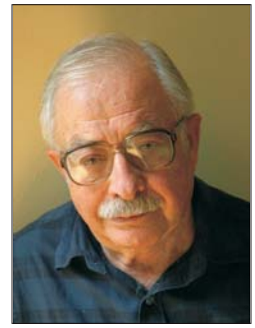

Kenell Touryan

Renewable Energy for a Sustainable Future: A Christian Imperative

Kenell Touryan

As a scientific affiliation that explores any and every area relating to Christian faith and science, ASA members should proactively face the challenges of determining sound energy policies, practicing energy conservation, and developing renewable energy sources. The mandate God has given us, to be good stewards, should be an imperative for seeking after every avenue leading to a sustainable future for humankind. Five significant converging trends have enhanced the penetration of renewable energy and energy efficiency in the world market. This, in itself, should give us an impetus to utilize energy resources such as solar power, water, wind, and biomass in residential, commercial, and industrial sectors.

The word "anthropocene" is a term coined by ecologist Eugene Stoermer and popularized by the Nobel Laureate atmospheric chemist Paul Crutzen.[1] It is an informal geologic chronological designation that serves to cover human activities that have had an impact on the global ecosystem. A more recent designation by Mark Lynas identifies humankind as "the God species."[2] In a previous article in *Perspectives on Science and Christian Faith*,[3] the author reminded the reader that the dazzling light shed by science has led to technological achievements unequaled in human history. The successes, which bear on nearly every aspect of human endeavor, have eclipsed contributions from the humanities.

In the optimism of the Enlightenment, technology assumed an exalted position in Western societies. In fact, science and technology have become the twin gods of the past century and no doubt will continue to remain entrenched in their lofty positions throughout the twenty-first century.

Technological optimists do not fret about the "two-edged sword" of technology, namely, the environmental, social, aesthetic, and spiritual impact on modern civilization. Most technological optimists—and apparently all economic determinists—believe that the boundless potential of human intellect will overcome problems of physical limits, thus making the earth's physical resources essentially inexhaustible. Edward Teller wrote, "Technology has opened the possibility of freedom for everyone."[4]

Nonetheless, archaeological evidence tells us that whole populations have

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disappeared due to the exhaustion of accessible resources. The long-running debate in journals and in the media between economist Julian Simon of Harvard University and bioscientist Paul Ehrlich of Stanford University included wagers over evidences supporting their convictions.[5] Simon cited historical evidence to argue that human ingenuity will remove all limits to growth, whereas Ehrlich insisted that we are on a course of resource exhaustion and ecological catastrophe. Their wager was settled in Simon's favor during his lifetime. But today the scale of human activity is so large that the impact on the earth's systems is becoming global, and recovery times could be measured in centuries, requiring a careful life-cycle assessment of all activities. Critical among these activities are the increasing global demand of energy and the earth's dwindling fossil fuel supplies. The curves shown in figure 1 represent the estimated availability of all known fossil fuel sources worldwide over two centuries, plotted against the rising world demand of energy. Although the data shown in figure 1 were prepared in 1985, *there have been no dramatic changes in these predictions over the past twenty-five years*.

Five Converging Factors

Over the past decade, five converging trends have emerged that are beginning to shape the energy future of this country and of the world.[6] These five trends are as follows:

1. *World Energy Demand Growth.* The world energy demand rate shows a steady, average upward trend of 2%, with China and India leading the developing countries. If we continue exploiting our nonrenewable resources, such as fossil fuels, this will inevitably lead to a global crisis in midcentury (barring the economically and technologically successful extraction of oil/gas from vast oil shale deposits). The United States constitutes only 5.5% of the world's population but consumes 26.5% of the world's energy. What will happen if China and India, which together constitute 35% of the world's population, attain the same level of prosperity by midcentury?

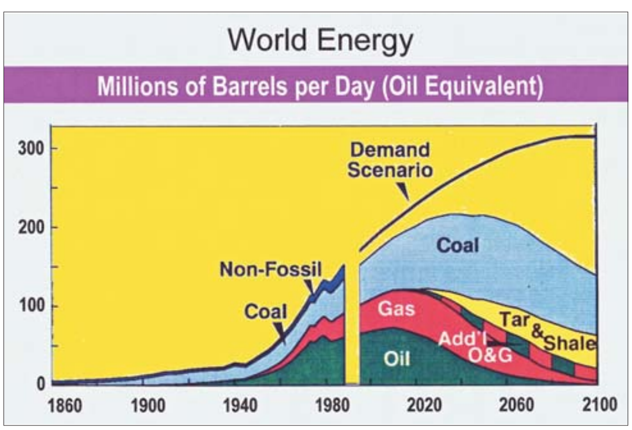

Figure 1. World Energy Sources since the Industrial Revolution
From John F. Bookout (President of Shell USA), "Two Centuries of Fossil Fuel Energy," International Geological Congress, Washington, DC, July 10, 1985, published in *Episodes* 12 (1989): 257–62.

