient (energy star-rated) furnace, hot water heater, and refrigerator. The washer/dryer still need attention.
- Replaced most light bulbs (except those on dimmers) with compact fluorescents.
- Added 12 in of insulation to the attic space
- Replaced windows with more energy efficient windows.
- Purchased a programmable thermostat. In winter we keep the house at 68°F during the daytime when at home and at 60°F at night and when we are not at home. In summer the thermostat is set to 77°F before the air conditioning goes on. We use a small window fan in our bedroom while sleeping for comfort.
- Reduced the amount of fertilizer and water we apply to our (relatively small) lawn.
- I ride bicycle or walk for nearly all of my personal transport within the urban area, weather and road conditions permitting.
- I have reduced the number of showers I take each week from daily to once every two or three days depending on need.
- We have begun to use Amtrak for trips to Chicago or to the western part of the country. We avoid air travel as much as possible.
- I use a manual-push reel mower to cut lawn grass unless the grass gets too long
- Built and use a composting box.
- Downsized from a two car to a one car family.
- Most recently we have changed our dietary habits from being omnivores to being vegan – partly for sustainability reasons and partly for health reasons

Appendix E. Peak Oil[34]

Of the three common fossil fuels, oil is both the most critical (it supplies nearly 40% of the world's energy and is used by upwards of 95% of the world's transportation systems for fuel) and appears to be the one that is in shortest supply. Conventional oil normally is pumped out of the ground and a typical oil field (or combination of oil fields) usually shares a similar oil-production profile with other fields over time. As a field is developed, oil production generally rises, reaches a maximum, and then begins a decline as it becomes more difficult to recover the remaining extractable oil. The production profile for an oil field generally resembles a bell-type curve. – low but rising production early, reaching a maximum rate of production, and then low production again late as the field reaches the end of its productive life. Such a production curve when applied to oil is known as Hubbert's Peak, after the US geologist, M. King Hubbert, who, in 1956, successfully predicted the peak in US oil production to occur in about 1970 – the very year in fact that domestic oil production did reach a maximum. Hubbert's 1956 prediction regarding domestic oil production was based on the assumption that the maximum in production of an oil field occurs when about one half of the recoverable oil has been removed - from that time forward recovering the remaining oil becomes more difficult[35] and production begins to fall.

What is true for an individual oil field or for a collection of oil fields within a nation must also be true for the collection of all the world's oil fields, since the earth is as finite as any nation within it. Eventually, worldwide production of conventional oil will peak, and it will probably peak when about one half of all the recoverable oil has been extracted.

We have a fairly good estimate of the amount of oil that has already been extracted and used up – about 1.1 trillion(T) barrels (bbl)[36]. Less is known about the amount of conventional oil that is still recoverable. Currently proven reserves[37] are listed at about 1.2 to 1.4 T bbl[38].. All of these numbers suggest that we are close to the halfway point in the production of conventional oil. If we are close to the half-way point in the extraction of conventional oil, then we are also close to the peak of production of world oil.

While there is disagreement about the precise time when we will reach peak oil production, there is no doubt that its arrival will signal a sea-change in the world's energy economy and the progress of modern civilization. Declining oil production will mean that we will have to do more with less. It will mean that we will have to make fundamental changes in the way we transport ourselves from one place to another. It will mean rising and perhaps quite volatile oil prices, some of which we already have experienced in the oil markets in 2008 when prices spiked to $150/bbl. It will mean increasingly risky searches for new oil fields in more and more difficult places to operate (the deep ocean, the Arctic Circle), explorations that are already underway. It will mean more and more costly efforts to develop low quality organic

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[34] Useful online sources for information about the question of when oil extraction will peak are: www.theoildrum.com and http://www.peakoil.net/ . Both of these sites are moderated by former geologists who are knowledgeable about the oil industry and don't have any particular axe to grind with respect its operations.

[35] This increased difficulty is due to several factors – the pressure drops in the oil filed as oil is removed and the remaining oil moves more slowly to the well bottom; remaining pockets of oil in the filed get harder to find; the least viscous oil is the first removed as it flows more readily to the well bottom., the more viscous (or heavier) oil moves more slowly and is harder to recover.