2. *Global Environmental Awareness.* Accidents such as the Chernobyl nuclear power plant disaster of 1986, the more recent catastrophe in Japan, the 2009 oil spill in the Gulf, and a factor-of-three increase in greenhouse gases in our atmosphere since the start of the Industrial Revolution have created something akin to an ecoshock. As responsible stewards of planet Earth, it is high time for everyone, and most of all the ASA members, to start looking at renewable technologies to provide a significant portion of our energy budget to fulfill our future energy needs.

3. *Energy Security.* Security risks associated with the unequal distribution of fossil fuel resources throughout the world pose major destabilization threats. Renewable energy resources on the other hand (solar, wind, biomass, mini-hydro, organic waste utilization, and geothermal) are quite equitably distributed, with one or more of these resources available to *every country* in the world. In addition, the *distributed* nature of renewable technologies provides an inherent security against terrorist attacks. Large power stations operated by fossil fuels or nuclear power plants are vulnerable to sophisticated terrorist attacks.

4. *New Energy Technology Options.* The new emphasis placed on alternate energy resources and serious efforts at energy conservation in developed countries, and even in developing countries, has led to the creation of new technologies such as more efficient gas turbines, better insulation of buildings, energy-efficient appliances, and a number of renewable technologies (such as solar hot water, run-of-the-river small hydropower plants, wind farms). All these are becoming economically viable and have begun to make a noticeable impact on the world's energy budget.

5. *Increasing Business Interest.* Power production in the electricity sector, fuel production in the transportation sector, and thermal energy applications together have become a trillion-dollar business throughout the world. All this has led to a competitive market and opened up potentially lucrative business opportunities in the world's energy sector, including the development of renewable technologies.

To repeat, the convergence of these five trends mentioned above has given renewable energy technologies a significant boost as an economically feasible alternative to fossil fuels and nuclear power. These technologies can provide greater independence to countries devoid of fossil fuel resources; they will stand for a cleaner alternative; and finally, they will provide greater energy security against sophisticated terrorist attacks. For these reasons, the European Council in March 2006 called for European Union (EU) leadership on renewable energies and asked a commission (established by the EU) to produce an analysis of how best to expand renewable energies over the long term, for example, by raising their share of gross inland consumption to 15% by 2015.[7] The European Parliament, by an overwhelming majority, called for a 25% target for renewable energies in the EU's overall energy consumption by 2020. To this end, the commission in 2006 prepared the framework for a renewable energy road map for all EU countries to employ as part of their ten-year strategy for achieving these targets.

Similar initiatives have been taken by Australia, Russia, and the USA. For example, in the USA, the Solar America Initiative (SAI) is part of the Federal Advanced Energy Initiative, whose purpose is to accelerate the development of advanced photovoltaic materials—with the goal of making it cost competitive with other forms of renewable electricity by 2015.[8] Other countries, such as Georgia, Turkey, and even Azerbaijan and Iran, have also started to pay serious attention to renewable energy, even though they are major producers of oil and gas.

Both eastern and western European countries have responded to this initiative, and their road maps can be found on the internet. It is beyond the scope of this article to provide a comprehensive review of all these road maps. However, it will be instructive at this point to look at two small countries, Armenia and Switzerland, as they look ahead to the coming decades in an attempt to meet their energy needs with minimum reliance on imported fuels. The reasons for selecting these two countries and not others are as follows:

1. The author was involved in preparing a road map for Armenia, based on the strategic plans for energy production in Switzerland by 2050;
2. Both are small countries with no fossil fuel reserves;
3. Both rely heavily on large hydropower for electricity generation;
4. Switzerland is a developed country, whereas Armenia is borderline between developed and developing country, often characterized as a "misdeveloped" country (under the Soviet System);
5. The political climates of Armenia and Switzerland are very different from each other in dealing with renewable technologies;
6. Switzerland ranks as one of the least corrupt countries, whereas Armenia ranks as one of the worst;
7. Finally, Armenia considers itself a Christian country in the Orthodox tradition dating from AD 301, and Switzerland is serious about their Reformed and Roman Catholic tradition.

Before we go into the details of describing the two road maps, it is important to define what is meant by *alternative and/or renewal energies* and to take a look first at *conservation and energy efficiency* before finally turning our attention to renewable energy resources.

The Terms Used—Alternative Energy versus Renewable Energy

Alternate or alternative energy is a term used to describe all energy sources *other than* energy from fossil fuels. Alternate energy by definition includes nuclear energy and fusion energy in addition to renewable energy sources.

Renewable energy, on the other hand, deals with the sun, wind, and water as the primary sources. Some add geothermal energy and energy from organic wastes to the list (geothermal can be considered renewable when used as a "hot-dry-rock" system in which water is injected into the rock formation through a central well, and steam is obtained from adjoining production wells). Renewable energy sources can lead to technologies via two separate paths (see figures 2–4). The first path (figure 3) is called thermoconversion. When *heat* is absorbed as by materials such as solids, liquids (e.g., water), or gas (e.g., air), then thermoconversion leads to solar thermal power, hydropower, wind, waves, and ocean currents. The second path (figure 4) is called photo-conversion that depends on *light* from the sun (electronic excitations rather than molecular excitations) and leads to photovoltaic power, photo-electro-chemistry, photosynthesis (which is responsible for all plant life), and synthetic chemical compounds that can store solar energy.

Both diagrams exhibit the steps that each conversion path takes from a primary process to a primary product, followed by the specific technology and finally to the useful product. The two morphologies show the wide range of basic and applied sciences involved in the development of renewable energy technologies.[9]

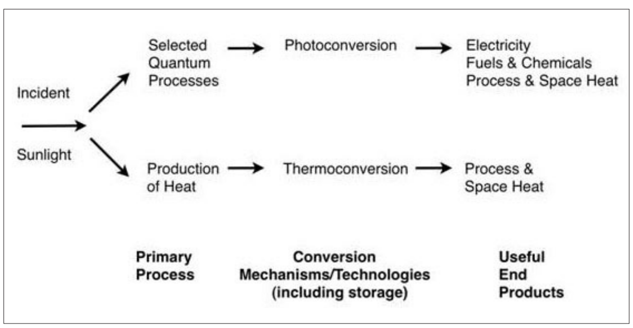

Figure 2. Solar Radiation Processes and Conversion

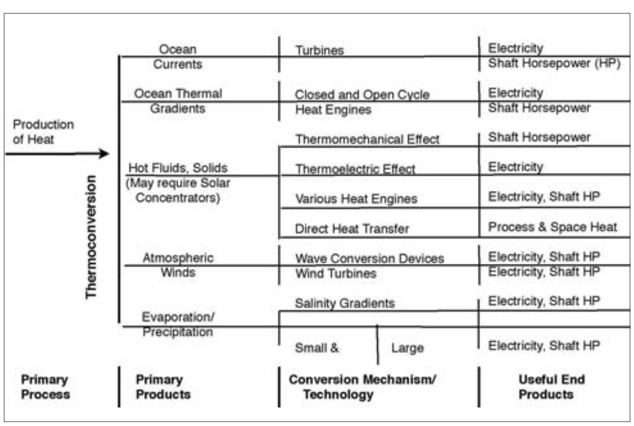

Figure 3. Detailed Morphology for Solar Thermoconversion Paths

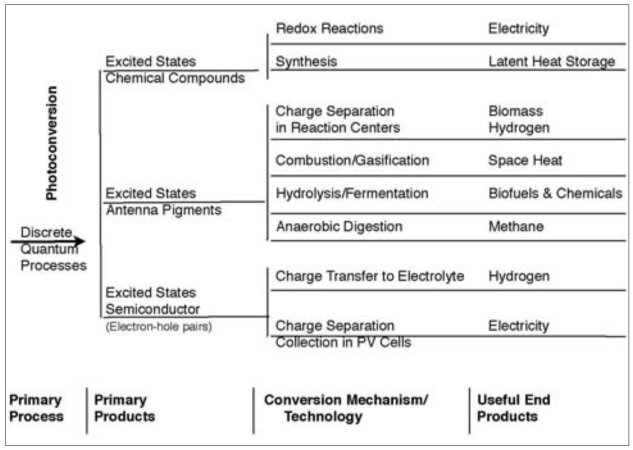

Figure 4. Detailed Morphology for Solar Photoconversion

Conservation and Efficient Use of Energy

The National Renewable Energy laboratory prepared a chart for global energy versus wealth relationship in 2002 (figure 5). What is significant in this figure is the apparent correspondence between GDP and Energy Consumption for each country: the higher the GDP, the higher the energy consumption. It is an accepted fact that all developing countries have *the desire* to reach the level of GDPs of the developing countries. Should that happen, countries such as China, which has already moved up the chart toward Japan, the USA, and Europe, could eventually exhaust most of the world's oil and gas resources, unless they too move toward well-planned conservation and energy-efficiency measures and follow the targets set