[36] A barrel of oil holds 42 American gallons. Currently the world usage rate of oil is about 85 million bbl/day or 31 billion bbl/year

[37] Proven reserves are estimates of the amount of oil that can be expected to be extractable at current prices and with current technology.

[38] Source: http://www.eia.doe.gov/emeu/international/reserves.html

resources such as the tar sands in northern Alberta or maybe even the organic-rich shale in Utah and Colorado, ventures that are also underway today, in an effort to produce liquid fuels. It will mean the adoption of unwise strategies such as corn-to-ethanol in an effort to find alternative liquid fuels to petroleum.

Some oil peakists believe that we are going through the peak of oil production right about now, others expect it to occur within the next decade or so, and nearly all believe that we have less than 20 years to the peak of oil production. Regardless of who is right on these issues, the time is now to begin significant steps toward an alternative energy regime.

Appendix F. Possibilities of Renewable Energy

Direct solar is massively abundant during the day when the sun is shining. It has been noted that if we could harness the sunlight that falls on the surface of mainland USA for one hour at high noon in July, we would have enough energy to supply the entire energy needs of the US for a year. All the technologies for capturing sunlight are already known. Solar photovoltaic systems (roof top solar panels that convert sunlight directly into electricity) are expensive – they produce electricity for about 4-5 times the cost of a modern coal-fired power plant (if you let the coal fired plant dump its exhaust into the atmosphere for nothing). Solar panels have a high capital cost of installation but comparatively low operating costs. Since the sun doesn't always shine, solar systems must either be operated with some back-up system (an additional cost) that is always available or we must be able store excess electricity generated when the sun is shining. The latter could be achieved by a bank of efficient rechargeable storage batteries in a building's basement, but of course that also introduces an additional cost.

Indirect solar is also quite massively available. Winds result from the capture of about 1% of the sun's energy by air molecules making up the atmosphere. Yet wind represents an enormous resource in many regions. Wind systems could be adapted to be distributed systems where one turbine supplies electricity for one or a few buildings or they can be configured in massive wind farms, requiring construction of a new electricity grid for distribution. In either case, because of the variability of wind supply, electricity storage systems would have to be devised or back-up systems constructed.

Biomass which results from photosynthesis has been and can be a partial energy resource. Ideally use of biomass can be neutral with respect to carbon emissions because growing plants remove carbon dioxide form the atmosphere, burning plants returns the carbon dioxide to the

atmosphere. Of course, if we use fossil fuels in the growing and harvesting of biomass, the carbon neutrality is reduced. Plants harvest less than 0.1% of the sun's energy, yet plant materials can play a significant, though likely not large, role in our energy future.

Hydropower is already mostly developed in the USA although other opportunities exist in several developing countries. An unfortunate drawback of hydropower systems is the requirement for damming rivers or streams, with negative impacts for human settlements and for ecosystems. River flow is determined by rainfall and glacier melt so under a changing climate regime, hydropower systems may be less sustainable than we think they might be. Ultimately most reservoirs suffer from insiltation; consequently, most hydropower systems have a finite lifetime.

In closing let me make the following observations.

- First, we should note that all of the above energy systems produce electricity as their primary output. Consequently, it is not too far-fetched to imagine a civilization that is entirely electrified. Perhaps we might reserve the use of some liquid fuels for agriculture, air travel and other services where the use of electricity is not feasible.
- Second, it is very likely that as we switch over from a fossil fuel based civilization to a renewable energy based civilization that the cost of energy services will rise. This is as it should be since for so long we have not paid the full cost of the use of fossil fuels.
- Third, it is also very likely that the total amount of energy resources available per capita will decline – especially in the developed nations – most notably the USA and Canada. Such a reduction will also likely result in a reduction in the supply and consumption of material goods. But this does not necessarily imply a declining standard of human well-being[39]. Human well being depends less on the availability of material goods – at least beyond that which is needed to meet basic needs of food, clothing, and shelter - than it does on the quality of relationships within the human community and with our Lord Jesus – as those of us who live within church communities very well know.

[39] The Christian writer, Bill McKibben in his book *Deep Economy* argues and provides evidence for the reality that human happiness and well-being stops growing after a relative low level of material well-being has been reached. Beyond that minimal level, additional consumption does not result in increasing human satisfaction. Often, the opposite is true.