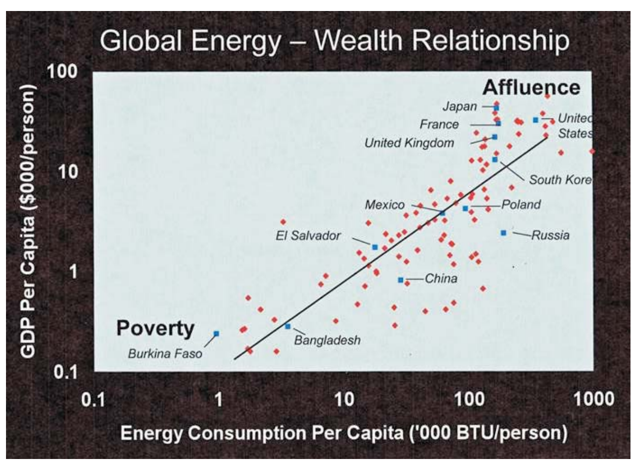

Figure 5. Global Energy and Wealth Relationship, prepared by NREL Staff. Originally published in Kenell J. Touryan, "Renewable Energy: Rapidly Maturing Technology for the 21st Century," *Journal of Propulsion and Power* 15, no. 2 (March–April 1999): 163–74.

by the European Commission. Needless to say, conservation measures and efficient energy use are less expensive to achieve than developing a new renewable energy technology. For example, retrofitting a building to make it energy efficient, whether residential or commercial, will cost about $2 per watt as compared to a cost of $3 to $5 per watt for small hydro stations, providing solar thermal heating or generating electricity from wind. (In 2010 dollars, costs for new energy range from $3 to $5 per watt.) Building-energy efficiency measures include, but are not limited to, proper insulation, electric lighting that uses compact fluorescent halogen bulbs, and efficient electric appliances.

Priority sectors in which energy savings can be obtained include production and distribution of electricity, irrigation and water supply, electric lighting, transportation, and food production. In industry, for example, losses in an electricity value chain (described as the sequence from energy production to energy consumption) using fossil fuels can amount to 80% between primary energy production and final industrial production. These losses can be reduced to 60% or less when using efficient gas turbines and smart grids that include demand-side management.

The Swiss Plan from 2010–2050

Historically, Switzerland's longest-serving and most important source of renewable energy has been hydropower; the same is true for Armenia. But the new renewable resources, including solar thermal, solar photovoltaic (PV), wood, biomass, wind, and geothermal, also play an increasingly important role in today's Swiss energy mix. For economical reasons, wood, biomass, solar thermal hot water, small hydropower, and wind are available now to a modest extent and, in some cases, are also economically attractive. The potential for PV and geothermal is large, but only in the longer term (2030). One of the goals of Switzerland's energy policy for 2030 is to increase the proportion of electricity production from renewable energy by an amount equal to 10% of the country's present-day electricity consumption. Since 2007, approximately 55.6% of the overall electricity production in Switzerland comes from renewable resources, with hydropower providing 53.6% of this amount and the rest coming from other renewable resources, of which the largest portion is biomass (wood and biogas). It should be noted that 39% of the electricity production comes from three aging nuclear power plants which the Swiss have decided to phase out by 2025. Three main forms of renewable resources are considered:

1. Electricity from hydropower, wind power, PV, and biomass;
2. Thermal energy from heat pumps, solar thermal heat, geothermal, and biomass;
3. Transportation from gas and liquid fuels extracted from biomass.

The Swiss calculate that their electricity consumption will increase by about one quarter to one third and that, by the middle of this century, a certain share of electricity production from fossil fuels will remain inevitable. This will be the case even in the event that the road map's recommendation of 10% from PV by midcentury is implemented. This is not the case for thermal requirements, which are anticipated to fall by 40% by 2035 compared with current levels. With the implementation of the road map, it will be possible to cover 40% of heat requirements with wood, biomass, and solar thermal by midcentury.

Besides electricity, the second major problem is the energy policy in the transport sector. Although the Swiss anticipate the energy demand to decrease by a third by 2035 (more efficient cars and public transport), only 16% of transport energy requirements can be met by gas and liquid fuels extracted from biomass—unless, of course, an all-electric vehicle system is instituted in the country by 2035.

However, it is noteworthy that Switzerland is very seriously considering instituting a drastic cut in energy consumption by 2050, down to 2,000 watts per capita, which represents a major cut from the 3,000 watts per capita at the current level of energy consumption. Energy supply that would rely mainly on indigenous sources of renewable energy is only possible given a far lower level of energy consumption than today. Thus, a "2,000-watt society" is being promoted at the level of the Swiss Department of Environment, Transport, Energy, and Communication.[10] To accomplish this reduction in energy consumption, an effective energy policy is required now, and in the years to come, to ensure, in the long term, an adequate, economical, and ecologically friendly supply of energy based on renewable sources.

The Armenian Strategy for the Next Decade (2010–2020 and beyond)

Unlike Switzerland, Armenia to date has not yet been ready to adopt renewable energy technologies (RETs) for its energy budget. It has no fossil fuel resources in the country and relies on nuclear power for 35% of its electricity production and on large hydropower for 30%, not unlike Switzerland. The balance comes from fossil fuel imports. In December 2010, the World Bank selected the Danish Energy Management to work with a team of Armenian engineers and scientists to prepare a ten-year strategy plan for bringing renewable technologies to Armenia. The road map was prepared along the same lines as the requirements set forth by the EU Parliament for their member countries, and as was done in Switzerland. The team completed its plan in June 2011, and presented it to all branches of the government.

The plan showed that the country can group RETs into three categories, as in the Swiss case:

1. Electricity production, from small hydropower (less than 10 MW per run-of-the-river project), wind power, PV, and biomass;
2. Thermal energy using heat pumps, solar thermal heat, geothermal, and biomass;
3. Transportation using gas and liquid fuels extracted from nonfood-related biomass (such as stover, switchgrass, algae); the eventual use of hydrogen fuel cells.

Findings of a comprehensive review of the renewable energy potential in Armenia have ranked small hydropower using run-of-the-river sources, and solar hot water, as the most advanced and economical sources for Armenia in the short- and mid-term (by 2016), followed by grid-connected wind farms and the use of heat pumps by 2020 (see figure 6). The wind farms will be located in several mountain passes with the potential of supplying 20% of the electricity for the country. PV and cellulosic biomass from Jerusalem artichokes planted in arid regions will become economical after 2020. Although the prediction for the growth of RETs is modest in Armenia, their use can increase five-fold by 2020 (not including large hydropower), forestalling the necessity for another nuclear power plant. However, Armenia compares very poorly with Switzerland in energy conservation and in energy efficiency. Japan is ranked the most efficient user of energy among developed countries. The road map prepared above for Armenia makes it clear that Armenia needs to increase its energy conservation and efficiency *before* it invests large sums in RETs.

Sadly, unlike Switzerland, Armenia has no formal plan for reducing energy consumption by 2020. In addition, implementing large scale RETs in Armenia, as with any other country, depends more on political measures than on technical capabilities. Furthermore, unlike Switzerland, which has decided to phase out their existing three nuclear power plants by 2025, the issue is complicated by the fact that the Armenian government is keen on replacing the present, aging nuclear power plant with new 1,000 MW ones, using Russian technology. The location of these plants is on earthquake fault lines which require special design features to secure their safety, thus making the proposed nuclear power plants a more expensive project than using RETs by a factor of three or more.

To be diplomatic in our approach, the author and a team organized by the Danish Energy Management presented two scenarios to the Armenian

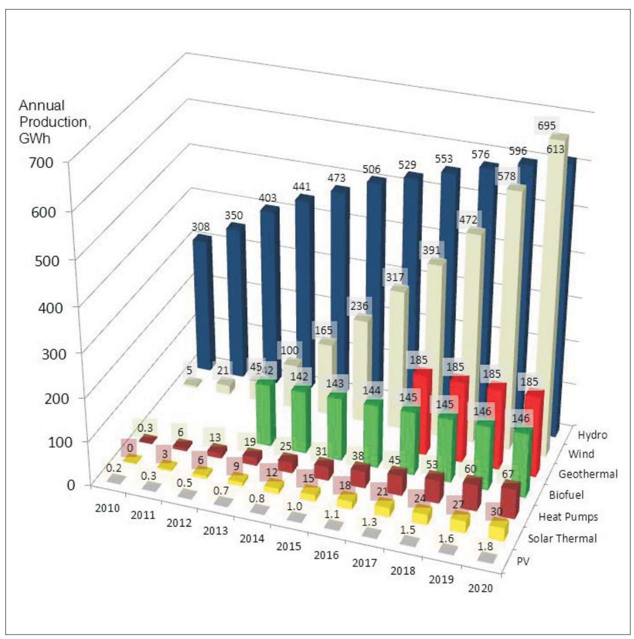

Figure 6. Renewable Energy Production over the Decade 2010–2020.

government. One scenario was with a new nuclear power plant; the other, without one. If a nuclear power plant becomes a reality after 2020, there will be *excess electricity* which then can be used to power electric cars in Armenia and/or generate hydrogen for cars running on hydrogen fuel cells. Armenia has eliminated tramways, but still uses electricity-operated buses. Unlike Switzerland, Armenia has very limited rail transport and is too poor to invest funds in an extensive rail system.[11]

Nuclear Power and RETs

Nuclear power has been an important part of the world's energy budget. Its advantages are several. It is nonpolluting, uses ten-thousand-fold less fuel (uranium or plutonium vs. fossil fuels) and makes an excellent base-load power plant. However, unless built with strict safeguards, the risks could be catastrophic in the event of a serious accident as, for example, the Three Mile Island accident, the Chernobyl event, and the recent Japanese tsunami. In addition, disposal of the rapidly accumulating high- and low-level radioactive wastes is becoming the "Achilles' heel" of the industry, along with the ever-existing fear of nuclear weapons proliferation (namely, the concern that so-called rogue states such as North Korea or Iran may go nuclear).

People are often incredulous when they learn that in spite of the author's thirty-year involvement with RETs, he still supports nuclear power plants, albeit cautiously. After spending fifteen years on nuclear power technology and fusion energy, the author appreciates the importance of such systems as part of an overall energy budget of the world. He does not subscribe to the present panic against nuclear power plants. But as stewards of this unique planet, and especially as Christians, we have been given the responsibility of using its resources wisely and at minimum risk to the environment and to humankind as a whole. After all, the sun, a nuclear-fusion power plant, has been placed at a safe ninety million miles away from Earth, and the planet itself has been provided with two types of filters to minimize destructive rays from the sun: a magnetic field that filters out the deadly solar wind that flows from the sun, and the ozone shield which moderates the flux of the sun's dangerous UV radiation, limiting the UV radiation to beneficial uses.

Scaling Up Renewable Energy Technologies

Having presented a favorable picture for renewable technologies, it is important to note some of the problems inherent in the *large-scale* use of these technologies. In a special section in *Science,* this problem was graphically illustrated (see figure 7).[12] First, it should be noted that the world population consumes 15 TW of electric power (1 TW is one trillion watts). The *potential* for the worldwide use of biomass is 9 TW; for wind, 20 TW; for hydroelectric power, 1.6 TW; for geothermal, 3.8 TW; and for solar, more than 50 TW.

All that is well and good; however, one needs to consider the land, water, and material demands of some of these technologies. The article gave an illustration of how much land is needed for San Jose, CA, to provide *all 740 megawatts* of its power from renewable technologies. To supply that power, coal mines and coal power plants would need 3,800 hectares of land; a wind farm would need 53,000 hectares, which is bigger than the area of San Jose itself. However, unlike coal mines, the land occupied by the wind farms would allow crops to grow and cattle to graze beneath the erected turbines. Solar would require 7,500 hectares; hydroelectric, 1,300 hectares (where abundant rain is available); and biomass, a whopping 270,000 hectares, unless algal biofuels were used for fuel from the lipids in the algae. The energy density of algae, compared with that of cellulosic biomass, is higher by a factor of three or more. These conditions make it clear that renewable energy cannot *by itself* meet *all* the energy consumption required by a given country. Another reason for this

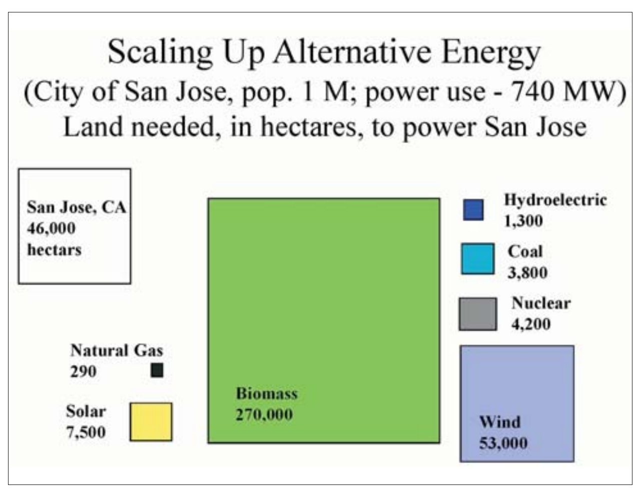

Figure 7. Scaling Up Issues for Renewable Energy

is that energy from the sun and the wind are intermittent, and energy from the use of hydropower can be seasonal. A backup base-load power plant, using fossil fuels or nuclear power, may be required.

Lastly, nuclear energy production would cover an area of 4,200 hectares. In fact, the *material needs* for solar thermal and solar photovoltaics could exceed the material needs for constructing a nuclear power plant that would produce the same amount of electric power. Another interesting number to consider is the use of water. Solar thermal, for example, will need 70% more water than an equivalent coal power plant, but not as much as a nuclear power plant would.

One solution to this large-scale application issue is to plan *distributed systems* in which each community uses its own mixture of RETs tied to the city's main power grid (see appropriate technology section below). Clearly then, one has to consider a *mixture* of energy sources to meet the growing energy needs of the world's population.

Finally, we look at a more economical option: *conservation and the efficient use of energy*. In fact, as mentioned above, before a country contemplates the development of renewable resources, it should first consider conservation measures such as proper insulation or less-energy-consuming appliances for residential, commercial, and industrial applications. A careful analysis shows that it is less costly to install such measures than to provide new renewable energy sources. The former would require expenditures on the order of two cents per watt, whereas the lowest cost for wind or solar energy subsystems would be in the range of five to seven cents per watt.

Renewable Energy and Energy Efficiency within the Scope of Appropriate Technology

In 1955, the British economist E. F. Schumacher came up with criteria for technologies that were small-scaled, decentralized, and not energy intensive. He also emphasized that technologies should be environmentally sustainable, based on renewable resources.[13] In one of the most famous essays in his book entitled *Buddhist Economics*, he blended *spiritual values* with economic progress in order to achieve "right livelihood" that would value people over tools and progress. This he thought would preserve the environment, and foster simplicity and nonviolence. What Schumacher called intermediate technology is now called appropriate technology.[14] The appropriate technology movement grew out of the energy crisis of 1970. It focuses on environmental and sustainability issues, both of which are fully applicable today. Although it is commonly discussed in its relationship to economic development of third-world countries, this movement can be found in both developing and developed countries.

Amory Lovins expands the definition of appropriate technology to "appropriate renewable energy."[15] Unlike the problems mentioned above that will arise when facing large-scale utilization for RETs, appropriate energy technologies are especially suited for isolated (off the grid) or small-scale energy needs. With these, electricity can be provided using PV panels, solar thermal collectors, small wind turbines, mini- or micro-hydro, etc., some of which are already being used in villages in Armenia and Switzerland. One curious experiment was conducted by students from the American University of Armenia. A German company donated simple, low-cost parabolic dish cookers which were taken to various villages in Armenia for demonstration purposes. One of the unexpected problems that arose was the complaint from some villagers that solar-cooked food did not taste as good as food cooked on wood stoves!

To avoid problems inherent in the large-scale use of renewable technologies, *distributed systems* may be more practical for use in large cities. These could loosely be classified as "appropriate renewable energy" networks. In distributed systems, each community in a large city installs its own electric power generation system, using renewable technologies such as PV, and connects its system to the main power grid of the city. All this could materialize once digitized, smart power grid systems are installed, and demand-side management becomes practical.

Finally, the other practical use of RETs is in locations where no power grid is available, and electric power is obtained through diesel generators. The hybrid system consists of a small wind turbine and/or PV modules with a diesel generator as backup. The system automatically shifts from wind or PV to diesel power when the renewable resource is unavailable (cloud cover, night-time use). Such hybrid systems may be classified as appropriate technologies and are being installed on small islands and in villages where no power grid exists, for example, the islands of Indonesia and several fishing villages in Mexico and Brazil. Figure 8 is a sketch of a typical hybrid system. Let me sound a word of caution though. In each village where a hybrid system is installed, the villagers should *take ownership* of the system to ensure the operation and maintenance needed to keep the system running. Another important point to consider is that before large numbers of such hybrid systems are installed, there should be trained operation and maintenance staff accessible to these locations in order to ensure their smooth operation.

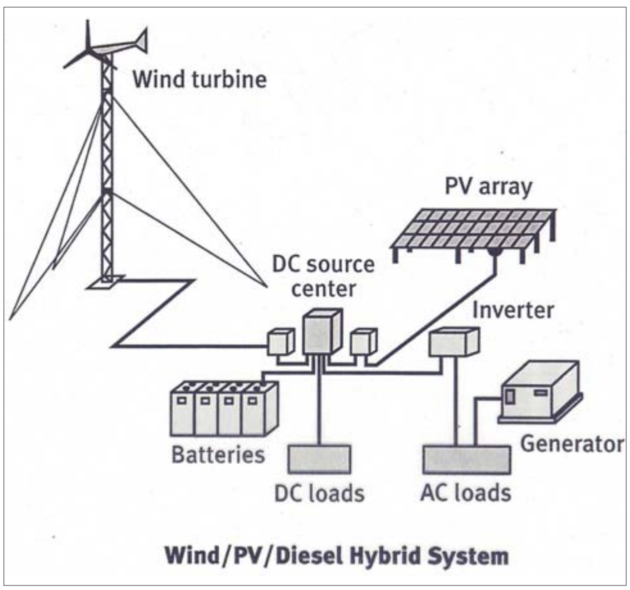

Figure 8. Micro-Grid System Architecture. This is a typical structure of a hybrid system with a diesel generator as backup.

Our Rare Earth and Concluding Remarks

The term "rare earth" was coined by Peter Ward and Donald Brownlee in a recent book with the same title.[16] In this book, the two professors from the University of Washington have joined with a number of astronomers and astrophysicists to show that, in spite of the possible existence of myriads of other planets throughout our universe, the chance for another planet like ours that can sustain life is indeed remote. They base their argument on a careful statistical evaluation of one hundred plus parameters that must be fulfilled with great precision before an earth-like planet can be formed. Such calculations, first started by the Cornell University astronomer Frank Drake fifty years ago, have led to the conclusion that there may be only *one* earth-like planet in the universe.[17] Decades of search for extraterrestrial intelligence (SETI) via radio telescopes have so far received no extraterrestrial signals to indicate their existence.

For those who believe in a God who created the universe, creating life elsewhere in the universe should not be a problem. On the other hand, why would God place such importance on *our planet,* and feel compelled to make a soft landing on Earth, through his Son's incarnation, to reconcile us with the Father?

In summary, let us note that as of today, no signals indicating intelligent life have been received from outer space. In addition, recent analyses seem to indicate that the probability of a "just right" planet like ours to exist more than once is highly unlikely, and that our Earth has a privileged position in the universe, described in detail by Guillermo Gonzalez and Jay Richards.[18] If we add to these considerations God's special concern for planet Earth, it becomes imperative for us to use appropriate technologies in a responsible manner. This will include encouraging the use of renewable resources, fuel-efficient cars, and energy-saving appliances. Many secular people are taking this issue seriously. We as Christians should be far more proactive in determining how to respond to limited resources, and energy and technology challenges. We *should lead* in making the necessary changes. In so doing, we can fulfill the Apostle Paul's exhortation to Timothy, in being satisfied with less, not more (1 Tim. 6:6–8). Living this way then becomes our "reasonable service" (see Rom. 12:2–3) and permits us to become good stewards in doing our best, individually and collectively, in sustaining and enriching our earthly home. ✦

Notes

[1]Paul J. Crutzen and Eugene F. Stoermer, "The Anthropocene," *IGBP Newsletter* 41, May 2000, http://www3.mpch-mainz.mpg.de/~air/anthropocene/. See also, "Welcome to the Anthropocene," *The Economist* (May 26, 2011).

[2]Mark Lynas, *The God Species: How the Planet Can Survive the Age of Humans* (London: Fourth Estate, 2011) (published in the USA by National Geographic as *The God Species: Saving the Planet in the Age of Humans*). For a review of the book, see *The Economist* (July 14, 2011): 86.

[3]Kenell J. Touryan, "ASA in the 21st Century," *Perspectives on Science and Christian Faith* 56, no. 2 (June 2004): 82–8.
[4]Edward Teller, *Better a Shield than a Sword* (New York: Free Press, 1987), 50.
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